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Table of contents

13 - Textile based sensors, smart textiles 222

17- Apparel science and production technology 271

18- CAD/CAE, modelling and simulation in textile and apparel 277

1- Recycling, life cycle analysis, sustainability and circularity

Recycling of pre-consumer wool waste: fiber length optimization for a closed-loop economy

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The textile industry, a key driver of the global economy, faces the harsh reality of being the second-largest polluter worldwide. Each year, approximately 1 billion garments are produced, with 30% going unused, and the remainder discarded after short periods of use. However, growing public awareness, spurred by the educational efforts of non-governmental organizations, is fostering a shift towards sustainability. The Department of Textile Technologies at Chemnitz University of Technology is leading innovative sustainability efforts, particularly through research on the recycling of pre- and post-consumer textile waste. The current focus is on pre-consumer waste, with an emphasis on wool and wool-blend textiles, such as wool-silk blends. The primary aim is to achieve a fully closed-loop material cycle, ensuring that 100% of the waste remains within the recycling process.

The initial phase of the research centers on a thorough examination of fiber length in the waste material. Key factors such as sorting, textile orientation before cutting, surface design, and binding methods significantly impact fiber length. The study also explores different material lengths to identify the optimal range for preserving maximum fiber length during shredding. Tests on pre-consumer wool and silk materials, with sample lengths ranging from 1 cm to 10 cm, revealed that the ideal cutting length is between 7 cm and 10 cm. At this range, the fiber lengths were found to be between 73.4 mm and 74 mm, maximizing fiber length in the shredding process. Additionally, fiber length was found to vary depending on the pattern type.

A systematic analysis of various cutting and tearing parameters is underway to further optimize fiber length in recycled yarns. Using laboratory spinning equipment, the recycled fibers are processed into yarn, allowing for detailed comparisons of parameters such as fiber length, yarn count, twist, tensile strength, and elongation with the original materials. The project aims for a recycling rate of 100%.

By exploring the nuances of pre-consumer wool waste recycling and optimizing key processes, this research seeks to set new benchmarks for closed-loop recycling. It advocates for a circular economy and encourages the adoption of more sustainable practices within the textile industry.

Keywords: textile recycling, pre, consumer waste, Wool blends, fiber length optimization, circular economy, sustainability

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Innovations in Multiaxial Textile Technologies: High-Performance Structures for Sustainable Fiber Composite

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This contribution provides an overview about innovative technologies for multiaxial load-adapted, high-performance textile structures for use in sustainable fibre-reinforced composites (FRCs). By using both multiaxial warp knitting technology and robotics, a sustainable material efficiency of FRCs is achieved, which are particularly relevant in the aerospace, electromobility and construction industries. The contribution comprises three sections:
1. Multiaxial Warp Knitting Technology for 3D FRC Components: This section addresses advancements in resource efficiency, focusing on reducing material waste associated with traditional roll goods. It highlights a novel inline production method for alternating weft and warp threads, resulting in significant savings in high-performance fibres like carbon. Additionally, a patent-pending textile technology for draping and mesh grid structures (NetzGT) for carbon concrete elements is introduced, which can reduce weight by up to 28 % compared to steel reinforcement while maintaining equivalent performance.
2. Improved Properties in Concrete Composites: This part explores new methods for profiling rovings used in construction applications. By utilizing impregnation forming technology, flexible profiled yarns from carbon fibre heavy tows are developed, enabling the production of rollable reinforcement structures. The use of tetrahedron-shaped rovings has shown up to a 500 % increase in bond strength between concrete and reinforcement compared to non-profiled rovings.
3. Robot-Assisted Textile 3D Reinforcements: This section discusses the application of robotics for yarn deposition, providing flexible and waste-free processing of high-performance materials. It includes the development of a compact in-situ impregnation unit and a yarn deposition frame for precise placement.
These innovations significantly reduce CO_2 emissions by minimizing material usage in FRC production. Furthermore, they aim to expand existing applications and inspire the development of new uses for high-performance textile structures, contributing to more sustainable practices in relevant industries.

Keywords: sustainability, fiber composites, non-crimp fabrics, robotic, multiaxial warp knitting

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The problem of functional assessment of rain jackets in the second-hand market

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The sale of second-hand clothing has increased dramatically in the last five years: By 2025, the global used clothing market is expected to generate $77 billion, up from $27 billion in 2020. The used clothing trade accounts for a not insignificant portion of the overall apparel and textile trade, which was estimated at around $160 billion in the same year. A number of reasons have contributed to the boom in the resale market, including the growth of internet marketplaces for vintage clothing, the preference of younger generations for sustainable shopping and the recent interest of mainstream fashion companies in vintage clothing. In low- and middle-income countries, second-hand clothing has gained importance as a source of garments; much of it being recycled from rich countries.
In most cases, a visual inspection is sufficient to determine the quality of second-hand clothing. However, when it comes to functional clothing, the problem of quantifying the functionality of the products arises: How can one be sure that an outdoor jacket sold in a second-hand shop is still functional in terms of performance such as waterproofness, water resistance and breathability?
In the present study, a sample of 26 second-hand (16) and end-of-life (10) rain jackets was examined in terms of visual inspection and functional properties (air permeability, water permeability, water resistance, water vapour transmission rate) and a statistical analysis was carried out to determine whether it is possible to infer the functional performance of the jackets from visual inspection alone.
The results revealed that visual inspection can help differentiate between end-of-life jackets that have lost key functions, such as water management, and second-hand jackets that still retain most of their functionality. While visual cues can offer some prediction of performance, physical testing is necessary to fully assess the condition of a used jacket.

Keywords: second, hand, rain jacket, membrane

*Speaker

Development of a Natural Fiber-Reinforced Composite with Recycled Carbon Fiber Rib Structure for High-Performance Applications

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A novel composite material has been developed, featuring a lightweight natural fiber-reinforced shell with a recycled carbon fiber (rCF) rib structure, providing enhanced strength and rigidity. The shell is constructed using highly aligned, pre-impregnated thermoplastic sheets of hemp fibers. The process chain for the production of recycled carbon fiber (RCF) reinforced base fiber shell structures is shown in Figure 1. Recycled carbon fibers are obtained through a solvolysis process using high-pressure water, avoiding harsh chemicals and preserving the fibers' mechanical properties. These reclaimed fibers retain most of the strength and stiffness of virgin carbon fibers. The use of the same thermoplastic material in both the shell and rib structures ensures high compatibility and efficient bonding, enhancing overall structural integrity.

The rib structure is fabricated through a winding process that employs specially designed pressing tools with cavities for rCF hybrid yarns. Integrating rCF ribs significantly improves the mechanical properties of the composite, allowing efficient force transfer and enabling it to withstand higher loads.

Mechanical testing and microstructural investigations, was conducted to assess the composite's performance. Cross-sectional microscopic images were analyzed using Digital Image Correlation (DIC) techniques. The results show a good connection between the shell and rib phases. Tensile test results showed that the integration of rCF ribs significantly improved stiffness and strength. The findings demonstrate the potential of this natural fiber-reinforced shell with rCF-based rib structure to deliver sustainable, high-performance solutions for demanding structural applications. This composite material is well-suited for applications such as wind turbine blades, automotive parts, and sporting goods, where weight reduction and high mechanical performance are critical.

Keywords: shell rib structure, basfiber, recycled carbonfiber, composite

*Speaker

Image Analysis Methods for Assessing Fibrous Microplastic Release

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Fibrous microplastics can be released into the environment through fiber breakage due to various factors. Analysis using light microscopes and digital cameras is among the most popular methods for studying fibrous microplastics due to its accessibility. However, manually processing images and assessing fibrous microplastics is highly time-consuming. This study compares different analytical image analysis methods to find the most suitable option for effective fibrous microplastics assessment.

To analyze the fibrous microplastics, three types of image analysis methods were applied: manual analysis with *ImageJ*, semi-automatic analysis with *ImageJ's Analyze Particles* plugin, and automatic analysis using AI-based *Ilastik* software. For the evaluation, a black knitted fabric was used with the following specifications: composition – 95% polyester / 5% elastane; mass per unit area – 224.0 g/m^2; thickness – 0.52 mm; course density – 23.0±0.5 cm^{-1}; wale density – 22.0 ± 0.5 cm^{-1}. Three specimens were prepared. Individual washing tests were performed on each specimen. Wastewater was filtrated through filters after each wash. Each filter was photographed using light microscope *(Lumenera Infinity)* and digital camera *(Nikon D5600)* with lens *(AF-P NIKKOR 18-55mm f/3.5-5.6G)*.

Results indicated that manual, semi-automatic and automatic methods were similarly effective in assessing non-overlapping microplastics. Images taken with the light microscope provided more accurate results. After training the AI-based software, the automatic method was the least time consuming and manual analysis took the longest. However, neither semi-automatic nor automatic methods were performing effectively on overlapping fibrous microplastics and manual corrections were required to attain more accurate results.

These findings suggest that AI-based automatic software can be the most effective and the least time-consuming solution for analyzing fibrous microplastics when they are well-separated on surfaces, but it needs further development to improve the analysis for overlapping fibrous microplastics.

Keywords: microfiber, microplastic, textile, sustainability

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Cleaning ability analysis of non-woven textile materials, for sustainable maintenance of solar systems

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Green energy transition is becoming a natural process, due to the urgent need to mitigate the negative climate change impact, from the conventional energy production methods. The sun, as a renewable source, supplies relatively constant and evenly distributed energy over the entire earth. On a global scale, solar systems are being rapidly installed worldwide, which according to the forecasts of the International Energy Agency (IEA), are expected to provide about 20-25% of the world's electricity production by 2050. This is part of the wider goal of achieving zero carbon emissions and significant increase of the share of the renewable energy sources. The efficient operation of the photovoltaic plants directly depends on the environmental conditions in which they work. Industry and transportation cause serious pollution over the solar systems, which significantly lowers the generated energy output. It is necessary to use different materials and technologies for cleaning the solar panels, which need to be effective and not to damage their solar absorbent surface. Nowadays, water is considered to be the best natural cleaner, to remove dust from the solar panels. However, environmentally friendly cleaning systems must function without water, due to the relative exhaustibility of this resource. Systems that work on a dry-cleaning principle in most of the cases use textile materials for the cleaning heads. In the presented study, the cleaning ability of non-woven textile materials with application for cleaning and maintenance of photovoltaic systems is analyzed. In addition to the high cleaning ability, these materials are characterized by an almost entirely synthetic composition, which has a strong negative environmental impact. Therefore, the aim of the study is to recommend cleaning materials from that type, that are suitable and sustainable for the presented application. The work is performed within an onsite experimental measurments, in natural uncontrolled conditions during the operation of a photovoltaic park. These measurements are supplemented with laboratory testing of the materials' properties and a proposed methodology for comprehensive analyses of the results.

Keywords: sustainable textile materials, solar panels cleaning, textile recicling, circular economy

*Speaker

Antibacterial characterization of bio-based and eco-friendly coatings for textile functionalization: insights from the Donizetti Project

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Functionalization of textile fibers and fabrics improves their performance, increasing durability and longevity, and providing various biological activities, including antibacterial ones. The antimicrobial effect is usually obtained through the application of chemical substances, employing expensive materials with high environmental impacts, as well as thermal treatment. For this reason, in the last decade, the textile industry has focused its attention on safer and more sustainable alternatives, using vegetable-based products, often obtained from residues or by-products from the agri-food industries, which have demonstrated to be a source of bioactive compounds with biocidal activity. In this study, the antibacterial activity of polyphenols (PPs), such as rosmarinic acid (RA) and eugenol (EU), and organic acids (OAs), including lactic acid (LA), ascorbic acid (AA) and tartaric acid (TA) was assessed. Biomolecules were then used as coatings for cotton fabrics and their antimicrobial activity against two bacterial strains, *Escherichia coli* as Gram-negative and *Staphylococcus aureus* as Gram-positive was determined by ASTM E2149 standard method, under dynamic contact conditions, for 1 hour. RA, EU and functionalized textiles reached excellent bacterial reduction. LA, AA and TA have biocidal effects against *E. coli* and *S. aureus*, with a bacterial reduction ranging from 96.3% to 100%. Cotton fabrics treated with OAs (at the concentration of 10% wt) showed antibacterial activity against *E. coli* and *S. aureus*, with bacterial reduction higher than 95.5%. These promising results demonstrated the antimicrobial efficacy of plant-derived compounds both against Gram-negative and Gram-positive microorganisms, representing a safer, sustainable and eco-friendly alternative for textile functionalization, according to circular economy principles, with future applications in industrial, biomedical, environmental and energy fields. This study was carried out within the MICS (Made in Italy – Circular and Sustainable) funded by the European Union Next-GenerationEU (PNRR) – MISSIONE 4, COMPONENTE 2, INVESTIMENTO 1.3 – CUP B53C22004100001.

Keywords: textiles, functionalization, antimicrobial, polyphenols, sustainability

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Sorting analysis of laundry waste from the textile service as part of the further development of chemical textile recycling

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This article discusses potential input streams for chemical textile recycling. While mechanical recycling is currently the prevalent form of recycling, chemical recycling is becoming increasingly important. As part of a research project by the Center Textile Logistics (CTL), the recycling of laundry waste was specifically discussed together with partners from industry and research. Due to the process flows in laundries, it is possible to feed specific fractions of laundry waste into suitable material recycling processes as an input stream. In this case, these are fractions with a high cotton fibre content from product categories such as hotel and catering linen.
In this context a sorting analysis with more than 7000 individual products like hospital linen and linen from food businesses were conducted. Therefore a categorisation into different quality classes was made. The sorting analysis was used to evaluate, among other things, which product defects occurred most frequently and which 'non-textile components' had been processed. These are used in workwear and service clothing in particular, which means that a potential upstream process step is required to remove them in order to increase the quality of the recycled material. Correlations were analysed in order to derive existing relationships based on the recycling potential. The quantitative proportion of fibre material used was compared based on the data collection of the near-infrared spectrometers information and the care labels in order to determine, among other things, the fibre abrasion during the use phase.
The project makes it clear that laundry waste has a high potential to act as an input stream for recycling processes due to the materials used, the product structure and its low colouring. In addition, the constant waste stream and the resulting calculable quantities are another basic prerequisite for implementing and optimising fibre-to-fibre-recycling in the long term in a practical manner.

Keywords: textile recycling, sorting, recyclability, chemical recycling, textile waste, secondary raw materials

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Eco-friendly and efficient all cellulose nano fiber as separator in zinc ion batteries

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The increasing demand for efficient and sustainable energy storage solutions has propelled research into zinc-ion batteries (ZIBs) as a promising alternative to conventional lithium-ion systems. A critical challenge in the development of ZIBs is the formation of dendrites during the charging process, which can lead to short circuits and reduced battery lifespan. This study explores the application of cellulose nanofibers (CNFs) as a separator material in ZIBs to inhibit dendrite growth and enhance overall battery performance. Cellulose nanofibers, derived from renewable biomass, offer unique mechanical and electrochemical properties that make them suitable for use in battery separators. Their high surface area, flexibility, and ability to form a stable gel-like structure in electrolyte solutions contribute to improved ion transport and uniform current distribution. This research investigates the incorporation of CNFs into the separator design, focusing on their impact on dendrite formation during zinc plating and stripping processes. Experimental results demonstrate that CNF-based separators significantly reduce dendrite growth compared to traditional separators. The presence of CNFs promotes a more uniform deposition of zinc ions, thereby mitigating the risk of dendrite formation. Additionally, the mechanical integrity and thermal stability of the CNF separators are evaluated, confirming their suitability for long-term use in ZIBs.This study highlights the potential of cellulose nanofibers as an innovative and eco-friendly solution for enhancing the safety and efficiency of zinc-ion batteries. By addressing the critical issue of dendrite growth, CNF-based separators pave the way for the development of more reliable and sustainable energy storage systems, contributing to the broader goal of advancing renewable energy technologies. Future work will focus on optimizing the CNF separator design and exploring its scalability for commercial applications.

Keywords: cellulose nano fibers, separator, zinc ion batteries, dendrite growth

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Sustainable recycling: Enzymatic degradation of cellulosic and synthetic fibre blends

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The growing need for sustainable textile recycling methods has promoted research into enzymatic treatments as an environmentally friendly alternative to recycle fiber blends, in particular those composed of viscose and cellulose with other synthetic fibers such as polyester or polyamide. Traditional recycling methods face difficulties in separating natural fibers from synthetic fibers, leading to degradation of fiber quality or limiting their reuse. Enzymatic processes, however, offer selective degradation of natural fibers while preserving the integrity of synthetic components, allowing for more efficient recycling and blended textiles.

This study investigates the use of specific enzymes, such as cellulases, to selectively degrade cellulose-based fibers (viscose and cotton) in blended fiber fabrics, facilitating the separation of synthetic fibers. The enzymatic treatment not only allows for the recovery of synthetic fibers, but also produces a controlled decomposition of natural fibers, which can be reused or reintegrated into new textile products. In addition, the process reduces the need for polluting chemicals and minimizes water and energy consumption, in line with the principles of the circular economy in the textile industry. Furthermore, the enzymatic activity of the cellulase used is analyzed according to the type and percentage of each fiber in the treated fabric.

The results show that the enzymatic treatments effectively degrade the natural fiber components without affecting the synthetic fibers, allowing them to be reused. As well as, the enzymatic activity is influenced by the type of cellulosic fibre to be degraded and the percentage in which it is found in the fabric.

Keywords: Blended fibre, recycling, separation, treatment, sustainable, cellulase

*Speaker

Life cycle assessment of textile recycling processes

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Due to the diversity and intrinsic complexity of products on the current market, the recycling of textiles is complex. Challenges are related to the material used to produce textiles, the separation of multiple components, the adjustments of recycling methods and parameters to deal with any product type.
Given that complexity, finding an optimal recycling path is not easy. As part of the VLAN* project, which aims to optimize end-of-life loops, the aim of this study is to examine textile recovery processes to develop a decision-making tool for industry actors. The purpose is to study recycling processes, using different criteria, to provide the industry with a proposal for recycling methods that offer the best balance.
One of the criteria studied as part of this project is environmental impacts of processes. Several end-of-life scenarios were established, and a Life Cycle Assessment (LCA) was carried out for each scenario, such as the collecting - sorting - mechanical recycling scenario, to quantify the associated environmental impacts. The LCA approach enables a comprehensive assessment of the entire recycling process, from the collection of end-of-life textiles to the final recovery of materials. This assessment considers not only energy and resources required for recycling, but also potential emissions and waste generated at each stage. By comparing different end-of-life scenarios with LCA as a tool, the study aims to identify processes that minimize environmental impacts while maximizing material recovery.
Literature enables us to set up flow diagrams, one of the first steps in the life cycle assessment process, which allows us to study the needs as well as the co-products generated, as shown in Figure 1, which presents the flow resulting from mechanical recycling.
The VLAN is the textile axis of the " PEPR Recyclage, Recyclabilité & Ré-Utilisation des Matières ", financed by ANR France.

Keywords: Life cycle assessment, Textile recycling, End of life textile, End of life loops

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Optimization of coffee pulp compound extraction as a dye for cotton fibers

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Coffee pulp, a byproduct of the coffee processing method, constitutes approximately 40-50% of the total weight of the fruit. This agricultural residue is generated in large volumes in coffee-producing countries. Despite its abundance, its utilization is limited primarily to minor applications such as organic fertilizer or infusions that provide health benefits. The majority of this pulp is discarded, leading to environmental issues due to its high organic content and the risk of soil and water contamination.
This study investigates the valorization of coffee pulp as a potential resource in the textile industry. The pulp contains a high concentration of dyeing compounds, such as polyphenols, anthocyanins, tannins, and natural pigments, making it a unique option for application as a natural dye in textile production. This strategy not only represents a sustainable alternative to synthetic dyes but also contributes to the reduction of agricultural waste, aligning with the principles of the circular economy. The research analyzes various dye extraction methods, including organic solvent extraction, ultrasound, Soxhlet, and microwave extraction, aiming to optimize the recovery of pigments. A detailed chemical characterization of the obtained extracts is performed using Fourier-transform infrared spectroscopy (FTIR) and other advanced instrumental techniques. These methodologies enable the identification and quantification of the compounds responsible for dyeing properties.
The application of the extracted dyes is evaluated on cellulosic fibers such as cotton, analyzing their effectiveness in terms of color fixation, wash fastness, light resistance, and durability. The results demonstrate the technical viability of using coffee waste in the textile industry and foster collaboration between the agricultural and textile sectors, promoting integrated and sustainable management of waste and resources.

Keywords: Coffee pulp, natural dye, polyphenols, sustainable textiles, circular economy.

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Zero twist hybrid yarns from recycled carbon fibres for high performance thermoplastic composites

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Compared to the mechanical properties of composites from recycled carbon fibres (rCF) based on moulding compounds and nonwovens, hybrid yarns from rCF and thermoplastic fibre with adjusted yarn properties offer an excellent potential for high fibre orientation, fibre length, com-pactness, high fibre volume content resulting in a high level of performance in composites. However, the spinning of hybrid yarns from rCF and thermoplastic fibres for carbon fibre rein-forced composites (CFRP) is based on modified flyer spinning technology with high yarn twists, which are indispensable to ensure sufficient yarn strength and a stable spinning process. However, high yarn twist results in undefined damage to the rCF, increased short fibre content during spinning and poor fibre alignment in the composite. These lead to drafting error, uneven fibre structures and irreproducible manufacturing processes as well as low mechanical properties of CFRP. Therefore, one of the main objectives of this work is to develop zero twist hybrid yarns from recycled carbon fibres for high performance thermoplastic composites. For this purpose, a new concept of false twisting spinning process for the production of twist-free (_˜0 T/m) hybrid yarns from rCF and thermoplastic fibres based on thermal activation of thermoplastic fibres is developed and patented. This spinning process consists of a modified drafting unit with adjustable gauges and fibre guidance elements for fibres up to 120 mm, a thermo-module, a false twister, a nozzle, take-up rollers and a winder. The new process is expected to help achieve higher tensile strength and modulus in composites compared to rCF hybrid yarns produced on conventional flyer machines with twists. As a result, the potential of rCF to achieve the high mechanical properties of CFRP can be realised.

Keywords: recycled carbon fibre, spinning, thermoplastic composites

*Speaker

Circular Textile Solutions: The Reuse of Unraveled Knitted Sweater Yarns in Weaving

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In the modern textile industry, sustainability is increasingly becoming a priority, prompting efforts to reduce waste at all production stages, including pre-consumer and post-consumer waste. The industry focuses on two key strategies to tackle textile waste: reuse and recycling. Reuse is often more advantageous than recycling, particularly as the volume of unused and used clothing rises, since it helps avoid the environmental and resource costs associated with producing new products. This study explores the potential for circularity by investigating the reuse of yarns from unraveled knitted sweaters in the weaving process. The sweaters, made from 100% polyester yarn, were produced using the fully fashioned method, a widely used technique for flat-knitted garments that allows for efficient unraveling after use.The findings show that yarn from unraveled sweater knitted parts has significant potential for upcycling, particularly in weaving applications where it can be repurposed as weft yarn in various stitch configurations. Approximately 78% of the unraveled yarn was successfully reused, while 22% became waste during the unraveling process. The research also assessed the performance and durability of the reclaimed yarns in woven fabrics, confirming their suitability for industrial applications. Moreover, a home textile group recommended the woven samples for production, demonstrating their commercial viability. This study underscores the feasibility of yarn reuse and offers practical, sustainable solutions for reducing textile waste, enhancing resource efficiency, and promoting circular economy principles in the textile sector.

Keywords: reusing, knitting, weaving, sustainability, yarn

*Speaker

Creating Eco-Friendly Air Filters Using Natural Fibres

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Making products that are good for the environment is becoming more important in many industries. One big challenge is to create air filters that work well and are also safe for nature, both during use and after they are thrown away. This study presents a new way of making air filters using natural fibres like flax, cotton, and other plant materials. These filters are made from simple fibre strands, without any chemical binders that are often used in regular filters.

By not using chemicals, the production process becomes more eco-friendly, and the filters break down more easily after use. This helps reduce the amount of waste that harms the environment. Even without chemicals, the filters still work very well. They can trap small particles of dust and dirt, making them effective for cleaning the air in homes and factories.

Natural fibre filters can work just as well as synthetic ones, but they are much safer for the environment. Because they are made from natural materials, these filters can be recycled or disposed of in a way that doesn't hurt the planet. This makes them an important step toward sustainable living.

These filters can be used in many types of air cleaning systems, helping to keep the air clean while also reducing the amount of waste from regular filters. They provide a simple, effective, and environmentally friendly solution for cleaner air and a healthier planet.

Keywords: Air filters, Natural fibres, Ecofriendly

*Speaker

Finished PET: Challenges During Recycling Processes

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Implementing Design-for-Recycling strategies is one of the goals of the EU Strategy for Sustainable and Circular Textiles. However, for many textile products, it remains unclear how a large-scale recycling process will be structured and what requirements it will entail. As a result, developing guidelines for design is not straightforward. The research project SiWerTEX aims to establish a first guideline through a systematic investigation of the influence of textile colourants, flame retardants, and certain additives (e.g., softening agents) on the alkaline hydrolysis recycling process of pure polyester textiles.
The project's goal is to simplify end-of-life considerations for textile producers who aim to make their textiles ready for chemical recycling. A significant challenge in textile recycling is the complexity of textile products, which mostly consist of mixed fibre contents, colourants, and functional and process additives. Predicting how a specific colourant or additive will behave during recycling is nearly impossible; therefore, selected chemicals are studied for their behavior under hydrolysis conditions. Transferable conclusions for other chemicals are discussed and assessed. For this purpose, test methods for simpler and faster testing of textile dyes and auxiliaries under hydrolysis conditions are designed and discussed.
The approach of an alkaline hydrolytic back-to-monomer process makes it possible to obtain recycled terephthalic acid (rTA) equal in purity and quality of virgin material. The requirement for positive-listed colourants and additives is foremost to ensure that they can be removed by filtration and purification steps to obtain clean rTA. Additionally, the process water must be purifiable for reuse in the hydrolysis process, and valuable substances like phosphorus should be extracted and recycled. Our results demonstrate the high quality of rTA that can be reached with finished textiles and the work will be placed in the broader context of current textile recycling research and efforts.
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Keywords: recycling, polyester, colourants, additives, finishing

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Credibility as the Key to Increasing the Efficiency of Textile Sustainability Labels: An Analysis of Criteria and Optimization Potentials

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Credibility is a key factor in the use of textile sustainability labels as guidance and quality instruments. This article examines the credibility of 26 textile sustainability labels based on established requirements, highlighting the need for further optimization regarding their thematic and formal structure. Using a theoretical framework and an evaluation matrix, the study assesses labels against criteria including the coverage of both environmental and social aspects, the transparency of certification processes, the consideration of the entire product lifecycle, and the involvement of independent third-party audits.
Results show that 42% of the examined labels can be rated as good, while 27% are satisfactory, 23% are insufficient, and 8% are inadequate. Notably, none of the labels achieved the highest "demanding" category, underscoring the urgent need for increased transparency and credibility within textile labels. The analysis reveals that 77% of the labels cover both environmental and social themes, with water consumption, chemical limits, and wastewater management being the most frequently addressed environmental criteria. Social criteria often align with ILO core principles, focusing on fair wages, non-discrimination, and freedom of association.
The study identifies significant areas for improvement in transparency and thematic coverage of sustainability labels. To enhance credibility, labels should provide clear and relevant descriptions, ensure public access to criteria and audit reports, involve interdisciplinary stakeholders in criteria development, undergo third-party certification, and consider the entire product lifecycle. The findings suggest that optimizing the credibility and transparency of textile sustainability labels can positively influence consumer purchasing decisions and thus impact market dynamics. Future research should focus on the specific impacts of individual criteria on label credibility and explore standardized reporting formats and long-term market implications of improved sustainability labeling.

Keywords: Sustainability, Credibility, Textile Labels

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Valorization of marine litter as a new source of textile raw material: Use of fishing nets and mooring cables in the creation of eco-conscious design

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The impact of marine litter, particularly plastics, on ecosystems is highly disruptive, occurring in an extensive and rapid way, with substantial loss, even unrecoverable in some situations, of the diversity of marine life. Alarming data point to the urgency of preventive practices and immediate actions, which strengthen scientific and technological knowledge and the applicability of innovative solutions, capable of minimizing the severity of the effects and risks associated with marine litter. The use of waste fishing nets and mooring cables at the end of their life in the development of new products makes it possible to achieve circular economy solutions, based on the principle of developing processes in which these discarded materials are collected, processed and reused as new raw materials, reintegrated into the production cycle, thus creating a closed system in which resources have the potential to be continuously used. Plastic waste has the potential to be used as a new source of raw material for the conscious design of new products. However, it is necessary to identify its composition, understand the adversities related to its processing, as well as identify its sustainable value and relevance in the social and economic context, as a source of income and remarkable potential. This research focuses on the identification of the main materials that make up the marine litter collected in the Azores Sea and the characterization of their chemical and mechanical properties. The sample of this study was limited to non-biodegradable fishing materials, namely fishing nets and fishing boat mooring cables, identified as polyamides (PA) and high-density polyethylene (HDPE), respectively. These materials were separated, analyzed and processed in different ways. The transformation experiments involved the processes of selection, cleaning, crushing, extrusion, granulation and micro-extrusion, with the aim of producing new structures, including continuous filament yarns. Subsequently, a creative process of developing new products began, resulting in different sustainable eco-design solutions, namely with the addition of biopolymers and infesting algae. The main end products were textile accessories obtained from plates and yarns, with different applications in design collections of home textiles and interior design products. In this study was possible to validate the importance of circular economy with the valorization of waste, reduction of primary resources consumption and the negative impact of its degradation in the marine environment.

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Keywords: Sustainable design, marine litter recycling, circular economy, polymers extrusion

Developing High-Performance Recycled Nonwoven Structures for Safety Footwear: A Focus on Perforation Resistance

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There are more than 23 billion pairs of footwear manufactured annually worldwide, resulting in a massive amount of waste generated from the residues produced during and after the manufacturing process, pre-consumer/post-industrial and post-consumer waste, respectively. This amount of footwear waste has a significantly negative impact on the environment and human health, as more than 22 billion shoes are discarded in landfills yearly. Large amounts of waste decomposing in landfills contribute to environmental pollution, contaminating groundwater and releasing greenhouse gases, which also impact public health. Thus, it becomes urgent to recycle footwear to generate new raw materials, entering the concept of circular economy.

AMF Safety Shoes Company, a safety footwear production industry in Portugal, produces various types of waste, such as polyester. In this work, the polyester waste, which comes from the cutting of anti-perforation insoles, was reused to produce new anti-perforation structures to be incorporated back into the company, thus creating a closed-loop circular economy.

Firstly, nonwovens were produced by incorporating polyester waste and commercially recycled polyester in an 80:20 ratio, using the needle-punching technique. To increase the perforation resistance behaviour of the nonwoven, two high-performance fabrics were incorporated: basalt and aramid fiber fabric. These structures were manufactured by layers, intertwining nonwovens with layers of basalt/aramid fiber fabric, by needle-punching. Several parameters were studied to improve the perforation resistance of the structures: number of passes in the needle-punching process; number of basalt/aramid fiber fabric layers; nonwoven thickness; layer orientation angle; needling entry angle, compression molding technique. The resulting structures are eligible for certification ($>$ 1100N) and achieved a maximum perforation resistance of 1283N.

In conclusion, this study embodies the principles of a closed-loop circular economy, repurposing waste (polyester) to create a new product (insoles), which is then incorporated into safety footwear.

Keywords: Circular economy, Footwear waste, Nonwoven structures, Perforation resistance, Recycling

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Alternative organic solvents for elastane removal from textile waste: a case study of polyester/elastane fabric

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The increasing demand for sustainable textile recycling has driven the search for effective methods to separate and recover valuable materials from fabric waste. Elastane, a widely applied synthetic polymer in the textile industry due to its flexibility and durability, presents considerable environmental challenges after the material life cycle. Thus, the development of effective methods for elastane degradation is of paramount importance to mitigate its environmental impact. The utilisation of conventional disposal techniques, such as incineration and landfilling, has been identified as a significant contributor to environmental pollution and the loss of valuable materials. This underscores the necessity for the development of alternative recycling processes. Dimethylformamide (DMF) and Dimethylacetamide (DMAc) are two organic solvents commonly used in the chemical processing of textiles for the removal of elastane. However, both solvents have notable environmental toxicity, health risks and regulatory constraints. This study focuses on evaluating alternative biobased organic solvents for direct elastane solubilisation (cyrene, γ-valerolactone, and tetrahydrofurfuryl alcohol (THFA)) in the presence and in the absence of an organic catalyst (1,5-Diazabicyclo(4.3.0)non-5-ene (DBN)) and studies a case using a polyester/elastane fabric. The results demonstrated that γ-valerolactone with DBN and THFA are effective in elastane dissolution using the exhaustion method over an hour at 80◦C. The degradation of elastane was evaluated through mechanical testing by determining the breaking force, elongation, tenacity and Young's modulus. Moreover, the physicochemical analysis was performed by Fourier transform infrared spectroscopic method with attenuated total reflectance (FTIR-ATR) and thermogravimetric analysis (TGA). This research contributes to the advancement of circular economy practices in the textile industry by identifying viable pathways for elastane recycling.

Keywords: Biobased solvents, polyurethane dissolution, spandex, textile recycling, polyester fabric

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What is a real sustainable approach

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In the paper the sustainability approach, in which all three pillars of sustainability are addressed, will be presented and discussed. According to United Nations, sustainability is described as having three dimensions (or pillars): environmental, social and economic. In everyday usage we often understand sustainability (wrongly) just as the environmental and economic dimension. Such an approach could be called also semi-sustainable approach. In addition to just environmental and economy dimensions, focus on social dimension is also needed. It will be shown that most of today's sustainability developments are just partly sustainable (semi-sustainable) since they do not consider all three pillars of sustainability. The "real" sustainable approach is only when all three pillars of sustainability are addressed. It will be shown that today, humanity is facing a crisis regarding all three pillars of Sustainability.
Additionally, it will be presented and discussed that only those developments which bring systems into equilibrium are sustainable developments. Only when all parts of the system are in equilibrium it can be anticipated that all parts of the system and the system itself are healthy.
It will be also shown that if real sustainably is holistic. Holistic, transdisciplinary and critical thinking about systems and consequence of their interconnections provides insight into the complexity of relationships in the world and encourages people to make more responsible and sustainable decisions for the future. Based on holistic knowledge and understanding of deep interconnection of technology and social sciences, the strategy(es) for the future would meet the needs of the present without compromising the ability of future generations to meet their own needs.
Finaly, an improvement of sustainability implementation on pedagogical, research and economy fields will be suggested since new approaches are needed if we want different (better) results.

Keywords: sustainability, pillars, environment, economy, social, holism, balance

*Speaker

Cellulosic fabrics bio-finishing with natural products

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Sustainability in the textile industry is of utmost importance, as greener processes using less harmful chemicals, water and energy are warranted. A strategy to diminish these consumptions is based on the usage of organic compounds that are extracted from Nature, or which are produced as residues from other industries. Thus, in this work, cotton and hemp fabrics were functionalized with several natural compounds to obtain fabrics with a variety of properties. Propolis (beehive byproduct made by bees), kraft lignin (extracted from trees or plants) and olive pomace (a byproduct from the production of olive oil, extracted from the olive pit) were used to confer fabrics with antimicrobial properties. Cotton and hemp fabrics were functionalized with propolis and kraft lignin through exhaustion process. Logarithmic reduction values between 3 and 4 were obtained for both and were classified as weak disinfectants. Olive pomace was combined with a commercial thickener and applied by a printing process to obtain strong decontaminant fabrics (log reduction values between 2 and 3). Diatomaceous earth and mordenite zeolite (SiO_2-based natural compounds) were applied by padding, in combination with biopolymers - sodium alginate (extracted from algae) and chitosan (obtained from crustaceans' shells, residue from food industry) - to obtain flame retardant textiles. These fabrics reduced the flame propagation speed by between 29 and 55%. Pine rosin (residue from the paper industry) was used to obtain a fluorocarbon-free hydrophobic fabric. The results obtained in this work demonstrated the ability to (re)use natural (by)products, with a considerable environmental impact on the textile industry. Furthermore, the use of other industries' residues or byproducts not only opens a possibility of synergism between industries but also promotes a circular economy.

Keywords: Sustainability, natural products, finishing, antimicrobial, flame retardant, hydrophobic

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Aqueous solutions for sustainable elastane degradation in textile recycling

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Elastane is a widely used synthetic filament in textile materials appreciated for its elasticity and strength. However, it poses a major environmental challenge, as its presence can hinder or even inhibit the recycling of materials, leading to their disposal in landfills or incineration. Due to its high elasticity, elastane cannot be effectively shredded by the equipment typically used for processing textiles. Its presence leads to clumping, clogging, and contamination in the machinery. To enhance fibre recycling rates, it is essential to separate elastane from textile blends or reduce its elasticity. In response to the growing demand for sustainable methodologies, research into elastane degradation has expanded with a special focus on chemical and thermal methods. Nevertheless, a considerable number of existing methodologies rely on the use of aggressive solvents and high levels of energy consumption, which ultimately constrains their environmental viability. This study explores the potential of aqueous solutions at moderate temperatures as a more sustainable alternative for elastane degradation. Thus, the materials can be processed through shredding equipment later without causing issues. The research assesses the efficacy of diverse aqueous-based systems in degrading elastane fibres under controlled conditions. The objective is to develop an efficient process that is aligned with the principles of a circular economy, with a particular focus on water-based solutions. Aqueous solutions offer several advantages over traditional methods, including reduced toxicity, decreased organic solvent usage, and the generation of less hazardous waste. In this work, the degradation of elastane filaments was tested by exhaustion method at 90○C for 7 hours using the principles of acidic hydrolysis (acetic acid), basic hydrolysis (sodium hydroxide) and chemical degradation with an organic catalyst (1,4-diazabicyclo(2.2.2)octane (DABCO)). The degradation of elastane filament was evaluated through a combination of mechanical tests, (*e.g.* breaking force and elongation), chemical characterization by Fourier transform infrared spectroscopic method with attenuated total reflectance (FTIR-ATR) and thermogravimetric analysis (TGA). The results indicate that the treatments can degrade elastane filaments at moderate temperatures, enabling the breakdown of elastane into smaller and recoverable components without the use of harsh chemicals.

Keywords: Elastane separation, polyurethane, recycling, textile waste, fibre recovery

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Investigation of the effect of recycled cotton fiber usage in woven fabrics on performance properties after the UV aging

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Today, promoting the use of recycled cotton in the textile industry is an important step for reducing the environmental impact of the industry and achieving a more sustainable future. On the other hand, people want to be informed about performance properties of fabrics including recycled fibers in deciding the choice for use; i.e. summer clothings would show dramatic loss in terms of mechanical performance and color when prone to long hours of use under sunlight. It is known that cotton fabrics are frequently preferred as summer clothings especially in regions where the sun is effective for a long time and UV aging tests are applied to simulate the long exposure time to the sunlight. In this study, it was aimed to promote the utilization of recycled cotton fibers in woven clothing fabrics through examining their performance properties after exposing to UV aging and comparing with identical fabric of virgin fibers. For this purpose woven fabrics with same sett values and weft yarn type differing the cotton fiber content, were produced: 55% polyester : 45% virgin cotton, 55% polyester : 45% recycled cotton, 38% polyester : 62% recycled cotton (w:w). The samples were bleached and dyed by commercially available chemicals and dyes. Then raw, bleached and dyed samples were exposed to UV aging test in accordance with TS EN ISO 4892-3 Cycle 6 standard, separately. The color coordinates, color fastness, pilling and tear strength values of the fabric samples before and after UV aging were measured. As a result of the study, the significant decrease was observed in terms of color difference and tear strength after UV aging for all samples, however samples with recycled cotton fibers gave non-significant performance with that of virgin fibers.

Keywords: woven fabric, recycled cotton, UV aging

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Promoting recycling of wool-polyester-elastane yarn through sustainable elastane degradation methods and impact on remaining fibres integrity

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Textile consumption has risen dramatically, with garment production doubling between 2000 and 2021, and is projected to reach 149 million tons by 2030, contributing to a growing volume of textile waste. EU regulations set to take effect in 2025 will require the recovery of textile waste and prevent it from ending up in landfills or incinerators. The most common method for textile recycling is mechanical shredding, where textiles are broken down into fibres and re-spun into new yarns. However, the presence of elastane in textile materials can make mechanical recycling impractical. As a result of its high stretchability, elastane causes blockages and contamination of machines. To improve mechanical recycling efficiency, it is crucial to remove elastane from textile blends or reduce its elasticity. Solvent extraction is the most common method. However, this poses challenges such as environmental toxicity, health risks, limited selectivity, high costs, regulatory compliance, and potential damage to remaining fibres. Thus, research for more sustainable practices in textile recycling is needed. This study investigates ecological methods for degrading elastane in wool-polyester-elastane blended yarns derived from industrial waste. Exhaustion methods at 45∘C or 90∘C, using water-based solutions (sodium hydroxide, acetic acid, hydrogen peroxide, sodium chloride, or calcium chloride), are employed to reduce the elasticity of the elastane and facilitate the shredding of the yarns. The impact of these treatments on the remaining fibres (wool and polyester) is also evaluated. To confirm the degradation of elastane fibres and the effect in the other fibres, mechanical tests were performed to determine the breaking force, elongation, tenacity and Young's modulus. The chemical modifications were assessed by FTIR-ATR and TGA, and the morphology of the fibres was evaluated by SEM. This research provides a pathway toward more sustainable textile recycling processes, reducing waste and contributing to circular economy goals within the textile industry.

Keywords: Textile waste, post, industrial waste, polyurethane, mechanical recycling, blended yarns

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Evaluation of QR code geometric parameters and readability under tensile stress

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Modern labels based on QR code could be an attractive solution to provide information about garment origin, composition, repair, maintenance and disassembly through the whole product life cycle, reduce waste and promote sustainable resource use. QR code is cost-effective, easy to implement technology, however it also comes with some limitations. The challenges of label quality related to the durability and readability of the integrated QR code in the fabric may appear over time when the label is subjected to mechanical impacts.
Earlier research aimed to evaluate the influence of different technologies (embroidery, sublimation, and heat transfer printing) on the quality and readability of QR code. It has proved that embroidery presents the biggest technical difficulties, but this technology has less limitations for fabric composition, heat sensitivity, etc. while compared with other used technologies. Additionally, embroidery conveys a sense of craftmanship, luxury and can also be as part of products design.
This study focusses on changes in the geometrical parameters of the embroidered QR code during tensile tests, considering deformations in both the wales and courses directions of the interlock jersey fabric. The geometric distortion of the QR code is estimated based on image analysis. The readability of QR code depends mostly on the finder, timing and alignment patterns that are created within QR code. Previous study revealed that unmatching value percentage is reliable parameter to evaluate the readability of QR code and analyse geometric distortion of QR image elements.
The chosen research and assessment approach may have wider applications, potentially extending to other small embroidered features beyond QR codes.

Keywords: QR code evaluation, geometric distortion, tesnsile test

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Transforming Waste Cotton and Polyester Fabrics and Polypropylene Packaging Waste into Sustainable Composite Materials for Sound Insulation

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Textile waste presents a significant environmental challenge, emerging both from the manufacturing and processing stages of textile products (industrial or pre-consumption waste) and from end-of-life products that have been used by consumers (post-consumer waste). Addressing textile reuse and recycling is essential to reduce environmental impact when compared to alternatives like incineration and landfilling. Repurposing textile waste as components in composite materials has gained attraction as a sustainable approach to convert waste into value-added products. On the other hand, the packaging sector, which mostly includes single-use products, also causes a large amount of waste. The raw materials of the products with the highest percentage among this waste group are polyethylene and polypropylene. These polymers' thermoplastic characteristics allow them to function as binders in textile-based composite structures. In this study, fiber-reinforced composites are produced using waste cotton fabrics, waste polyester fabrics and waste polypropylene packaging materials. In this context, plastic wastes converted into plate form by hot press method are laminated to waste cotton and polyester fabrics. Then these laminated surfaces are opened to their fibers by using shredder and placed in hot press for the production of recycled fiber reinforced composite panels. The produced panels are subjected to two more additional shredding processes and the effect of recycling degree (1, 2 and 3) on the acoustic properties including sound absorption coefficent and sound transmission loss of the produced structures is examined. This study aims to demonstrate the potential of thermoplastic composites as a recyclable raw material with adequate sound insulation properties, suitable for applications in the automotive and construction sectors.

Keywords: textile waste, fiber reinforced composite, sound absorption

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Design and development of a bio-based coating composed of robust sustainable raw materials, based on 100% alkyd emulsion enhanced with colloidal nano-SiO_2

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Bio-based coatings are a rapidly expanding market driven by consumer awareness and green regulations, but there are still some obstacles to be solved such as the high price of the final product, and the performance, that in many cases is inferior to the conventional ones. It is estimated that the bio-based coatings market increases at a compound annual growth rate (CAGR) of 9.5% and tends to reach 16.6 billion euros in 2027 and 17.9 billion euros in 2032.

This study is focused on the design and development of waterborne masonry coating, with minimized content of volatile organic compounds (VOC) contributing to a healthier indoor air quality, and with technical characteristics compliant to sustainable "green" building programs criteria such as LEED, WELL Building or BREEAM. The intended use of such a coating is internal walls and plasterboards, on overcrowded rooms as offices, malls but also on kindergartens, schools and domestic applications such as on childrens' rooms and kitchens.

Six coatings with different Pigment Volume Concentration (PVC) were formulated. Specifically, two versions of high PVC coatings approx. 64% and four of low PVC approx. 44%, were prepared and characterized with various methods. The novelty on the formulation of such coatings is based on the use of alkyd emulsion binder enhanced with colloidal nano-SiO2 and ingredients such as sustainable alginate rheology modifiers, and fillers derived of processed oyster shell powder. Important factors that have impact on bio-content and important manufacturing parameters were evaluated and specific properties such as whiteness, yellowness, contrast ratio and mechanical properties such as film hardness, adhesion, bending, wet scrub, stain and burnish resistance were scrutinized. Important results on microbial contamination, wet scrub resistance and yellowness depending on the PVC and fillers composition, arise.

Keywords: polymers, nanocomposites, coatings, colloidal nano, SiO2, alginates, bio based

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Using high resolution X-ray microtomography to track cotton biodegradability

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The biodegradability of natural fibers like cotton is a key concern in both textile and environmental research, as cotton is one of the most commonly used fibers in the world. Traditional biodegradability tests, such as burial assays, often present challenges due to contamination of the sample when extracted, leading to a loss of critical information. To overcome these limitations, advanced imaging techniques such as electron microscopy combined with computed tomography offer a non-invasive solution for tracking the degradation process over time, without disturbing the sample. The aim of this study is to evaluate the effectiveness of computed tomography (CT) combined with electron microscopy in analyzing the biodegradability of cotton fabric. The primary goal is to observe and quantify changes within the cotton fibers over a three-month period of degradation, without the need for sample retrieval and cleaning, which can result in data loss.

Cotton fabric samples were subjected to controlled biodegradation conditions over a period of three months. Using electron microscopy coupled with computed tomography, we obtained high-resolution 3D images of the cotton fibers at various stages of degradation. This technique enabled non-destructive analysis, providing detailed insights into the internal structure of the fibers and the progressive breakdown at a microscopic level. Unlike traditional burial tests, no physical sample extraction was needed, eliminating the risk of contamination or alteration from external cleaning procedures. The imaging results demonstrated significant structural changes in the cotton fibers over time, particularly in the fibrillar components and fiber surface. Degradation patterns were clearly observable, including fiber thinning, surface erosion, and internal fragmentation. These findings would not have been as readily apparent using traditional methods due to the potential loss of fiber fragments during sample cleaning. The CT scan data allowed for precise tracking of the degradation process within the fiber matrix.

This study highlights the advantages of using electron microscopy combined with computed tomography for the analysis of cotton biodegradability. The ability to observe the degradation process in situ, without disturbing the sample, provides more accurate and detailed information on the fiber's breakdown mechanisms. This method eliminates the issues associated with soil contamination and sample cleaning inherent in burial assays. These results suggest that CT imaging can serve as a valuable tool for future biodegradability studies, offering a non-invasive approach to understanding fiber degradation at

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a microstructural level, and can potentially be applied to other natural fibers beyond cotton.

Keywords: non invasive analysis, textile, sustainability, 3D imaging, microtomography

Use of heat pumps in the textile finishing industry: state of the art and the need for further research

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Textile finishing processes such as dyeing, finishing, drying and heat setting require high amounts of hot water and hot air. Partly these processes run with temperatures up to 200°C. To date the required heat is mostly generated by fossil fuels. Waste heat is mainly released into the atmosphere, only in some cases it is recovered by heat exchangers or heat recovery systems and reused in the production or other (external) processes. To reduce the CO2 emissions of the textile finishing industry in the future, technologies to gradually electrify and reduce/reuse waste heat move into focus. In other industries it can be recognized that especially the use of industrial or high temperature heat pumps increases to generate heat and reduce or either substitute fossil fuels. This approach may also be interesting for the textile finishing industry. So it is important to develop approaches in which heat exchangers recover a significant amount of waste heat, then high temperature heat pumps systematically upgrade the recovered heat to a higher temperature level (which may be far over 100°C) and subsequently supply it to different (sub-)processes. This approach should also include the idea of integrating heat storages to improve the flexibility regarding different operating times.
A literature research and analysis has shown that a few research projects have already worked on first approaches to integrate heat pumps in dyeing processes. In addition to the technical challenges researchers also analyzed the economic aspects. But when taking a closer look on the studies, it becomes clear that these mostly focus on individual (sub-)processes, individual heat flows (e.g. only preheating fresh water) or temperatures below 100°C. To integrate heat pumps at a larger scale in the textile finishing industry and reduce fossil fuels, further research is needed especially with a focus on a more holistic approach. The aim should be to design, simulate and analyze the technical as well as the economic aspects of the integration of heat pumps in a whole textile finishing process – from the material preparation up to the drying and heat setting process with the most effective interconnections possible, instead of focusing on individual (sub-)processes only. Being in contact with experts from the heat pump sector could additionally help to overcome previous temperature limits as a lot of research and development is currently carried out in the area of industrial heat pumps. A collaboration could also help to identify and directly communicate the needs of the textile finishing industry regarding technological features towards the heat pump market.
As already mentioned, additionally to the technological and ecological analysis of a holistic approach, it is also important to take the economic aspects into account. For the

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transfer into practice certain recommendations might be needed. Because, even if the technical implementation and a reduction in CO2 emissions may successfully work with this approach, topics like amortization period as well as the ratio of electricity and gas/fuel prizes, etc. will play an important role to motivate and convince users to switch their production from conventional heat suppliers towards the heat pump technology.
In order to continue working on options to implement heat pumps in the textile finishing industry, a PhD research project at University of Applied Sciences Hochschule Niederrhein and University of Applied Sciences Hochschule Karlsruhe focuses on the development of a holistic approach as the one described above.

Keywords: textile finishing, textile dyeing, textile drying, high temperature heat pumps, exhaust heat recovery, heat exchanger, heat storage, reduction of co2 emissions in textile finishing processes

Functionalization of 3D-printed gyroid structures with active agents for enhanced dye adsorption in textile wastewater treatment

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The textile industry is a major consumer of water, contributing significantly to global water pollution due to the discharge of untreated wastewater containing dyes and chemicals. Consequently, water contamination in this sector is a pressing issue that demands immediate attention. Hence, the present studies alternative filtration solutions using strategically designed gyroid structures for Plate and Frame filtration systems. These structures were produced via 3D printing following a stereolithography process using a resin based on urethane dimethacrylate. Samples were functionalized, via vacuum infusion, with active agents (zinc oxide nanoparticles or activated carbon), aiming at improving their filtration properties through the adsorption of contaminants. A solution based on an aliphatic polyurethane dispersion containing different concentrations of zinc oxide nanoparticles or activated carbon was applied to the gyroid structures. The resulting structures underwent characterisation tests to confirm the integration of the active agents and their adsorption capacity. Their morphological, mechanical, thermal, UV resistance and chemical resistance (pH=1, pH=3 and 1g/L Cl) properties were studied. Additionally, the gyroids' ability to resist biofouling was assessed conducting standard protocols, using reference strains of *Staphylococcus aureus* and *Escherichia coli* to evaluate its bactericidal effectiveness. Initial antibacterial testing on zinc oxide nanoparticles demonstrated effective bactericidal capabilities against *Staphylococcus aureus*, with a minimum inhibitory concentration of 6.25 g/L. Additional results show a substantial increase in adsorption capacity of the functionalized gyroids following the inclusion of the active agents, namely zinc oxide nanoparticles, indicating potential for enhanced dye removal, specifically Remazol Yellow RR, Remazol Red RR Gran and Remazol Brilliant Blue BB Special. The results demonstrate that the incorporation of zinc oxide nanoparticles enhances adsorption and bactericidal properties of these structures, making them promising candidates for filtration systems of textile wastewater. Future developments focus on refining the functionalization process and assessing scalability for effective wastewater treatment.

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Keywords: 3D printing, gyroid structures, dye adsorption, textile wastewater

End-of-life cotton textile-based engineered cellulose composites

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This study describes creating textile waste-based cellulosic composites (TWCCs) by upcycling used cotton fabrics. The research aims to develop a new fully/partially biodegradable composite material using textile waste obtained during the production process of textile materials. Textile waste poses a significant environmental challenge due to its accumulation in landfills. This study explores the potential of repurposing textile waste into composite materials through advanced manufacturing techniques. Three distinct sample types are developed for the comparative analysis of the characteristics: TWCCs, TWCCs laminate, and cotton/epoxy TWCCs composite laminate. The fabrication process is optimized to enhance the TWCC's mechanical and thermal characteristics. The structural integrity and performance of the developed composite materials are assessed by mechanical testing, Fourier-transform infrared spectroscopy (FTIR), and scanning electron microscopy (SEM). Furthermore, the developed composite's biodegradability was investigated. The results show that TWCCs made from textile waste have the potential to be an effective way to lower environmental pollution, encourage circular economy principles in the manufacturing industry, and provide good mechanical properties for various applications.

Keywords: Sustainability, Mechanical property, Textile waste, Recycling.

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Enhancing Traceability and Circularity in the Textile Sector: Leveraging Digital Product Passports for Sustainable Innovation

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The Digital Product Passport (DPP) represents a strategic opportunity to store and share detailed information about a product's lifecycle. This mandatory electronic system, scheduled for implementation by 2030, aims to provide stakeholders-including industry, businesses, authorities, and consumers-with a comprehensive view of the materials used and the environmental impact of products. The DPP is integrated into the European Union's Green Deal legislation, under the Sustainable Textiles and Ecodesign Strategy, and is a central component of the European Commission's Ecodesign for Sustainable Products Regulation.

In recent years, the DPP has become a tool to enhance product traceability, promote circular economy practices, and support regulatory compliance. The European Commission's Circular Economy Action Plan in 2020 emphasised the importance of adopting a full lifecycle approach, from production to disposal. As part of the ecodesign regulation, the DPP strengthens transparency and provides crucial information to help consumers and manufacturers make more informed decisions aligned with environmental sustainability.

This article adopts two primary approaches: laboratory research and descriptive research. In the laboratory research, textile products of different compositions will be analysed in controlled environments, undergoing repeated washing to observe changes in colour, print, density, and texture. Simultaneously, consumers will use the products daily and respond to surveys on performance and comfort over time, providing qualitative and quantitative data.

The descriptive research will focus on the sensory analysis of the products, with evaluators of varying experience levels describing the qualitative and quantitative attributes of the textiles studied. This approach is essential for characterising sensory perceptions, such as tactile feel and visual appearance, after use and multiple washes. The aim is to understand the factors influencing longevity and its impact on consumer comfort.

Keywords: textile industry, traceability, circular economy, product passport digital innovation, sustainability

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Assessing Fiber Release and Durability of Textiles Under Various Washing Conditions

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Around 35% of environmental microplastics originate from synthetic textiles, with additional sources including tire abrasion, fishing nets, abrasives, and other textile products. A significant portion of these microplastic fibers are released during washing, especially from clothing. Currently, about 30–50% of clothing materials are made with synthetic fibers such as polyester, and each individual washes between 200 and 300 kilograms of textiles annually. In addition to the environmental effects of microplastics, the durability of textiles - often impacted by washing - plays a critical role in clothing sustainability. Adjusting washing settings can help extend textile lifespan and minimize damage. The amount of fiber loss during washing varies based on textile properties such as strength, susceptibility to pilling, and resistance to abrasion. Specific factors in the washing process contribute to fiber shedding and the wear of textiles. This study aims to evaluate fiber loss from textiles under various washing conditions over five cycles, examining the effects of detergent type (powder or liquid) and spin speed (600 or 1000 RPM) on fiber shedding. It also investigates the abrasion resistance and pilling behavior of the textiles involved.

Keywords: Fiber loss, washing, washing machine, pilling, abrasion resistance, sweatshirts, knitted textiles

*Speaker

Modeling for textile sustainability assessment: objectives, methodology and tools

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In this article, we consider life cycle modeling as a tool for the study, analysis, prediction and optimization of the impact of textile industrial activity on the environment. This article aims to introduce a conceptual framework for the modeling of the environmental sustainability of the textile industry. It aims to raise the issue of sustainability modeling in the textile industry. It is a contribution aimed at highlighting the importance of the modeling approach in under-standing, analyzing, predicting and optimizing environmental sustainability in the textile industry. LCA-based modeling presents a comprehensive, flexible methodological framework. This LCA-based modeling has the advantage of being a global method that can be applied across the entire textile value chain, but also that it can be deployed at all levels of this value chain. Mathematical, statistical, analytical, artificial intelligence modeling methods and their associated tools are introduced and can be used for the optimization of LCA-based modeling

Keywords: life cycle modeling, mathematical modeling, sustainability assessment, textile industry

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Fibers made from peach waste

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The foundation of circular economies lies in their capacity to reuse, regenerate, and recycle waste, and their growth hinges on the establishment of industrial symbiotic ecosystems. In this context, we researched the idea of utilizing peach peels and pomace from the Greek compote and juice industries to extract cellulosic pulp that could be turned into textile fibers. The successful extraction of the peach pulp was followed by its blending with α-cellulose powder at a ratio of 25:75 and the addition of the organic solvent N-Methylmorpholine N-oxide (NMMO) to prepare the spinning dope. Next, laboratory experiments using a wet spinning machine confirmed the suitability of the pulp to produce regenerated cellulosic fiber from airgap spinning of NMMO solution, establishing proof of concept that the agro-industrial peach waste can be upcycled to produce manmade cellulosic fibers (MMCFs). A lab-scale process was developed after implementing technical adjustments to improve both the process and the morphology of the fiber. The latter was confirmed via scanning electron microscopy. Measurements of chlorinated phenols and organotin compounds by gas chromatography-mass spectrometry confirmed their absence in the produced fibers, making them compatible with the EU regulation on the Registration, Evaluation, Authorization, and Restriction of Chemicals (REACH) and the $OEKO-TEX^{®}$ Standard 100 as to the specific parameters. pH values confirm the compatibility of the produced cellulose fibers with the skin and indicate the absence of finishing or other chemicals.

Keywords: agro-industrial waste, cellulose, pulp, textile, peach, upcycling, fiber, NMMO

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Development of Circular Apparel with Good Handle Properties from Post-Consumer Denim Wastes and its Life Cycle Assessment

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Textile recycling is now inevitable for addressing environmental challenges arising from waste produced by the textile industry and can contribute to the achievement of Sustainable Development Goals (SDGs). Though mechanical recycling of textile wastes has lot of advantages, the quality of the recycled products has a long way to go. This research presents a novel approach for converting post-consumer textile waste (denim) into knitted apparels having good handle properties. To accomplish this objective, post-consumer denims were mechanically recycled and spun into rotor yarns (10 Ne). Then fabrics were produced using different ratios of recycled denim yarn (r-denim) and virgin cotton yarns (v-cotton), in the direction of course, in a flatbed knitting machine. Three different knitted structures i.e., rib, half cardigan and cardigan were produced. To improve the handle properties of the developed fabrics a silicone based softening treatment was given. Developed fabric samples were characterised for low stress mechanical properties, namely shear, bending, compression and friction, using Kawabata Evaluation System (KES). The experimental results were statistically analyzed using a three-way ANOVA. The results show that knitted fabrics are becoming a little stiffer and rigid with the increase in recycled fibre content. However, by course mixing and applying softening treatment comparable handle properties like those of virgin fabric were achieved even with 50 % recycled fibres. Additionally, using 50 % recycled fibres into the fabrics reduces environmental burdens significantly. Therefore, developed fabrics consisting of post-consumer textile wastes can not only reduce the requirement of producing virgin materials to a great extent and but also ensure the efficient use of natural resources and fossil fuels.

Keywords: circular economy, handle, life cycle assessment (LCA), post, consumer, sustainability, textile waste.

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Investigating the Transformative Potential of Textile Air Distribution Systems for Enhanced Sustainability

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This study examines the potential of textile air distribution systems, highlighting their advantages over traditional sheet metal ducting in efficiency and maintenance. We introduce an experimental technical textile with advanced properties, including variable antistatic features achieved through innovative single-finishing techniques. A comprehensive life cycle assessment indicates that gradual enhancements using cutting-edge textile technologies can significantly improve sustainability parameters.

Keywords: technical textile, ventilation, construction product, LCA, carbon footprint, surface finishing

*Speaker

The influence of mechanically decomposed waste polyester textiles of different sizes as fillers on epoxy composite materials

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Due to the excellent properties of polyester, as well as its low cost and simple manufacturing process, polyester fibers are widely used in various fields around the world, and show an annual growth trend. Due to its non-degradability and environmental harm, the recycling and utilization of polyester fibers has become increasingly important. With the development of modern composite materials, the innovation and sustainability of fillers have become a research hotspot. As a common polymer waste, waste polyester has excellent properties such as high strength, low density and processability, which makes it potential for application in composite materials. Therefore, this article aims to use appropriate methods to use mechanically decomposed waste polyester particles as fillers to change the properties of composite materials, so as to reuse waste polyester and realize the concept of recycling and environmental protection. The main purpose of the paper is to explore the effects of polyester particle/segment size on the properties of resin/fiber fiber-based composites. The system analyzed its impact on the mechanical properties of composite materials, such as toughness, elongation, and bending stiffness. This study not only provides new ideas for the high-value recycling of waste polyester, but also provides theoretical and technical support for the development of new lightweight, low-cost, and environmentally friendly composite materials.

Keywords: mechanically decomposed, waste polyester, composite materials, particle/segment size, recycling

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Chemical Recycling of PET : Water-based Decolorization and Depolymerization by Hydrolysis Method

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Polyester (PET) is the most widely used fiber in the textile industry, accounting for over 70% of all textile products. However, PET is non-biodegradable, leading to the accumulation of large amounts of textile waste each year and raising concerns over long-term environmental issues. Thus, there is a growing need to recycle PET either physically or chemically. One of the major challenges in chemical recycling of PET is that most PET textiles are dyed, which complicates the recycling process. Dyes interfere with depolymerization reactions, reducing the yield of monomers (TPA) in the depolymerization. Therefore, it is crucial to remove the disperse dyes from waste PET fibers to improve chemical recycling efficiency. The common method for decolorizing PET fibers involves using organic solvents, such as DMF, to extract disperse dyes. However, the organic solvents are expensive and difficult to recover at a commercial scale, posing additional environmental risks. This study explores a water-based decolorization using alkali and a reducing agent, with or without an additive. Under optimal decolorization conditions, a decolorization efficiency of over 95% was achieved. To assess the impact of dye removal on the PET depolymerization yield, depolymerization was carried out via hydrolysis method. Compared to the depolymerization yield of virgin PET, the yield decreased for disperse-dyed PET. However, PET with disperse dyes removed through a water-based decolorization method showed an increased depolymerization yield, achieving results similar to those of virgin PET.

Keywords: decolorization, depolymerization

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Optimization and Innovation in the Textile Supply Chain Using Specific Fibers

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The textile and clothing industry is key for economic development in emerging countries, yet its environmental impacts remain significant. With textiles accounting for 4% of CO_2 emissions and vast global resource consumption, sustainable transformation is critical. This research focuses on optimizing the textile supply chain by integrating bast fibers-such as hemp and flax-as sustainable alternatives to cotton. Life Cycle Assessments (LCAs) reveal that bast fibers significantly reduce water consumption and land use compared to conventional cotton. The study also explores circular economy strategies, including efficient knitting and weaving techniques, chemical management, and water recycling, tailored for Uzbekistan-a prominent textile producer facing water scarcity. Advanced partnerships with German and European institutions aim to foster innovation through sustainable processing methods, modernizing industrial practices, and exploring biomaterial reuse, including waste from silk and linseed production. Preliminary results indicate that adopting bast fibers and circular practices could reduce freshwater toxicity by 31% and land use by 24% in textile production.

Keywords: textile industry, bast fibers, circular economy, sustainability, Uzbekistan, Life Cycle Assessment, resource efficiency

*Speaker

Recycling of personal protective equipment: Evaluation of image-based methods for damage detection

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Textile products are one of the most significant emitters of greenhouse gases, with clothing textiles making a considerable contribution. Workwear, in particular personal protective equipment (PPE), is often not considered in this context. As the focus of PPE is on protection, sustainability aspects often take a secondary role. However, due to the high-quality and highly functional materials used in PPE, it is reasonable to include them in recycling strategies. In order to retain as many functionalities of the materials as possible, a recycling strategy should aim to preserve the textile surface. This requires the reliable identification of areas that cannot be reused.
The objective of this work is to compare different image-processing algorithms with regard to their capability to analyse such areas. For this purpose, a catalogue of non-reusable areas was created, including holes, slits, stains and construction elements such as buttons and zips. Each of these defects was analysed using the same algorithms and the results were compared with each other.
The quantitative comparisons of the analysis results show that the biggest challenge is in the multidimensionality of the areas to be recognised. Depending on the angle of illumination, a textile fold can be recognised more easily than a hole. A central problem is to clearly distinguish the areas to be recognised from possible interfering variables such as prints or folds. In addition, the variety of appearances of stains, cuts and similar defects complicates the analysis.
The outcomes of this work demonstrate that the correct selection of filter and image processing algorithms is capable of reliably recognising numerous of the areas described. However, there is a considerable susceptibility to a large number of disturbance variables.

Keywords: textile recycling, personal protective equipment, image processing, defect detection, sustainability

*Speaker

Method of recycling protein fiber waste and decoloring-bleaching melanin with metal salt

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The object of the research was the wool fiber of the "Hisori" breed of sheep grown in the climatic conditions of Uzbekistan, with a diameter of 55.35 μm and a length of 12-14 mm. Taking into account that colored pigments in the fiber form chelates with metal salts, it has been shown that the pigment that gives natural color to wool can be separated from the protein using $FeSO_4 \cdot 7H_2O$, followed by bleaching, thereby reducing fiber destruction. Colored wool fibers were decolorized by treating the fiber in a solution of ferric sulfate at 50∘C followed by treatment in a bleaching solution. In this method, decolorized-bleached coarse wool fiber has soft properties, the spinning structure is preserved, besides, this method consumes less energy. The bleaching process consists of hydrogen peroxide, ammonium hydroxide, and non-ionic surfactants. Hydrogen peroxide decomposes to form perhydroxyl ions, which, since this ion is unstable, form atomic oxygen, which decomposes the pigment in the wool to a water-soluble state. Since the samples did not turn white after the bleaching process, the degree of whiteness was assessed by the yellowness index (YI,%). The procedure and approach for the process of decolorization-bleaching of wool coloring pigments, namely eumelanin and pheomelanin, was developed: $FeSO_4 \cdot 7H_2O$ (10 g/l), $HCOOH$ (6 g/l), non-ionic surfactant (0.5 g/l), pH=6, process duration 40 minutes, temperature – 500°C. At the final stage of the research work, various natural finishes were used to soften wool. The amphoteric property of keratin was selected in the treatment of wool with different compositions, conditions were selected that were proportional to the destruction and softness of the fiber depending on the pH environment. According to the results of the research was proposed a sequence of washing-decolorization-bleaching-softening processes for coarse wool, which is not used in the textile industry.

Keywords: wool fiber, keratin protein, amino acids, melanin substances, pigment, softening process and protein fiber waste

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Characteristics of mulberry silkworm cocoons and results of the experiment on their unwinding

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The object of the study is was yellow cocoons, which are not used in the silk industry. Our scientific work presents their geometric dimensions, rigidity indicators and the results obtained after unwinding hybrids of yellow cocoons with high silkiness and bright yellow color. In order to study the technological characteristics of yellow cocoons in accordance with the climatic conditions of the Republic of Uzbekistan and study the features of the hybrid, they were grown at home, and then their parameters were studied in accessible conditions in the scientific production laboratory of our institute. In the course of the work, the geometric dimensions of silkworm cocoons were studied, the mass of cocoons, cross-sectional diameters, volumetric and surface parameters were determined. The results obtained on the geometric characteristics of yellow cocoons were positive and had a predominantly oval shape, which is excellent for unwinding. The rigidity indicators of cocoons were also determined and their silkiness was studied. To determine the technological and physical and mechanical characteristics of yellow cocoons, studies were conducted on a device designed for single, that is, individual unwinding of cocoons. As a result, it was noted that the cultivation and processing of yellow cocoons brings great income to the silk and textile industry and in the production of various types of silk threads.

Keywords: yellow cocoons, geometric dimensions, rigidity index, silkiness, reeling.

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Development of multifunctional hemosorbents from silk industry fibrous waste

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This study explores the transformation of fibrous waste from the silk industry into multifunctional fibroin based hemosorbents via advanced modification techniques, including hydrothermal hydrolysis, ultrasonic dispersion, and high-frequency irradiation. The modified fibroin demonstrated significantly enhanced sorption characteristics, paving the way for their application in detoxifying blood and plasma. The sorption properties were evaluated using water vapor and vitamin B12 as model sorbates.
Key findings indicate that the specific surface area of the modified fibroin reached 673.2 m^2/g, with a monolayer capacity of 5.497 mol/kg and a sorption capacity of 7.6 mg/g for vitamin B12. Compared to untreated fibroin, the resulting hemosorbent exhibited a six-fold increase in micropore volume and a 7.5-fold enhancement in mesopore volume, along with a twofold improvement in vitamin B12 adsorption efficiency. These improvements are attributed to the structural modifications that enhance porosity and the presence of active functional groups.
Biocompatibility and medical-biological assessments confirmed that the developed hemosorbent meets the criteria for use in medical applications. The material's high sorption efficiency, combined with its ability to selectively target toxins, positions it as a potential candidate for clinical deployment in hemoperfusion and plasma adsorption therapies.
This research highlights the innovative utilization of silk industry by-products for the creation of high-performance hemosorbents, addressing both waste valorization and the need for advanced biomaterials in medical detoxification applications.

Keywords: fibroin, hemosorbent, silk industry waste, sorption properties, hydrothermal hydrolysis, vitamin B12 adsorption, biocompatibility, medical applications.

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Exploring Future Materials for Sustainable Textiles: Innovations and Insights

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Fibres are essential materials in textiles, characterised by their high length-to-diameter ratio and properties such as flexibility, strength, comfort, and functionality. They have been fundamental to traditional textiles, and ongoing innovations continue to enhance their relevance. However, current textile fibre production relies heavily on fossil fuels, which are projected to be depleted between 2050 and 2090. There is an urgent need to identify sustainable alternatives to fossil fuel-based fibres.

Natural and regenerated fibres from renewable resources offer viable solutions but face challenges such as processing inefficiencies, environmental impacts, and limited scalability. Plant-based fibres like cotton dominate due to high cellulose content, but their production is unlikely to meet future demand. Other natural fibres, such as hemp and flax, offer potential due to their high cellulose content but require innovations in retting, mechanical processing, and eco-friendly chemical treatments to address the challenges posed by lignin content. Advances in genetic modification, selective breeding, and sustainable farming practices can further optimise fibre yield and quality.

Additionally, cellulose regeneration from agricultural wastes, discarded textiles, and microbial sources like bacterial cellulose presents opportunities for sustainable fibre production. Emerging sources, such as algae and seaweed, hold promise for developing biodegradable textiles but require further research to achieve commercial viability.

Future research must prioritise efficient lignin removal, renewable energy integration, and the development of scalable processing methods. A focus on sustainability, economic feasibility, and innovation in fibre production and regeneration will ensure a robust and diverse textile fibre supply, addressing the pressing challenge of reducing dependence on fossil fuels while advancing environmental goals.

Keywords: Fibres, Future Textiles, renewable resources, sustainability.

*Speaker

Improvement of the saw gin increase in the rotation speed of the raw roller

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Cotton fiber is widely recognized as a liquid product, and its demand in the global market continues to grow annually. To meet this rising demand, an increase in cotton fiber production is necessary. In saw ginning, a significant portion of the energy consumed is attributed to overcoming the frictional forces between the raw roller and the inner surface of the working chamber, as well as the forces required to separate fibers from seeds. This study aims to analyze how the friction coefficient of cotton fiber changes when it contacts a heated steel surface.
As part of this research, a novel device was developed to measure the friction coefficient of natural fibers on a steel surface. Existing designs and methods for determining friction coefficients were reviewed, and their primary limitations were identified. Our goal was to create a device capable of measuring the friction coefficient of fibrous materials at various surface temperatures, which could be applied in designing an improved working chamber for saw gins. This would enhance energy efficiency and product quality.
The resulting device was used to investigate how temperature affects the friction coefficient of fibrous materials as they move along a steel surface. Experimental data revealed numerical values for the friction coefficient based on the moisture content of raw cotton and the temperature of the steel surface. Results showed that as the surface temperature increased from 80°C to 100°C, the friction coefficient decreased from 0.6 to 0.46. This indicates that higher temperatures lead to increased raw roller rotation speeds.

Keywords: saw gin, working chamber, friction coefficient, raw roller, friction force, measuring device

*Speaker

Sustainable and innovative waterless piece dyeing method

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The textile industry is one of the most environmentally damaging sectors, especially due to traditional piece dyeing processes that require large amounts of water, chemicals and energy. These processes also generate significant amounts of waste, further increasing environmental concerns. As sustainability becomes an increasing priority, there is a need to investigate alternative dyeing methods that can reduce resource consumption and minimize environmental damage.

This study investigates an alternative recipe designed to reduce the environmental burden of conventional piece dyeing processes. Cotton woven fabrics were selected as the test material and the dyeing process was carried out with reactive dyestuff without using water and at room temperature. 400 g of powdered reactive dye mixture was applied to 4 kg of pretreated wet fabric with 80% moisture content using the spray method. The developed apparatus was attached to the sample machine and the powder combination was sprayed with the help of air.

In line with sustainability goals, the new dyeing process minimized steps such as prewashing and chemical use. The traditional pre-wash at 60°C for 15 minutes was reduced to 5 minutes at room temperature, and dyeing at 65°C for 60 minutes was completed in 15 minutes at room temperature. Rinsing and finishing were also carried out at room temperature, further reducing process time and resource consumption.

As a result of the study, 66% reduction in water usage and 73% reduction in processing time were observed. Colour fastness to water and sweat was measured as 4.5. Tensile strength was 145.7 lbs in warp direction and 86.0 lbs in weft direction, while tear strength was 5.4 lbs in warp direction and 5.7 lbs in weft direction. These results show that the new dyeing method offers a similar performance to conventional methods while significantly reducing water, energy and chemical consumption.

Keywords: sustainability, waterless dyeing, piece dyeing, waste management, energy, water efficiency.

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Solvolysis of polyesters sport-textiles wastes combined with polyurethane fibers for polyol production

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This work explores the chemical recycling of blended fabric from technical sportswear through many solvolysis processes in order to face one of the biggest environmental pollution factor of these years: the textile waste. The huge demand for increasingly high-performance materials, in terms of resistance and elasticity in the sports field, led to the creation of products composed by different materials that will be treatable differently once the product reaches its end of life. The final goal here is to obtain a polyol liquid product, with a single process, that can be useful in the production of new rigid foams.
The analyzed waste is made up of a polyester fiber matrix containing a percentage of polyurethane elastic fiber between 3-12%, percentages widely used in clothing nowadays. The processes suggested for this purpose are glycolysis and acidolysis. Glycolysis is a well-known technique that exploits a glycol as a medium in which the polymer chain of some plastic material, as in this case polyurethane and polyethylene terephthalate, are broken, usually under the action of temperature and catalysts, an acid in case of acidolysis. The main variables studied are the ratio waste/glycol, the quantity of the catalysts and the reaction temperature, instead of the typology of the catalysts, an acetate salt for the polyesters and a di-carboxylic acid for the polyurethane, that is kept constant.
The resulting polyols from the glycolysis processes are then characterized in terms of viscosity and hydroxyl number. Both of them are important because the product must be compatible with the virgin polyol used to produce new foams. Furthermore, the free amine content in the polyol is evaluated using high-performance liquid chromatography. This value must be below the regulation limit of 1000 ppm (0,1% wt) due to the cancerogenic nature of the toluene diamine, byproduct of the reactions.
Finally, the polyols produced are tested into many formulations to produce new rigid foams with ever-increasing quantity of recycled polyol. The new foam, characterized in terms of morphological, mechanical and thermal properties, shows good results even with a percentage of recycled polyol up to 25% in the formulation.

Keywords: Sport-textiles, chemical recycling, solvolysis, recycled polyols

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Open-loop chemical recycling of coupled technical textile waste

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Coupled technical textiles integrate multiple materials to enhance performance, providing improved strength, durability and specialized functionality. However, recycling these materials remains a significant challenge due to their complex multi-material composition, which hinders the efficient recovery of individual components. Among the available chemical recycling methods, solvolysis processes have gained attention for their versatility - enabling both open- and closed-loop recycling routes - and their effectiveness in treating various textile waste compositions.

This study focuses on the glycolysis process for the open-loop recycling of coupled technical textiles, specifically targeting post-industrial ski boots padding waste. These materials consist of a polyester fiber (PET) fabric laminated to a layer of flexible polyurethane foam (PUF), with the polyester content ranging between 33% and 60% by weight. Glycolysis experiments were conducted in conventional glass reactors, systematically varying key operational parameters such as reaction time, temperature, cleaving agent, and the type and concentration of catalytic systems. The goal was to optimize the characteristics of the recovered polyols, by targeting specific hydroxyl values (HV) and maintaining low viscosity.

The reaction progression was monitored over time, revealing an interaction between the polyester fraction and polyurethane-derived species. Notably, aromatic amines - specifically the 2,4 and 2,6 isomers of toluene diamine - are generated as side products of polyurethane glycolysis and were found to actively participate in polyethylene terephthalate de-polymerization. The gradual consumption of these aromatic amines was confirmed through high-performance liquid chromatography (HPLC) analysis. This phenomenon is particularly significant, considering that these compounds are classified as carcinogenic and require additional post-treatment, such as deamination, to minimize their presence in the final product. The resulting recycled polyols were progressively incorporated into the formulation of new polyurethane (PUR) and polyisocyanurate (PIR) rigid foams. The newly synthesized foams exhibited competitive thermal conductivity and optimal compression strength.

Keywords: Technical textile, chemical recycling, solvolysis, recycled polyols

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2- Fibre science and engineering, biopolymers

Evaluating fabrics for comfort under dynamic conditions – identifying effects of fiber type

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Humans produce different rates of sweating depending on the intensity level of a given activity and these rates will in reality also vary with time. Until recently, test methods to evaluate evaporative cooling, however, have focused on steady state heat loss only. With the recent dynamic hot plate tests, this is starting to change but these methods (e.g. ASTM F3628) still seem incomplete on their evaluation of a full sweating and drying cycle, let alone evaluating multiple cycles. Over the last few years we have conducted a number of studies that explore these wetting and drying cycles, using fabrics with different properties, such as hydrophilic, hydrophobic and hygroscopic and evaluated hot plate data in terms of peak cooling, drying time and total cooling energy. We performed these dynamic hot plate experiments at various 'sweat' rates and for different times, and comparing these experiments to results from a human subject evaluation, allowing for a better evaluation of the materials tests to actual human thermal comfort responses. These results show that the dynamic plate tests can be helpful, but still need to be considered within their scope of use. Some rapid wicking fabrics exhibit quick cooling, but may also show strong after-chill when sweating has stopped and less cooling would be needed. On the other hand, some hygroscopic-based fabrics exhibit slower increase in cooling, with less after-chill, effectively buffering these rapidly changes needs on cooling, where subjects did not report worse thermal comfort during the work where cooling was lower. Overall, the new test methods, evaluating dynamic cooling conditions have added values, but their interpretation depends on the intended environment, and the focus should not only be on maximum cooling but also allow for analysis of after-chill effects to fully evaluate wear comfort.

Keywords: thermal comfort, fiber type, dynamic test, sweating guarded hot plate

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Production and characterization of regenerated cellulose fibers using ionic liquid: comparison with different biomass plants

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Recently, the production of regenerated cellulose fiber (RCF) with ionic liquids has attracted much attention as an environmentally friendly process. However, the main raw materials used are cotton linter and wood pulp, and other cellulose resources have not been used much. In this presentation, cellulose purification from different biomass plants under the same conditions and dissolution with 1-Butyl-3-metylimidazolium Chloride; BmimCl were studied. In addition, we compared the effects of different plant species on the properties of RCFs.

The raw materials were selected *Andropogon virginicus* (AV) of the weed, *Cryptomeria japonica* (CJ) of the softwood, *Betula platyphylla* (BP) of the hardwood, and *Phyllostachys edulis* (PE) of the bamboo. These samples were compared by FT-IR and cellulose refinement measurements after the cellulose pulp was purified under the same conditions. The stock solution from cellulose pulp (5 wt%) was prepared in a mixture of BmimCl and DMSO (wt/wt=6/4). The spinning method was the dry-jet-wet spinning, and the winding speed was set at 170 mm/sec. The strength properties of the obtained RCFs were examined.

In the FT-IR, purified samples showed the disappearance of peaks derived from non-cellulose components. The α-cellulose content of the pulps varied slightly among the species, with AV at 84.5%, CJ at 81.4%, BP at 81.2%, and PE at 78.3%. Fiber strength of AV, CJ, BP, and PE was 479±78, 452±86, 313±72, and 283±132 MPa; elongation at break was 4.2±0.7, 2.6±0.9, 4.4±0.4, and 3.9±0.8%; and initial modulus was 27.7±2.6, 26.9±0.8, 27.1±2.0, and 20. 3±2.4 GPa respectively. Fiber strength and initial modulus correlate with the amount of α-cellulose in the pulp, and thus the degree of pulp refining affects these strength properties. In conclusion, we conclude that the properties of RCFs vary among different plant species. Highly refined cellulose pulp was shown to contribute strongly to the mechanical properties of RCFs.

Keywords: regenerated cellulose fiber

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Impact of wet spinning process parameters on the quality of ecoresponsible man-made cellulose fibres

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In 2022, cellulosic man-made fibres were the third most produced fibre worldwide, with 7.27 million tonnes. Due to growing consumer interest in bio-based products and the production difficulties associated with cotton, demand for this fibres type is increasing rapidly. However, the production of these fibres presents both environmental and economic challenges. The viscose process, the most common, requires the use of carbon disulphide (CS_2), a Carcinogenic, Mutagenic and Reprotoxic (CMR) chemical. The Lyocell process offers a more environmentally friendly option but requires a large amount of energy and an expensive organic solvent.
The RegenCell project (ANR-22-CE43-0015) aims to rise to this challenge by using green or recyclable products at ambient temperature. Therefore, cellulose is double oxidized (by sodium periodate and sodium chlorite), introducing carboxyl groups and thus increasing the hydrophilicity of the polymer. This functionalization is carried out because the main difficulty in the transformation of man-made cellulose fibres lies in the amphiphilic nature of cellulose, making its dissolution complex. A balance must be achieved between cellulose dissolution (high oxidation degrees, low polymerization degrees) and regeneration (high polymerization degrees). Once a compromise has been found within the cellulose modification between these two characteristics, a modification of the wet-spinning process must be developed to meet the characteristics of this new dope (oxidized cellulose solubilized in sodium hydroxide).
A continuous wet-spinning bench is divided into several interdependent steps, each of which is important for its own phenomena and parameters. The optimization of spinning, coagulation and drawing parameters is studied considering the physico-chemical phenomena and the final filaments properties. The influence of different formulation parameters (dope concentration) and process parameters (temperature, coagulation time, draw ratio, ...) are assessed on the final filaments. In particular, the mechanical and hygroscopic properties are compared to those of common cellulosic process, as viscose.

Keywords: textile processing, wet spinning, cellulose, green process, biobased textiles

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Textile photonic yarns for infrared electromagnetic wave control

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Nowadays, one of the most important objectives of our society is to improve thermal energy control. Many fields are targeted as car industry, space traveling, houses, surveillance, ... The present study focuses on this latter, as infrared camouflage plays a crucial role in shielding soldiers from thermal detection.
This research work aims to propose an innovant photonic textile multifilament yarn in order to design an infrared (IR) camouflage fabric, comfortable and easy-to-wear. The physical and geometrical filaments' properties are investigated through numerical simulations using the finite elements method in COMSOL software. The modelling was based on multifilament yarns made up of a bundle of very fine, infinitely long threads (filaments) based either on polyethylene (PE) as a reference sample, or on polyethylene terephthalate (PET).
To modelized the experimental situation, a micrometer-wavelength light source, representing the soldier, is directed at circular filaments arranged in a periodic pattern and embedded in an air matrix. The modulation of the incident light is then recorded and analysed. Two geometrical or structural parameters are investigated, i.e., (i) the filament diameter meaning the polymer/air ratio in the lattice, and (ii) the angle of light incidence. The transmission spectra through the structured membranes are then calculated in which non-transmission regions, known as photonic band gaps, are identified and are attributed to either absorption or reflexion properties. By varying the filament diameters, which results in a filling fraction ranging from 8% to 84%, the band gaps shift toward higher wavelength, while also narrowing in width.

Keywords: simulation, camouflage, polymer, photonic, infrared

*Speaker

Polylactide/Polycaprolactone blends properties for thermoplastic composite fibrous reinforcements

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Nowadays, most of the polymer materials used in composites come from the petrochemical industry. To facilitate their recycling, thermoplastic materials are growing in use as an alternative to conventional materials and thanks to the raising awareness of sustainable development, biopolymer development has known growing interest in recent years. Among these polymers, polylactide (PLA) accounts for over 31% of global biopolymer production and is one of the most interesting due to its biobased origin, biocompatibility and compostability under industrial conditions. PLA is emerging in the development of composites in various applications (biomedical, packaging) owing to its inherent properties. The objective is to produce PLA-based all thermoplastic (reinforcement and matrix) biocomposites via thermoplastic resin transfer molding (TP-RTM), allowing *in situ* polymerization of the matrix around the reinforcement. While PLA is used as the main component, its low glass transition temperature and weak elongation at break limit its uses, particularly for sustainable applications, therefore polylactide/polycaprolactone (PLA/PCL) blends are used in a fibrous reinforcement to compensate for PLA limitations and enhance reinforcement/matrix adhesion with PCL phase melting. The main challenge is to control the morphological properties of the PLA/PCL immiscible polymer blend.

This work presents the optimization of the properties of PLA/PCL polymer blends to obtain suitable multifilaments via melt-spinning to produce a woven reinforcement for producing biobased thermoplastic composites. Blends from PLA90/PCL10 to PLA60/PCL40, in increments of 10 wt% PCL, are processed via 2 steps (twin-screw extrusion then melt-spinning) to assess the impact of PCL ratio on the properties of the multifilaments. Scanning electron microscopy observations are conducted on multifilaments with different draw ratios (DR) for each blend and their mechanical properties are examined as well via tensile testing. Multifilaments with suitable properties (tenacity of 15 cN/tex and elongation at break of 50%) are selected for processing fibrous reinforcements, their compatibility with the TP-RTM process is examined and a comparison with similar all-PLA structures is made.

Keywords: polylactide, immiscible polymer blend, melt spinning, woven reinforcement, thermoplastic composite, RTM

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Lignin-based carbon fibers

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Lignin is a natural biopolymer that is the third most abundant in nature after cellulose and chitin. Despite its widespread occurrence, however, it has been little used industrially to date, as it is usually regarded as a by-product of the paper industry and is generally only exploited thermally. However, there have recently been many efforts to make further technical use of this biopolymer. Besides applications in the food industry (reduction to vanillin as a flavoring agent), as a binder in asphalt or as a filler in elastomers, research into lignin as a precursor material for carbon fibers has been carried out for many years. Due to the wide range of possible applications, new processes have been developed to extract the lignin specifically from the biomass. The properties of the lignin obtained in this way depend on the extraction process on the one hand and on the original source of the biomass on the other. This results in a broad spectrum of commercial lignin qualities with different properties.

For the use of lignin in textile applications, the solubility and fiber formation properties are of essential importance. Therefore, the solubility of severeal commercial lignins in different organic and inorganic solvents were investigated in order to further process them in a wet spinning process. The resulting fibers were used as precursor material for carbon fibers and for that purpose subsequently processed in a stabilization and carbonization process.

Keywords: lignin, carbon fibers, analytics

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Unlocking the Potential of Freshwater Algae for Functional Textiles

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The "AlgaTex" project, funded by the German Federal Ministry of Education and Research (BMBF), aims to explore the potential of filamentous freshwater algae as a raw material for textiles. Various application areas, such as clothing, filter media, and technical textiles, are being investigated. The innovation lies in processing the algae in their natural fiber form (aquatic natural fiber), which significantly differs from existing cellulosic regenerated fibers (chemically produced fibers from natural raw materials) that contain algae components in the form of additives, with only small percentage amounts. Using algae in their natural fiber form as aquatic natural fibers is entirely new. Given the ecological challenges of producing natural fibers like cotton, as well as the issues surrounding synthetic fibers, such as microplastic pollution, algae fibers offer a promising, sustainable, and environmentally friendly fiber alternative for the future. The project involves developing a potentially sustainable cultivation and production structure and supply chain, from algae cultivation to the final product, with a strong focus on the recyclability and functionality of the fibers and products. Analytical investigations indicate that algae fibers represent a technological innovation in textiles. Initial material developments have already shown the potential for industrial processing of these algae into carded slivers and yarns. The algae, mixed with other natural fibers (up to 50% algae content), were processed into fiber slivers using industrial methods, which were then spun into test yarns at the laboratory scale. From these algae fiber yarns, knitted fabrics were produced in laboratory trials as demonstrators, and tests regarding product and performance characteristics were carried out. The algae fiber knits were constructed using different knitting structures to impart functional and technical properties to the textile. The material developments show promising properties for the production of bio-based functional clothing and technical textiles.

Keywords: algae, textile, aquatic fiber, functional

*Speaker

Optimization of Hybrid Polymer Matrices for Enhanced Mechanical and Impact Properties

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This research presents the optimization of preparing hybrid polymer matrices composed of thermosetting and thermoplastic to address the resistance against impact forces and mechanical characteristics of glass fiber reinforced polymer composites. A hybrid polymer composed of thermoplastic and thermoset were obtained at various ratios. A glass reinforcement in which glass microspheres were added to a thermoset resin at various percentages (0-10%) and a composite manufactured via hand layup followed by compression molding with 4 layers of fiber preserving a fiber volume fraction of 0.6. Mixture of hybrid polymers showing a better property against impact forces and mechanical features. Notably, 7-9% glass microspheres displayed an improved mechanical property, highlighting increasing in tensile strength at 7%. These results encourage the potential effect of hybrid matrices and micro-reinforcement in fabricating high featured composites considering for high impact engineering applications.

Keywords: hybrid matrices, glass microspheres, optimization, fiber composites, mechanical properties, impact resistance

*Speaker

A textile intervertebral disk implant from silk fibers

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The intervertebral disc (IVD) acts as a shock absorber during movement. Degeneration of the IVD can result in low back pain, which is one of the most common diseases in today's society and affects up to 70 % of the Western population at least once in their lifetime. In the core, a gelatinous tissue called nucleus pulposus (NP) is present, which has a high capacity of binding to water molecules. This allows withstanding and recovering from compressive impacts. The NP is surrounded by the annulus fibrosus (AF), a tissue of highly oriented collagen sheets with a fiber orientation around 30-60°to the vertical and an alternating orientation in the adjacent sheets, which makes it resistant to tensile strength.

The main objective of this interdisciplinary research project is to develop new flexible therapies for spinal surgery. By using a proven biomaterial such as silk, innovative alternatives to classic discectomy, the removal of the intervertebral disc and subsequent stiffening through ossification, are to be researched. The aim is to improve the flexibility and effectiveness of spinal surgery.

Therefore, the structure of the intervertebral disc was completely reproduced in textiles for the first time. For this purpose, an inner structure made of an isotropic, porous fleece was developed by fiber-based additive manufacturing (FAM) and connected to an outer, ring-shaped, multi-layer reinforcing structure made of anisotropic, flat, lamellar layers, which were produced using an embroidery technique from unidirectionally arranged silk fibres with alternating fibre orientation. With this textile structure of silk fibres, which mimics the structure of the human intervertebral disc, it was shown in cell culture experiments that it is possible to develop artificial intervertebral disc tissue with a cell density and cell size that is similar to the healthy human IVD. In addition, the tissue-specific morphology of the silk scaffold influenced the differentiation potential of the cultured MSCs.

Keywords: silk, intervertebral disk, implant, fiber, based additive manufacturing, embroidery

*Speaker

Extraction and Characterisation of Cellulosic Fibres from Himalayan Nettle (Girardinia diversifolia)

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Lignocellulosic fibres, derived from various plant sources, have gained prominence as a sustainable alternative to the synthetic fibres due to being biodegradable, renewable, and ecofriendly. Himalayan nettle (*Girardinia diversifolia*) plant, abundantly found in India, Nepal, Sri Lanka, China, Indonesia, and others, is a potential source of lignocellulosic fibres. Himalayan nettle fibres are currently being utilised for conventional applications like ropes, fishing nets, carpets, and bags. The fibre extraction is still carried out using the traditional method, having limitations in scaling to a commercial level. There are very limited studies available on nettle fibre extraction and their structure and properties. To fully exploit Himalayan nettle fibres, a simple, fast, and scalable extraction method and well documentation of the structure and properties of fibers are necessary.

Himalayan nettle ribbons were treated with alkali under optimised process conditions (8% NaOH, 85°C, 1 h), determined using the design of the experiment. The fibre yield and their physical and mechanical properties were determined using various standards. The fibres were also characterised for their morphology, chemical functional group, chemical composition, thermal behaviour, and crystallographic parameters using scanning electron microscopy, FTIR spectroscopy, chemical analysis, thermogravimetric analysis, and X-ray diffractometry. The fibre was found to be hollow and unicellular, having flatten elliptical cross-section. The fibre yield with respect to ribbon was 56.65%. The extracted nettle fibres were fine (1.9 tex) and showed good mechanical (tenacity 6.2 gf/den and elongation 4.1%) and thermal properties. The structure and properties of the fibres indicate their possibilities of being used in apparel, home textiles, biocomposites, and insulating materials.

Keywords: lignocellulosic fibre, nettle fibre, fibre extraction, characterisation

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Microcapsule Doped Melt-spun Poly (ε-caprolactone) Fibers for Medical Applications

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Humanity encountered synthetic polymers in the early 20th century, which have since become essential raw materials for a variety of industrial applications. This development marked a significant advancement in materials science, facilitating the creation of innovative products across numerous sectors. However, recently, there has been growing interest in developing biodegradable polymers globally due to environmental pollution concerns because of non-biodegradable synthetic polymers. The production of fibers from synthetic biodegradable polymers is a niche area within the range of applications for biodegradable polymers. Poly(ε-caprolactone) (PCL) is a biodegradable polyester synthesized from petrochemical feedstocks. It is characterized by its versatile properties and potential applications in various fields, including tissue engineering, drug delivery, and environmental remediation. A multitude of studies have employed spinning techniques for the processing of fibers derived from polycaprolactone (PCL) and its copolymers. The thermoplastic nature, low melting point, and high extensibility of PCL make it a favorable candidate for processing with the melt-spinning method. Numerous studies have examined the production of PCL fibers through melt-spinning techniques; however, there remains considerable potential for enhancing fiber properties through functionalization. In this study, functional PCL filaments doped with microcapsules were produced using a lab-scale melt spinning device. Microcapsules were prepared using biodegradable Poly(3-hydroxybutyrate-co-3-hydroxyvalerate) as the shell polymer and Momordica charantia L. plant extract in olive oil as the core material. Neat and microcapsule-doped fibers were analyzed under three main headings: structural, thermal, and functional properties. As anticipated, the addition of microcapsules did not significantly alter the structural or thermal properties of the fibers. However, the results from the antibacterial activity tests show that microcapsule-doped PCL fibers possess antibacterial properties. This functionalization can broaden the applications of PCL fibers in medical textiles by leveraging their biodegradability.

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Keywords: biodegradable fibers, poly (ε-caprolactone), poly(3-hydroxybutyrate-co-3-hydroxyvalerate), melt spinning, microcapsules, medical textiles

*Speaker

Study of the influence of the process of primery processing of cocoons on the production of high-quality raw silk

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This article is devoted to the study of dividing cocoons into three groups, killing their cocoons at an angle of 90 degrees for different periods and sucking them out. In order to study the influence of various factors on obtaining high-quality silk thread, samples selected from 300 cocoons belonging to the Gozal I and Gozal II breeds and hybrids brought to the Silk Technology Department from the Research Institute of Sericulture. The samples divided into three groups and the initial weight of each cocoon are measured. The first group of cocoons was prepared for single cultivation without any cocoon processing. First, the weight of the second and third groups of cocoons are measured, and then their cocoons processed for one hour and four and a half hours in a moisture-determining dryer at a temperature of 90 C in the quality laboratory of the institute. After processing, the weight of the cocoons measured again. The prepared cocoon samples spun on the only spinning machine available in the department, and the properties of the cocoon thread, such as silkiness and fluffiness, were analyzed. Based on the results of the experiment, on samples divided into three groups, accounting work carried out on parts of the cocoons and the lengths of silk threads pulled out of the cocoons were determined. Based on the table, such indicators as other parts of the cocoons, fungus, louse, worm skin were given.

Keywords: live cocoons, pupae, lump, larval skin, raw silk.

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Dyeing process of mixed fiber fabrics thermodynamic analysis

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The growing attention to environmental and energy issues around the world requires the production and use of new environmentally friendly and sustainable textile fibers. As a natural biological material, bamboo is widely used in the furniture, textile, construction and transport sectors. Technologies for processing this fiber to obtain textile products and chemical processing have been developed. However, there has been insufficient research on the kinetics and thermodynamics of the dyeing process of textile materials made from bamboo fibers and their blends with other fibers.
This article is aimed at studying the thermodynamics of the dyeing process of blended fabrics based on bamboo fibers, as well as identifying favorable conditions for increasing the efficiency of the process.
Thermodynamic analysis of the dyeing process requires the study of parameters such as temperature, enthalpy, entropy, and Gibbs free energy.
Bamboo, cotton, and their 50:50 ratio yarns were dyed with the active dye "Sunfix Blue SPR" in a continuous process for 10, 20, 30, 40, 50, 60, 70, 80, 90 minutes at 90°C, and the amount of dye fixed to the fiber was determined using the residual solution method using a UV-755 spectrophotometer. The calculated propensity showed that a strong covalent bond was formed between cotton and bamboo fibers and Sunfix Blue SPR. It was found that the binding energy formed between cotton fiber and dye was 0.3-1.2% higher than that between bamboo and dye, which is related to the morphology and supramolecular structure of the fibers. The orientation of the dye in bamboo fibers is somewhat lower than in cotton fibers, expressed by dyeing enthalpy. By alkaline treatment of cotton fiber, a diffusion coefficient close to each other was achieved in both components of the fiber substrate.
Depending on the morphology of the fibers and their supramolecular structure, it has been determined that different colors are formed in the mixed material. By alkaline treatment of cotton fiber, colors of the same color were obtained on the fiber substrate. By calculating the kinetics and thermodynamic parameters of the dyeing process, it was determined that the color formation between the fibers and the active dye is stable against washing.

Keywords: bamboo fiber, mixed fiber material, dyeing, thermodynamic analysis, spectrophotometric method.

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3- Nano fibres, nanotechnologies and electrospinning

Electrospun nanofibers and spray-coating with silver nanoparticles for antiviral and antibacterial textiles

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Silver nanoparticles (AgNPs) exhibit much higher antibacterial efficacy than in bulk. This work reports the results on antiviral/antibacterial properties of AgNPs in polyvinyl alcohol (PVA) matrix against SARS-CoV-2, *Escherichia coli* and *Staphylococcus aureus*. The protective coating was applied on textiles as a nanofiber layer by electrospinning and as a film by spray-coating.

The materials used are AgNPs at 0.1% w/w in water solutions of PVA (molecular weight 130 kDa, hydrolysis degree > 99%) at the volume ratio 1:1. PVA concentrations were 1% w/v for spraying and 15% w/v for electrospinning. The substrates used were 16-μm polypropylene spun-bonded non-woven (23 g/m^2), polyamide 66 fabric (59 g/m^2), and polyethylene terephthalate fabric (130 g/m^2).

AgNPs/PVA dispersions were electrospun at +30 kV at the tip and -5 kV at the collector (50×50 cm). The PP spun-bonded non-woven was cut into squares of the same size as the collector and stuck on it. The addition of AgNPs destabilized the electrospinning, producing multiple jets instead of a single jet from the metal tip as usual. The AgNPs/PVA nanofibers were treated in an oven at 155°C for 3 minutes to fix the nanofibrous porous structure making them water-stable.

Spray-coating was performed using 5 mL of AgNPs/PVA dispersion on 20×20 cm specimens, then dried in an oven at 80°C for 2 minutes. Washing tests were performed according to ISO 105-C06 at 40°C for 30 minutes with ECE detergent. Abrasion tests were performed according to ISO 12947-2 with 12 kPa loading.

The virucide activity of AgNPs/PVA spray-coated substrate was reduced by 33% compared to the untreated substrate. While AgNPs/PVA spray-coated substrates showed 100% bacterial reduction against both bacteria. The spray-coated fabrics were stable to washing and abrasion. AgNPs/PVA electrospun nanofibers showed excellent bacteria reductions (> 99%).

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Keywords: silver, spray, coating, electrospinning, antibacterial, antiviral

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Synergistic effect of sericin and keratin in gelatin based nanofibers for in vitro applications

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This work evaluates the physico-chemical properties of electrospun nanofibers resulting from the combination of gelatin from bovine skin with keratin from wool and sericin from silk fibers to validate their use for *in-vitro* interaction studies. Gelatin is a natural protein obtained by partial hydrolysis of collagen. It is recognized that its use for the fabrication of bioinspired scaffolds is favorable due to peculiar biological properties, including bioactivity, biocompatibility, biodegradability, non-antigenicity, non-immunogenicity, non-toxicity and non-carcinogenicity. Keratin is a protein characterized by a high sulfur content found in different biomasses (wool, feathers, hairs, horns). Keratin is used to produce nanofibers, sponges, flexible films and fibers. Sericin is the protein that makes up 15-35% of the silk cocoons of the *Bombyx mori* silkworm with recently recognized properties in terms of biodegradability, antibactericity, cytocompatibility, UV resistance and antioxidant properties.

We demonstrated that the presence of sericin influences the fiber morphology at the macroscopic level and affects the chemical and thermal behavior of electrospun nanofibers in comparison with gelatin-based ones. Moreover, we verified that sericin, in combination with keratin macromolecules, can amplify the biochemical signal of gelatin, improving the *in-vitro* stability of gelatin-based nanofibers. *In vitro* results confirm a synergistic effect of sericin and keratin on human Mesenchymal Stem Cells (hMSCs) proliferation associated with enhancing *in-vitro* stability directly ascribable to the peculiar physical interaction among the proteins. These findings suggest the use of sericin/keratin/gelatin-enriched electrospun fibers as nanostructured platforms for interface tissue engineering.

Biocompatibility is investigated in terms of hMSCs proliferation at different days. CCK-8 assay data showed cell growth after 3 days without significant differences among the different groups. A significant increase in cell proliferation is recorded in the case of GLKASR only after 7 days, thus confirming the synergic effect of sericin and keratin on hMSC response, respect to the other groups.

Keywords: Keratin, sericin, gelatin, nanofibers

*Speaker

PROTECTED - By-PROducts based innovative TEchnologies for green and low Cost acTivE wounD dressings

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Keratin is a biocompatible protein that promotes cell adhesion, migration, and proliferation. Keratin-based nanofibers (KS-NFs) can be produced using a technique involving an electric field called electrospinning. KS-NFs have demonstrated potential in wound healing due to their high surface area, porosity, and ability to mimic the extracellular matrix. Polyphenols are a group of compounds, widely present in the plant kingdom, with biocompatible, antioxidant, and antibacterial properties. The goal of the PROTECTED project, representing the framework of this study, is to develop a new technology for active wound dressings that not only promotes effective and active healing but also incorporates environmentally friendly and sustainable materials and processes. In this direction, keratin and the functionalizing polyphenols are extracted from discarded wool and agri-food by-products, respectively, offering green and cost-effective sources to be applied also in the biomedical field. The effectiveness in tissue repair applications given by keratin-polyphenols nanofibers can be seen in the combination of antioxidant, anti-inflammatory and antibacterial properties of phenolic compounds with the support to cell growth provided by keratin. In this study, keratin has been successfully extracted from discarded wool and electrospun in blend with PEO from a water-based solution. Active polyphenols were extracted from agri-food by-products, through green procedures, and have effectively functionalized to keratin. Zeta potential measurements confirmed the presence of polyphenol functionalization. A biological evaluation was also carried out. KS-NFs supported the adhesion, spread and metabolic activity of human fibroblasts, as well the presence of bioactive polyphenols conferred a bacteriostatic effect. Future perspectives of this study include the development of functionalized polyphenols to enhance pH-dependent color change, the functionalization of keratin fibers with novel polyphenols and 3D printing of keratin. This study was carried out within the PROTECTED project (P2022XT785) and received funding from the European Union - NextGenerationEU, Missione 4 Componente 1 - CUP B53D23027682768.

Keywords: active dressing, surface functionalization, by, product, sustainable materials, local economy, green chemistry

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The effect of nanofibers diameter and particles concentration on the optical/thermal properties of electrospun PAN/ZnO smart membranes

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Abstract: Personal thermal management is a novel topic that researchers are focusing on to enhance individual thermal comfort and reduce energy consumption. The body's thermal comfort is achieved by controlling the heat dissipation generated by the body under various environmental conditions. Body heat is dissipated through conduction, convection, evaporation, and radiation (Body thermal radiation range is 5-15 μm). Different methods exist to control these heat loss pathways, either individually or in combination. In typical indoor conditions, radiative heat loss accounts for approximately 50% of the body's total heat dissipation. Therefore, this study focused on exploring methods to control this specific pathway. Recent research has paid significant attention to the development of membranes that can reflect thermal radiation. In this context, electrospinning technology was selected for membrane fabrication due to its ability to produce thin and breathable membranes because of high porosity. Polyacrylonitrile (PAN) was chosen as a substrate because it does not absorb body thermal radiation and Zinc Oxide (ZnO) particles were chosen due to the reflection of thermal radiation. This study evaluated the effect of electrospun nanofibers diameter and ZnO concentration (0-70 wt.%) on the optical and thermal properties of the membranes. Thermal camera and Fourier Transform Infrared Spectroscopy (FTIR) tests showed that increasing nanofibers diameter and ZnO concentration resulted in greater thermal radiation reflection. Additionally, these membranes exhibited smart behavior, reflecting thermal radiation toward the skin model in a simulated cold environment (15°C, 65% RH), resulting in a 1.6 °C heating effect. In contrast, they reflected thermal radiation outward in a simulated warm environment (40°C, 65% RH), causing a 3 °C cooling effect. These results demonstrated that these smart membranes could be used to provide personal thermal comfort in both cold and hot environments without energy consumption.

Keywords: Electrospun membranes, Thermal comfort, Personal thermal management, Thermoregulation textiles, IR radiation

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Design and manufacturing of wearable nanofibrous acoustic energy harvesters

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Nanofibrous acoustic energy harvesters (NAEHs) are gaining attention for their potential use in wearable devices that convert ambient noise into electrical energy, powering distributed systems and sound amplification for assistive listening. However, achieving efficient power generation, particularly in low-frequency ranges ($<$ 1 kHz), remains a challenge. In this study, we present an advanced approach to improving the performance of NAEHs by optimizing the fabrication of electrospun polyvinylidene fluoride (PVDF)/polyurethane (PU) nanofibers. Our method focuses on fine-tuning the electrospinning parameters, such as applied voltage, nozzle-collector distance, spinning time, and drum rotation speed, to enhance the acoustic-to-electricity conversion efficiency. By systematically experimenting with these variables, we identified optimal conditions that significantly increased power density and efficiency. The resulting wearable PVDF/PU NAEH platform delivers a maximum acoustoelectric power density of 829 $\mu W/cm^3$ in everyday noise environments. Moreover, the device demonstrates stable performance across a wide frequency range (0.1–2 kHz), with an energy conversion efficiency of 66%. This study also includes a comprehensive sound recognition analysis, showing a strong correlation ($>$ 0.85) for related sound patterns. The proposed platform offers a practical solution for energy harvesting in wearable applications, extending its potential use in both consumer electronics and healthcare. This work introduces a refined fabrication strategy for improving NAEH performance without the need for complex algorithms or computational models, making it more accessible and scalable for real-world applications.

Keywords: acoustic energy harvesters, nanofibers, piezoelectric

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PVA nanofibres: Retention of microplastics during the washing of textiles

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Microplastics released from textiles during washing and degradation processes have emerged as a significant environmental concern, contributing to the widespread contamination of aquatic ecosystems and posing potential risks to both marine life and human health. This study investigates the reduction of microplastics in wastewater generated during the washing of textiles. The approach involved the use of polyvinyl alcohol (PVA) nanofiber filters obtained through the electrospinning process. These nanofibers were structurally modified to make them insoluble, and both their structural integrity and filtration efficiency were evaluated. Various filters were developed by varying the electrospinning time, and sequential filtration of the same wastewater sample through multiple filters with different electrospinning times was examined, as well as the filtration of various water samples using different filters with varying electrospinning times. The results confirmed the release of microfibers during the washing process, indicating water contamination. However, when applying the filtration system with PVA nanofibers, a high capacity for microplastic retention was observed, with greater efficiency as the electrospinning time increased. In sequential filtration tests, over 80% of the microfibers, particularly the larger ones, were retained by the initial filters with shorter electrospinning times, while the remaining 20% were captured by nanofiber filters with longer electrospinning times, due to the porous structure formed during the process. Additionally, in partial filtration tests, a higher retention of microplastics was observed as electrospinning time increased. This study concludes that PVA nanofiber filters obtained through electrospinning represent a sustainable and effective solution to mitigate the growing microplastic pollution in the textile industry and daily life.

Keywords: Microfiber, pollution, filtration

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Active wound dressing of electrospun lignin/cellulose acetate on cotton gauze

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Wounds that do not heal within a reasonable time frame can be considered as chronic wounds and it is estimated that 1.51 to 2.21 per 1000 people worldwide are suffering from this condition. Chronic wounds can be characterized as permanently in the inflammatory stage. This stage comprises a continuing influx of neutrophils that release cytotoxic enzymes, reactive oxygen species (ROS), and inflammatory mediators. The antioxidant activity of lignin, the second largest eco-friendly lignocellulosic biopolymer, may play a pivotal role in wound healing due to its mitigation of ROS present in the wound environment. Continuous ROS release leads to inflammation downregulation, promoting collagen production, thus tissue repair and regeneration. In addition, lignin possesses other remarkable properties such as: antimicrobial, thermal, and mechanical. Cellulose acetate is a biocompatible and biodegradable polymer which may be promptly electrospun. The interconnected and porous network of nanofibers is beneficial for wound dressings. Its nano structure prevents microorganisms infiltration. Therefore, electrospun lignin mixed with cellulose acetate onto cotton gauze may display an interesting set of active properties. Cotton gauze is one of the most often used wound dressing materials and is responsible for providing additional mechanical resistance to the wound dressing. Hence the study aimed to improve the antibacterial and antioxidant properties of cotton gauze by coating it with electrospun lignin/cellulose acetate fibers. The samples were tested for antimicrobial, antioxidant, mechanical, wettability, and thermal properties. The results demonstrated the excellent antioxidant properties of the composite dressing, thus potentially being used in active wound dressing applications.

Keywords: Lignin, Wound Dressing, Chronic Wounds, Antioxidant, Electrospinning

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Electrospun $La_{0.6}Ca_{0.4}CoO_3$ Perovskite Nanofibers for Solid Oxide Fuel Cell Applications

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Electrospinning technique, which employs electrostatic forces to draw ultra-thin fibers from a variety of materials, is considered as a common fiber production technique. Electrospinning also enables the production of perovskite nanofibers with remarkable morphological features, such as; very small diameters, high surface areas, extremely long length, and small pore size, which make them ideal candidates for solid oxide fuel cell electrodes (SOFCs). The fabrication of perovskite nanofibers is usually achieved in three main steps as preparation of an electrospinning solution containing a carrier polymer and sol–gel precursor, electrospinning of the solution to generate nanofibers, and conversion of precursor nanofibers into the perovskite nanofibers by calcination/sintering. In this study, $La_{0.6}Ca_{0.4}CoO_3$ (LCC) perovskite nanofibers were prepared by electrospinning followed by calcination. Polyacrylonitrile was used as the carrier polymer and solutions with varying polymer and precursor concentrations were prepared for electrospinning. The electrospun nanofibers were calcinated at 700 and 800°C to remove the polymeric content and obtain the desired perovskite structure. X-Ray diffraction was used to confirm the desired perovskite phase formation. Scanning electron microscopy was employed to examine fiber morphology with regards to the structural continuity and nanofiber diameter before and after the calcination process. Results indicated that the continuous perovskite nanofiber structure, and the desired perovskite phase were achieved, supporting the potential use of LCC nanofibers in SOFCs with enhanced performance.
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Keywords: Electrospinning, nanofibers, perovskites, solid oxide fuel cells

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Multifunctional applications of advanced electrospun nanofibers

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Nanofiber technology has significant potential across various fields due to its unique properties, including high surface area-to-volume ratio and controllable porosity. These characteristics make nanofibers suitable for applications in healthcare, environmental science, and sensing technologies. Among various production methods, electrospinning has become the most widely used technique for generating nanofibers due to its simplicity and efficiency. This process applies a high voltage to a polymer solution or melt, resulting in ultrafine fibers collected as a nonwoven mat. By incorporating different active agents, electrospun nanofiber surfaces can be designed to create functional materials for specific applications.

This study presents results from the authors' previous research on multifunctional nanofiber applications created through the incorporation of functional additives. For instance, drug-loaded nanofiber wound dressings were developed to provide sustained therapeutic delivery, enhancing healing and minimizing infection risks. The authors found that the thickness, collection time, and drug content of electrospun mats significantly influence the drug release rate, while drug–inclusion complex-loaded electrospun nanofibers enable immediate drug release for acute pain treatment. Antibacterial wound dressings with essential oils were also produced, utilizing their natural antimicrobial properties to prevent bacterial growth. The antibacterial properties of essential oil-loaded nanofibers increased with oil concentration, though this led to increased cytotoxicity. Thus, determining the appropriate essential oil concentration for nanofiber wound dressings is crucial.

Additionally, UV-sensitive nanofibers with photochromic dyes were developed as UV sensors, providing real-time monitoring of UV levels, which is important for skin protection. Another study demonstrated the effectiveness of nanofiber surfaces in dye adsorption from

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textile wastewater, with PVA nanofibers removing over 80% of Reactive Red 141 dye, contributing to environmental sustainability.
These findings highlight the versatility of electrospun nanofibers and their transformative impact in healthcare, environmental applications, and sensor technologies.

Keywords: Nanofibers, electrospinning, wound dressings, sensors, adsorption

Emulsification performance of mechanically fibrillated silk fibroin nanofibers

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Fibroin is a protein that constitutes cocoon silk produced by silkworm moths. Its high mechanical properties and biocompatibility have led to its development for a variety of applications, including medical materials, cosmetics, and foods.It has also been shown to have good emulsification performance due to its hydrophilic-hydrophobic structure and amphiphilic nature.
However, regenerated fibroin, an existing fibroin material, has the concerns that it requires a complicated manufacturing process and chemicals harmful to the human body.
The silk fibroin nanofibers (FNFs) can be prepared directly from degummed silk by a simple water-grinding treatment. Herein, We report on the emulsification properties of FNFs.
Commercial B. mori silk fibroin was used, where sericins had been removed using a 0.9 wt. % Na2CO3 solution applied at 95°C for 120 min. A 1 wt. % purified water slurry of silk fibroin was passed through a grinder (MKCA6-3, Masuko Sangyo Co. Ltd., Saitama, Japan) four times at 1500 rpm with the grinding stones pressed closely together. FNF was obtained well dispersed in water. Emulsions of the resulting FNF water dispersion and 1-octanol or hexadecane 9 : 1 were prepared by sonication using an ultrasonic homogenizer.The obtained emulsions were measured for changes in stability over time and oil droplet diameter. The emulsions were also prepared to check stability against environmental changes in different temperatures, salinities, and pH.
Stable emulsions were obtained even after more than one month. Furthermore, the emulsions showed high stability against changes in temperature, salt concentration, and pH. These results indicate that the emulsions have higher emulsification properties than conventional emulsifiers made from regenerated fibroin, and are less susceptible to the effects of manufacturing and storage processes, suggesting the potential for a wide range of uses. In addition, the FNF emulsifier in this study exhibited strong emulsifying action regardless of oil type, whereas in general emulsification requires the selection of a surfactant for each oil type due to the different action of surfactants.

Keywords: Fibroin nanofiber, Emulsification, Pickering emulsification

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Fabrication and Release characteristics of Fentanyl-loaded Zein and Gelatin Nanofiber scaffolds for Transdermal use in Burn Wound Therapy.

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An antimicrobial barrier can expedite recovery by aiding the healing of living tissues damaged by burn injuries. Nanotechnology-based fibrous mats have been extensively studied for their potential in drug delivery systems. This article explores the development of Electrospun polymeric Nano-fibrous mats incorporating Non-steroidal anti-inflammatory and antibacterial agents. Electrospinning techniques have been used to produce nanofibrous mats from pure zein and pure gelatin, as well as their combination with Fentanyl, an NSAID. These mats effectively manage wound exudate, keeping the site dry and protected from microbial activity, making them highly suitable for wound care. The fentanyl transdermal patch ensures consistent fentanyl delivery over three days by maintaining close skin contact, facilitating desorption, moisture-based release, and improved skin absorption. Beyond serving as an antibacterial barrier to support wound healing, these mats also function as drug delivery vehicles. The study provides a detailed analysis of drug release profiles from nanofibrous mats and characterizes their properties using techniques such as Fourier-transform infrared (FTIR) spectroscopy and scanning electron microscopy (SEM). The drug release kinetics of these mats are compared to standard mathematical models like Korsmeyer-Peppas and Higuchi. Findings confirm that the cumulative drug release aligns well with Higuchi's model, indicating diffusion-controlled super case-II transport ($n > 1$). The results demonstrate efficient ibuprofen loading within the nanofibers, with uniform drug distribution across the matrix. This ensures controlled, sustained drug release, thereby enhancing wound healing efficacy.

Keywords: Fentanyl, Drug Delivery, Burn Wounds

*Speaker

Effect of Cure Kinetics Method on Structure Formation of Modified Carbon-Based Nanocomposites

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The development of carbon-based nanocomposites has garnered significant attention due to their remarkable mechanical, thermal, and electrical properties. This study explores the effect of cure kinetics on the structure formation of modified carbon-based nanocomposites, aiming to establish a more in-depth understanding of the relationship between curing parameters and final composite properties. Utilizing advanced curing techniques and dynamic thermal analysis, the research investigates the impact of temperature profiles, heating rates, and curing times on the nanocomposite matrix. Key structural changes, including dispersion of carbon nanoparticles, cross-link density, and interfacial bonding, are analyzed using microscopy, spectroscopy, and X-ray diffraction. The findings reveal that optimized cure kinetics lead to enhanced uniformity in nanoparticle dispersion and improved matrix integrity, significantly influencing the mechanical strength and thermal stability of the nanocomposites. Moreover, the study highlights the critical role of curing parameters in tailoring the microstructure for specific applications in aerospace, automotive, textile and electronics. This research provides valuable insights into designing carbon-based nanocomposites with superior performance by fine-tuning their cure kinetics, contributing to the advancement of material science and engineering.

Keywords: kinetics, nanocomposites, MWCNT, polyester

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A method for obtaining graphite-based nanopowder to extend the service life of the elastic coating of a pressure roller

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The article presents an innovative method for increasing the wear resistance of elastic coatings of pressure rollers of textile equipment by modifying their surface with graphite nanoparticles. An original technology for obtaining spherical nanoparticles by electric discharge in a paraffin vapor environment using copper electrodes has been developed. The optimal process parameters have been experimentally established: electrode gap 3 mm, voltage 220 V, current 2 A, cycle time 30 seconds.
The effect of the electrode material (steel, aluminum, copper, graphite) on the yield and characteristics of the resulting nanopowder was investigated. Using a set of analytical methods, including electron microscopy and laser diffraction, the morphology and size of particles were determined. It was shown that the resulting particles have a spherical shape with an average size of 3.036×10^{-7}m and a narrow size distribution (coefficient of variation $< 15\%$).
A technology has been developed for modifying the surface of elastic coatings by introducing nanoparticles that form a stable three-dimensional structure at a depth of 10-15 μm. It has been established that the optimal concentration of nanoparticles in the surface layer is 0.8-1.2 mg/cm^2. The modified coating shows a reduction in the coefficient of friction from 0.82 to 0.45 while maintaining the elasticity of the material. Long-term production tests have shown an increase in the service life of the modified rollers by 35-40% with a stable quality of processing of textile materials.
The presented technology provides an effective solution to the problem of increasing the durability of pressure rollers without deteriorating their technological characteristics and can be recommended for industrial implementation in the textile industry.

Keywords: nanopowder synthesis, pressure roller, elastic coating, graphite nanoparticles, wear resistance, electrical discharge, surface modification.

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4- Science of textile and apparel machine development

Machine unit dynamics cotton cleaner section with new drive circuit

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The article presents a modernized drive scheme for a cotton-ginning unit of installation cotton-ginning-complex (ICGC). The computational and mathematical models of machine units of the cleaner with mechanisms of sawing, peeling, and transporting drums have been calculated and completed. Based on the numerical solution of the problems of the dynamics of machine units, the regularities of the movement, graphic dependences and parameters of the working bodies obtained considering on the given calculations. Analyzes of the constructed graphical dependencies with justified and recommended specific values of the parameters of the working bodies and belt drives in the drive of the cotton cleaner with the recommended drive layout.

Keywords: raw cotton, fine and coarse litter, saw peg, conveyor, drum, belt drive, law of motion, angular velocity, dissipation, cleaning effect

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Highest flexibility for braiding machines combined with high production speed

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Individualized, complex braided vascular implants with many wires pose ever greater challenges to current manufacturing processes. In addition to urgently needed flexibility in machine braiding, it must be possible to carry out the production process in a time-efficient manner. Both requirements - highest flexibility combined with high production speed - are technologically mutually exclusive. By applying modified physical principles of action to control the braiding paths and intelligent production equipment, the production process of braiding has been further developed in a forward-looking way. The use of single driven horngear and a magnetic switch between the horngear allow more flexibility. Now it is possible to create braids from 3 to 192 wire ends on a single braiding machine. Creating bifurcations, multilayer braids with interlocks, even flat braids are possible with the new machine concept. The production of patient-specific vascular implants (stents) is thus possible economically and in the highest quality.

Keywords: 3D braiding; flat braiding, flexible braiding, medical braiding; bi-furcation

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5- Science and technology of textile processing

Further development of 3D woven spacer fabrics with partial chambers for technical and protective textile applications

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Weaving technique has been used for many years to produce 3D textile structures and preforms and many different methods have been developed. One of these methods is the weaving of conventional woven spacer fabrics with lancets. Woven spacer fabric structures consist of two different fabric layers where these fabric layers are connected to each other with binding yarns or pile yarns, leaving a certain space between them. Binding warp yarn interlaces through the top and bottom fabric and the distance between the layers can be adjusted using lancets with desired height. Lancets are mainly used across the entire fabric width without any missing for the production of conventional spacer fabrics. It is possible to arrange the lancets intermittently to a predefined width of chamber fabric. This may provide a flexibility for the production of spacer fabrics as side-closed structures in order to produce a chamber fabric with a targeted width. Spacer fabrics with partial chambers can be manufactured with less confection works for some predefined geometries and they can be used for the manufacturing of protective textiles and lightweight construction technology. This study aims to describe a new approach to the weaving of spacer fabrics with partial chambers with polyester multifilament yarns on a technical double rapier weaving machine. The setup of different warp yarn systems and the new lancet arrangement will be presented and usability of this new approach for the manufacturing will be discussed within the study. The applications of these newly developed spacer fabrics in the manufacturing of protective textiles will be shown by means of textile-particle foam composites. Furthermore, the application of this method for the weaving of 3D near-net-shape preforms for airfoil structures will be presented.

Keywords: 3D woven, spacer fabric, protective textiles, lancet, particle foam, lightweight

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Spinning of thermoplastic fibers using ring spinning technology based on friction free superconducting bearing system without compromising quality

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A new high-speed ring-spinning machine featuring a superconducting magnetic bearing (SMB) system, along with a modified control and drive mechanism, has been designed and developed to achieve angular spindle speeds of up to 50,000 rpm. Subsequently, an innovative SMB-based twisting system was integrated to further enhance its performance. These result in benefits such as wear-free, redundancy of the control and sensor units as well as high reliability. However, fundamental questions regarding the technological and physical limits of this new technology still need to be addressed. Therefore, extensive investigations were conducted to characterize the influence of process and material parameters, particularly with the use of thermoplastic fiber, to determine the spinning limits of the SMB system. For thermoplastic fibers, productivity is limited to only 15.000 rpm in order to guarantee optimal yarn strength. Friction and the frictional heat not only generate melting points in thermosensitive manmade yarn, but also significantly impair yarn quality. The results of yarn from thermoplastic fiber material properties based on the developed pilot ring-spinning tester confirm that the SMB ring yarns show a comparable yarn quality even at significantly higher productivity, as no frictional heat occurs during imparting twist to the yarn.

To characterize key physical factors such as yarn tension and twist propagation, sophisticated sensors were developed, and their interdependencies were analyzed. Based on the results of twist distribution at high spindle speeds, such as 50,000 rpm, effective measures were taken to enhance twist propagation, particularly to address weak points in the spinning triangle. These measures were also implemented to improve process stability, reduce yarn tension and breakage, and further advance the SMB spinning process. The results highlight the immense potential of this innovative, frictionless twisting system to produce high-quality ring-spun yarns from both natural and synthetic fibers through a gentle ring spinning process, with the capability to even triple productivity.

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Keywords: ring spinning, twisting system, productivity, superconducting magnetic bearing, yarn quality, twist propagation

*Speaker

Multi-Level Modelling and Characterization of Knits

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The complex hierarchical structure of knitted textiles, comprising of fibers, yarns, and a fabric, necessitates a multi-level modeling approach to capture the critical interactions influencing their mechanical behavior. This work presents a multi-fidelity modeling framework for knitted fabrics, beginning from the individual fiber and yarn level and extending to the fabric and homogenized textile level. The models address how microstructural features such as fiber entanglement (texturing) and fiber friction at smaller scales propagate and influence the overall mechanical response of the knit. By incorporating both high-fidelity and reduced-order models, we explore the relationship between these fine-scale features and macroscopic load response. Additionally, we present experimental techniques, including fiber, yarn, and fabric-level testing, to characterize and validate the model predictions. The combination of experimental data and computational models provides deeper insights into the role of fiber and yarn structure on the performance of knitted fabrics, contributing to improved predictive capability in textile engineering.

Keywords: finite element, simulation, knits, characterization

*Speaker

New Weft Knitting Process for Novel Mechanical and Smart Knitting Structures

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In this study, an innovative knitting technology, based on a patent application, is investigated. Three yarn carriers are needed: one carrier (SY3) knits on both, cylinder and dial needles, forming a 1x1 rib structure. Another carrier (CY1) feeds yarn to the cylinder needles alone, creating a front-side single jersey, while a third carrier (DY2) feeds yarn only into the dial needles to form a back-side single jersey. This method creates a new plated fabric, where each needle carries two yarns. To examine the plating effects, prototype yarn carriers were designed, and fabrics were produced with various machine settings. Key variables, including timing, yarn tension, and cam depth, were adjusted to study their influence on the fabric's plating. The results confirmed that it is possible to create a fabric with different characteristics on each side. The mechanical properties of these novel fabrics were then compared with those of 1x1 rib, Milano rib fabrics to explore potential applications. The new fabrics show significantly less multiaxial stretchability and a more balanced modulus compared to 1x1 rib knits. When compared to Milano rib fabrics, the new fabrics exhibit a higher cover factor and increased modulus. These findings indicate that the new fabric type is well-suited for applications that require low deformation-especially in course direction-or a balanced, high modulus.
To evaluate their potential for smart textiles, the electrical properties of these fabrics were tested. A prototype fabric was created with a conductive material on one side and a non-conductive material on the other. This innovative fabric showed high conductivity on the conductive side and low conductivity when measured from the conductive to the non-conductive side. Compared to conductive 1x1 rib fabrics, the new fabrics have lower conductivity in both relaxed and stretched states, along with high robustness to deformation. Overall, the new fabrics deliver better conductivity with reduced yarn consumption and incorporate a non-conductive layer in a single production step, making them a material-efficient and cost-effective alternative to conventional conductive 1x1 rib fabrics.

Keywords: Knitting, Plating, multiply fabric, innovative yarn supply, Novel structures, technical textiles, structural properties, electrical properties

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Distribution of Recycled and Virgin Fibers in Open-End Spun Yarns

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Fiber-to-fiber recycling is important as the Global Textile Complex moves towards a Circular Economy and closed-loop manufacturing. Research has evaluated the impact of yarns made from recycled and virgin fibers on final fabric performance properties and some have looked at yarn strength. However, there is no published work investigating how blending recycled cotton with virgin cotton fibers impacts yarn structure evaluating the distribution of the recycled fibers throughout the yarn structure of their impact in traditional fiber migration theory. In this study, virgin (V) cotton fibers were blended with black recycled (R) fibers at the fiber opening stage and then spun (OE). The recycled cotton fibers were obtained from cutting room scraps that were then shredded. For this study, three yarns at different blend levels, 10 R/90 V, 20 R/80 V, and 30 R/ 70 V were created and evaluated. In addition to measuring the yarn's mechanical properties, cross-sections of the yarns were qualitatively analyzed using microscopy techniques. Based on color, the distribution of the virgin and recycled fibers was examined to determine if there was consistent and uniform mixing and to determine if traditional migration patterns occurred along the yarn axis or if non-traditional migration patterns were observed. Results showed that at all blend levels there appeared to be some disruption of the expected migration. Although the recycled fibers appear to move from the yarn interior to its exterior surface, the recycled fibers were clumped together rather than evenly distributed throughout the yarn structure. It was also noted that the intended blend and the final percentage of virgin vs recycled fibers were inconsistent with a lower percentage of recycled fiber than designed. This is thought to be due to the shorter recycled fibers being removed during traditional carding processes.

Keywords: recycle, yarns, properties, circular economy

*Speaker

Tailored fiber placement: process-dependent mesostructures for resin transfer molding application

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Material and energy efficiency are now crucial to combat recent climate challenges. In lightweight construction, additive manufacturing techniques, such as the Tailored Fiber Placement (TFP) technology enables precise, curvilinear fiber placement, making it well-suited for applications requiring lightweight anisotropic composites. By allowing fibers to be strategically oriented along stress trajectories, TFP facilitates the efficient use of materials while reducing overall weight.
For the infiltration of TFP components in resin transfer molding (RTM) processes, the complex architecture of the reinforcements poses a special challenge. Therefore, the development of meso-scaled models of the fiber architecture that account for production-specific characteristics is essential to conduct molding simulations for virtual process design. These models must reflect the influence of TFP-specific morphological characteristics, like the positioning of the sewing threads and base material as they affect the local fiber orientation, undulation and fiber volume content of the composite.
This work introduces an explicit modeling approach for the TFP process using simplified geometric structures. The aim is to predict the process-induced mesostructure and provide a basis for understanding the interaction between rovings and sewing thread. These models are used to investigate the resin flow through TFP structures which is highly influenced by the cavities and undulations caused by the TFP production method. We present models for various thread architectures of single layer and multilayer composites. All models are calibrated using microsection measurements on TFP composites where cavity sizes and local fiber volume content were determined. The findings contribute to the development of process-dependent infiltration models that are beneficial for optimizing the manufacturing of TFP-based composites and their associated RTM processes.

Keywords: Tailored Fiber Placement, composites, resin transfer molding, process simulation, infiltration simulation

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Removing Print Paste from Knitted Fabrics for Enhanced Wash Fastness: Optimizing Conventional Washing with Ultrasonic Technology

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Print paste is a mixture used in textile printing processes to apply patterns or colors onto fabrics. This mixture ensures the adhesion, proper transfer, and fixation of the print on the fabric. After printing, any excess print paste residues on the fabric are removed through a washing process. A significant amount of water is needed for complete removal due to the high viscosity and low water solubility of the printing paste. Conventional methods for the washing process typically rely on a combination of water, chemical agents, and mechanical actions. However, these traditional approaches often involve high consumption of water, energy, and chemicals, which can pose significant environmental and economic challenges. To overcome these drawbacks, modern, sustainable alternatives like enzyme-based processes and ultrasonic washing are being developed, offering greener and more efficient solutions. Ultrasonic waves traveling through a liquid generate cavitation, which produces microscopic bubbles. These bubbles display dynamic behaviors, including translation, oscillation, growth, and collapse. The energy released during bubble collapse creates localized high temperatures and pressures, enhancing the cleaning effect. Studies have shown that ultrasonic systems with an acoustic intensity exceeding approximately 0.4 W/cm^2 achieve superior washing results compared to conventional washing systems. This enhanced performance makes ultrasonic washing a highly effective and efficient alternative for various cleaning applications. In the textile sector, ultrasonic washing applications are expanding in processes such as cleaning raw, printed, or dyed fabrics, washing denim, and treating delicate textiles. Ultrasonic washing efficiently eliminates excess chemicals used during the fixation of reactive or pigment-based dyes, enhancing the durability and lifespan of prints. This method improves the wash fastness of the prints, making them more resistant to abrasion and repeated laundering. This study aims to achieve high washing fastness by effectively removing print paste from knitted fabrics. This project aims to move beyond laboratory experiments and be carried out under factory-scale conditions. To accomplish this, the conventional washing process, which typically requires two cycles, is replaced with a combined process integrating ultrasonic washing and conventional washing methods. By utilizing a combined process, the removal of print paste from knitted fabrics can be achieved in a single cycle, resulting in improved efficiency in water and energy usage. This does not only enhance resource savings but also provides a cost-effective solution by reducing operational expenses.

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Keywords: Print Paste, Washing Fastness, Ultrasonic, Knitted Fabrics, Textile

Complex evaluation of the quality indicators of interlock-based weft-knitted fabrics

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Effective actions are underway in our Republic to develop the textile and knitting industries, expand the types and assortment of products being produced, and facilitate the export of finished products. In the ongoing scientific research, knitted fabric based on interlock using cotton yarn has been developed, and its physical and mechanical properties have been analyzed. The production of new structured fabrics based on interlock has allowed for the diversification of yarn types used, the expansion of product assortments based on the produced fabrics, and the improvement of their physical and mechanical properties. The interlock fabric with a warp was knitted on a flat double-needle knitting machine of type LXA-252 produced by the Chinese company "LONG XING." The analysis of the physical and mechanical properties of knitted fabrics showed that including warp yarns between the fabric loops enhanced the physical and mechanical properties of interlock knitted fabrics. By implementing interlock knitted fabrics into practice, the competitiveness of the produced products has increased, and the manufacturing of products that meet global standards has enabled knitted products to enter the world market.

Keywords: Interlock, loop, course, needle, cotton, yarn, PAN

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An effective method of preparation from varieties of cotton fiber "Porlock"

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To ensure high competitiveness of cotton products in Uzbekistan, modern approaches are used to increase the yield and quality of cotton fiber. Gene knockout is a technology developed by Uzbek scientists and patented in many cotton-growing countries, which made it possible to create unique varieties of genetically modified cotton of the Porlock (P) series with improved characteristics both in terms of cultivation and vegetation, and in terms of fiber quality. New genetically modified selection varieties of cotton fiber, having distinctive structural and volumetric properties compared to zoned varieties, require certain changes in the technology of chemical finishing.
Technological parameters of the processes of preparation for chemical finishing have been developed taking into account the structural and sorption properties of textile materials based on selected varieties of cotton fiber "Porlock". Economical technological modes and compositions of baths for preparation for dyeing and printing for textile materials (yarn and fabric) from new varieties of cotton fiber taking into account their structural features have been proposed.
The technological mode of preparation for dyeing of cotton yarn of the selection varieties "P-2" and "P-4" has been put into practice at the enterprise LLC "OSBORN TEXTILE". As a result, high whiteness, capillarity and improved physical and mechanical properties were ensured taking into account the structural features of cotton yarn. The process of preparation for dyeing of yarn from the selection variety P-2 with a denser structure requires relatively high concentrations of an alkaline agent (up to 10%) and a low concentration of hydrogen peroxide (up to 17%), and the selection variety P-4 with high volume properties - a smaller amount of an alkaline agent (by 20%).
The technological mode of preparation for dyeing and printing of cotton fabric "Satin" based on cotton fiber "P-4" has been implemented at the enterprises of LLC "Urganch Baxmal", LLC "Marwa Impex". As a result of using the proposed mode, the physical and mechanical properties of the fabric are preserved and its operational properties are improved. Due to the introduction of a stronger alkaline agent into the impregnation bath, its and hydrogen peroxide savings are 3 and 0.25 times, respectively.

Keywords: genetically modified, cotton, process of preparation for chemical finishing and dyeing, structural and sorption properties

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Preparation of Meltblown Nonwovens from Polypropylene and Poly (butylene succinate) Blends

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The meltblown method is a common method to produce micro and nanofibers, and these fibers offer high surface area and good insulation properties with their lightweight structures. The rapid growth of the nonwoven fabric market produced by meltblown indicates that the demand for innovative products in this field is increasing and will offer greater economic opportunities in the future. This study aims to investigate the morphological and mechanical properties of nonwoven fabrics produced by meltblown technique, blends formed with polypropylene (PP), and a new biodegradable polymer, poly (butylene succinate) (PBS). In the research, monofilaments with different PP and PBS ratios were prepared and their production was carried out as meltblown technology. After the production process, the physical properties of the samples such as fiber diameters, air permeability, unit weights and tensile properties were examined. The results show that the fiber diameters decrease inversely proportional to the PP ratio, increasing air permeability. The 20PBS/80PP sample has the highest air permeability, while the 100PP sample reaches the highest unit weight. Strength tests reveal that the increase in PP increases the tensile strength but causes the elongation values to decrease. This shows that PBS offers a potential contribution to improve the material properties but affects the fiber production stability and reduces the mechanical properties. In conclusion, the findings obtained in the study emphasize the importance of carefully selecting the material combinations to optimize the properties of meltblown nonwovens. This can contribute to obtaining more functional and environmentally friendly products in engineering applications.

Keywords: meltblown, nonwoven fabrics, biodegradable polymers, poly(butylene succinate), mechanical properties

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6- Textile Structures, Properties

Cyclic shear test under biaxial loading in bias direction: application to coated woven fabrics

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Coated woven materials are increasingly used in a variety of applications, but their mechanical behavior, particularly their shear properties, remain poorly understood. This study focuses on the experimental investigation of the shear behavior of coated woven materials under monotonic and cyclic biaxial loading. Specifically, we implement biaxial testing in the bias direction, at 45°to the warp and weft, introducing new experimental protocols to better understand their mechanical shear properties.
Common mechanical shear tests on woven materials, such as the Kawabata Evaluation System (KES), Picture Frame Test, and uniaxial bias extension tests, have limitations, particularly the appearance of a blocking angle between warp and weft, leading to out-of-plane deformations and wrinkling. In contrast, the biaxial tension shear test offers better control of wrinkle formation. For this study, we used "DACRON 300 SF HTP Plus," a material commonly employed in sail manufacturing, and tested cruciform specimens with three incisions in each arm. Deformation field measurements using Stereo Digital Image Correlation validated the specimen's shape, showing homogeneity in the useful part during shear tests.
We employed local strain measurements in the useful part of the specimen, using a CCD camera, to characterize variations in the angle between the warp and weft, as well as deformations along these directions. The results indicate a coupling between cyclic shear effects and deformation in both warp and weft directions. Notably, they reveal a novel cyclic ratcheting phenomenon, where deformation progressively increases in both directions with each shear cycle. To our knowledge, this phenomenon has not previously been observed, in woven materials. This behavior is reminiscent of the phenomenon of axial torsional ratcheting or axial plate shear ratcheting observed in metals and solid polymers. This is manifested by a systematic increase in the value of axial strain with each shear cycle.

Keywords: biaxial tensile test, woven fabrics. visco elastoplastic behaviour, synthetic fibers, sailcloths, hysteresis

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Development and Multi-Scale Behavior Analysis of Auxetic Fiber-Reinforced Composite Materials

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This work focuses on developing a fiber-reinforced woven composite material with auxetic properties, characterized by a negative deformation ratio. Several studies have demonstrated that auxetic materials differ from conventional ones in terms of mechanical performance; for instance, they offer better resistance to compression, impact, and fracture.

In the literature, research has been dedicated to the study of architected auxetic materials. However, fiber-reinforced auxetic composites have garnered relatively less attention. The intended application for these innovative materials is in automotive silent blocks. The goal is to evaluate the impact and advantages of fiber reinforcements with auxetic properties on the dynamic and mechanical performance of the composite material.

In this study, the objective is to produce a 3D hollow multilayer fabric using a bicomponent yarn, composed of a thermoplastic yarn at the core, used as resin, and two aramid multifilaments in the structure, used as reinforcement. The fabric is then thermoformed to create an auxetic honeycomb geometry with re-entrant hexagons. This configuration, which displays orthotropic behavior, has been widely studied in the literature through various analytical approaches. However, it's important to experimentally investigate its behavior, considering the anisotropy caused by the woven reinforcement.

The first part of the results focuses on the compressive mechanical response of the multicellular auxetic composite material, particularly the deformation ratio of the overall structure. The second part is dedicated to examining the behavior of the individual elementary cell derived from the multicellular composite.

Keywords: auxetic, woven reinforcement, hollow fabric, composites

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A comparative analysis of thermal properties of double-face cotton-wool knit structures

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The global winterwear market expected to be a USD 359.78 billion business by 2025, is dominated by wool and acrylic fibers with moderate usage of polyester and cotton. Despite being the world's third-largest cotton producer, cotton contributes less than 1% of worldwide winterwear production. The recent advent of knit micro-factory to facilitate reshoring domestic production has the potential to spike knit winterwear production in the US. Therefore, there is a need to focus on enhancing domestic cotton use in winterwear instead of imported wool and non-biodegradable petroleum-based acrylic fiber.
This study attempted to investigate the thermal properties of cotton-wool mixed double-face structures for winterwear. Double-faced knit fabrics facilitate better thermal insulation via structural air gaps.
A pragmatic approach to knit fabric design parameters: stitches, fabric construction, yarn selection, knitting machinery, and the effect of these design parameters on aesthetics, mechanical performance, cost, and overall sustainability of the fabric were examined. Three cotton-wool mixed knit structures - bi-layer, spacer, and net jacquard were designed and knitted using a Stoll® CMS knitting machine (12 gauge). These knitted structures were evaluated for fabric weight (ASTM D3776), fabric stitch density (ASTM D8007), fabric thickness (ASTM D1777), moisture management (AATCC TM195), air permeability (ASTM D737-18) and thermal and evaporative resistance- dry and wet (ASTM F1868-17).
The net jacquard construction depicted the thickest, better evaporative and thermal resistance, and the lowest air permeability albeit poor Overall Moisture Management Capacity (OMMC). This construction also has the potential to significantly reduce costs as the average price of wool is $4/lb compared to cotton at $0.99/lb. However, a thinner and lighter net jacquard construction may offer better air permeability with OMMC and can be used for various winter sports and performance activities such as marathons, mountain running, and skiing.

Keywords: cotton, winterwear, thermal, knitting

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High Performance and material-saving CRC-Slab Systems on basis of branched reinforcement layout, biologically inspired design and robot-based automatic yarn deposition

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Carbon reinforced concrete (CRC) is characterized by its corrosion resistance, material efficiency, and high load-bearing capacity. To fully leverage the potential of high-performance carbon reinforcement structures, load-specific and component-adapted textile reinforcement structures are essential. For retrofitting and reincoring planar structural elements, biaxial grid structures and rebars have been established as effective solutions. However, for three-dimensional, more complex geometries, these reinforcement structures often require complex subsequent forming processes and often result in overdimensioning and therefore an inefficient use of the carbon reinforcement strucure.
For the tailored and efficient reinforcement of components with complex 3D geometries, such as hollow-core slabs and beams, load-path-based reinforcement structures are needed, according to the biological principle of "form follows force." A particularly promising reinforcement structure is the so-called "Netzgitterträger". First Netzgitterträger were fabricated manually as well as using advanced multi-axial warp-knitting technology with specialized warp thread manipulation and shaping systems for hollow-core slab systems. This reinforcement structure, consisting of branched and alternating, diagonally offset roving paths with overlapping edge area, enables high material efficiency and advantageous anchorage of the reinforcement. This principle of branched and merged reinforcement paths can also be found in botanical structures. Thus, biologically inspired load-path designed reinforcement layouts can also be applied to slab systems such as T-beams. For high performance and more complex, branched reinforcement structures, robot-based automated yarn deposition is particularly suitable. This paper presents the Netzgitterträger principle through examples of slab and beam systems, selected experimental results on load-bearing behavior and productive manufacturing processes for the fabrication of complex, biological inspired reinforcement structures.

Keywords: carbon reinforce concrete, slab system, textile reinforcement, robotic, design

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Characterization of an auxetic woven reinforced composite material

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Composite materials, known for their exceptional mechanical performance-to-weight ratio, are increasingly used in the aerospace and defense sectors. Additionally, innovative technologies like the open rotor (with possible increased fuselage impact situations) are being integrated to mitigate aircraft fuel consumption. This evolution introduces new design challenges, particularly concerning energy absorption during impacts.
Several studies indicate that auxetic materials may exhibit promising properties for energy absorption during impacts. Auxetic materials have a negative Poisson's ratio, which causes it to expand or contract laterally under longitudinal tensile or compressive stress, respectively. In compression, this results in material densification, enhancing mechanical properties such as indentation resistance, shear modulus, and energy absorption capability. Consequently, these materials emerge as viable options for enduring impact loads. Most auxetic structures are typically studied experimentally using foams or additively manufactured materials. The latter option offers advantages such as precise geometry but has drawbacks due to its layer-by-layer construction process.
Para-aramid based woven structures are known for their ability to absorb energy during impact events due to their high resilience and deformability. By manufacturing auxetic structures from para-aramid-reinforced composites, both energy absorption capabilities may be synergized.
The aim of this study is to conduct experimental and modelling research of fiber-reinforced auxetic composites to ensure both efficient stiffness for static loading and energy absorption capacity during dynamic loading such as impact. This involves several tasks, including designing and manufacturing of composite material specimens, setting up characterization tests, and developing a numerical model to gain a comprehensive understanding of the mechanical behavior of these materials.

Keywords: composite materials, auxetic textile architectures, auxetic materials, impact, energy absorption.

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Hybrid 3D woven structures for concrete reinforcement under impact loading. Part 2: composite quality and mechanical performance

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Concrete structures are particularly vulnerable when subjected to dynamic events, such as impact, due to their poor energy absorption. To protect existing concrete structures, a new thin-layered, mineral-based composite is under development by the Research Training Group GRK 2250. This composite consists of strain-hardening, short fiber-reinforced concrete (SHCC) and continuous textile reinforcement. Due to the low strain capacity of conventional two-dimensional grid fabric reinforcement (2DFT), which is typically made from carbon or glass, a novel three-dimensional hybrid woven fabric (3DWT-M) was proposed and later developed at the Institute of Textile Machinery and High Performance Material Technology (ITM) at TU Dresden (TUD). This novel reinforcement was manufactured on a modified Dornier HTVS4 rapier weaving machine and combines the excellent mechanical properties of metallic fibers (e.g., tensile strength, ductility, workability) with the stiffness and high tensile strength of carbon fibers. It is characterized by a pyramidal metallic cellular core, achieved through a specially designed weaving pattern that utilizes preformed steel wires in the weft direction (mono-axial spatial reinforcement), alongside in-plane reinforcement with carbon fiber tows at the upper and lower faces of the structure. Through further technological and structural developments of the 3DWT-M, the initially mono-axial core design was enhanced into a bi-axial topology (3DWT-B), incorporating carbon fiber towpregs in the warp direction. Two concepts were designed and later manufactured on the Dornier HTVS4 weaving machine, then casted with concrete. Several tests were conducted to assess the quality and the performance of the mineral-based composite with 3DWT-B reinforcement.

Keywords: weaving technology, textile reinforcement for concrete, impact loading, 3D reinforcement fabric, hybrid structure

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Meso-Structure Analysis of Woven Fabrics

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For the manufacturing of fibre-reinforced polymer (FRP) components, the forming process is a crucial production step that gives the textile structure a curved, three-dimensional shape. The draping creates distortions within the textile structure. With woven fabrics in particular, this occurs in the form of shearing, as the weave points (crossing points between warp and weft threads) allow rotation. This results in friction between the warp and weft threads. In addition, the thread cross-sections change as the shear angle increases. This leads to a change in the surfaces at the bonding points and consequently to increasing frictional forces between the threads. Membrane stresses induced during the forming process, for example by material guidance systems, also increase the frictional forces at the crossing points due to the crossing of warp and weft threads in woven fabrics. Especially in woven fabrics, the structural integrity, which depends on the fabric structure or weave pattern and the shearing during forming, strongly influences the effects and mechanisms that occur.

The aim is to comprehensively characterize the fabrics, in particular the meso-structure, which change in particular due to tensile and shear deformations of the fabric during draping, and thus influence the deformation behaviour of the fabric. A method is being developed with which samples can be taken from the textile structure in the deformed state and examined microscopically for structural characteristics. This is used to analyze the deformation mechanisms at roving level.

The defined deformation of the textile structure is carried out in shear tests and coupled tensile-shear tests of single layer and multilayer woven fabrics with different weave patterns. A standard picture frame for applying pure shear and a picture frame for the simultaneous application of membrane and shear forces are used for this purpose. Fabric samples are taken in different deformation states (shear angle, membrane force). Microscopic examinations of micrographs in the undeformed and deformed states are used to clarify the structure (analysis of roving cross-sections, courses, waviness) and their change in the course of fabric deformation. From this, laws are derived for the dependence of the deformed meso-structure on the fabric structure as well as on the state of tension and distortion.

Keywords: composite, woven fabric, shear

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Analytical and experimental approach to study fiber transfer and breakage during the needling process of fibrous structures

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The needling process is commonly used to produce 2.5D composite preforms, especially in the aeronautical and aerospace sectors. It depends on the transfer of fibers across a fibrous structure to ensure its cohesion. However, when fibers are transferred across the structure, some filaments may break, affecting the mechanical properties of the preform. Thus, understanding the needling process mechanisms is crucial to optimize both the process and the resulting composite material.
The present research adopts an experimental methodology and aims to develop an existing analytical model, developed by Chaudey et al. to now estimate the number of fibers transferred by the needle and examine the fiber breakage during their transfer.While Chaudey's original model focused on the homogeneous stresses in needle-punched monofilaments, the enhanced version of our research accommodates multiple filaments and incorporates the needle geometry. Therefore, the new upgraded model simulates the sequential loading of several filaments across multiple needle barbs and predicts the filament breakage during the needling process. Moreover, this model enables the filament stress calculations, in particular, the stress in the critical contact zones between the barbs and the filaments. The upgraded model has been validated by experiments on PA66 filaments, using a 3D printed needle presenting three barbs on the same edge, confirming the robustness of this model.
The results showed a single solution that accurately replicates the experimental curves with accounting the filament breakage variability and their mechanical behavior and allow to determine the number of fibers loaded by the barbs.
Eventually, estimating the number of filaments loaded could be now used as an indicator of the impact and efficiency of process parameters.

Keywords: needling, analytical model, mechanical behavior, stress calculations, number of transferred filaments, barbs

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Automated production of mineral-impregnated carbon fibers for durable and high-temperature-resistant concrete reinforcements

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Textile-reinforced concrete (TRC) is an innovative composite material used in construction, where the interaction between the cement-based matrix and yarn reinforcement is essential. Mineral-impregnated carbon fiber (MCF) yarns, as an alternative to conventional polymer-impregnated heavy tows, offer enhanced compatibility, sustainability, temperature resistance, and flexibility. Most mineral-impregnated reinforcement elements are unidirectional rods which require curing periods of up to 28 days, thereby increasing storage and post-treatment costs. To support large-scale industrial application, recent advancements in automated production are moving toward the development of load-adapted, multidimensional, flat or curved textile reinforcement structures. Herewith, ensuring adequate robustness and precise positioning of conjunction points is critical for practical implementations.

This research focuses on developing materials and technologies for the design, construction, and mechanical performance of MCF reinforcement structures. A robot-assisted structuring methodology combined with post-treatment via thermal activation offers industrial application with optimized efficiency and flexibility. The thermally activated unidirectional MCF rods were mechanically tested through tensile and bending tests. The robustness of yarn-crossing interconnections prepared by scalable methods such as vacuum sealing, knitting, and adhesive bonding was assessed with a specifically developed tensile test. Production quality and damage models were characterized morphologically using microscopy and micro-computed tomography (μCT).

It could be shown that the presented fast-setting regime, robotic deposition process and yarn-interconnection approach can be effectively integrated into the manufacturing of flat and three-dimensional MCF elements, facilitating their transition from laboratory or pilot scale to large-scale commercial production.

Keywords: carbon, fiber composite, mineral impregnation, automation, textile processing, thermal curing.

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Interpretation of mechanical characteristics of plain woven textiles by homogenization method

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Although plain weaving is one of the most fundamental textile structures, its analysis is still difficult due to its complexity and the nonlinearity of materials. In this presentation, a numerical analysis method using the homogenization method of FEM (finite element method) will be presented to study the effect of friction behavior at the intersection of warp and weft yarns especially on the stiffness of the final textile product. To simplify the problem for numerical analysis, each yarn is considered as monofilaments, and evaluation conditions are set to examine the shear behavior of the woven product as well as the effects of the weaving process. Regarding the mechanical properties of yarn, a basic linear elastic body is adopted to focus on the analysis of the effect of weave structure. Numerical simulation has been conducted to evaluate the product characteristics of plain weaving under these conditions of textural and mechanical properties. It has been revealed that the differences in the elastic properties of the yarns are observed with high linearity throughout the plain weave structure, and that although the friction at the intersection of the warp and weft yarns affected stress distribution within the yarns, even though it had little effect on the macroscopic properties of the product.

Keywords: Plain weaving, finite element method, friction, shear

*Speaker

Development of an Analytical Mechanical Model of Staple Fiber Yarns

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Fiber-based materials are ubiquitous in both daily life and industry, appearing in applications such as clothing, insulation, civil engineering, and composite materials. The study and modeling of the mechanical behavior of yarns-structured assemblies of fibers or filaments-has been a foundational research area in the textile field since the pioneering work on staple fiber yarn by Gégauff in 1907. Between 1940 and 1980, extensive theoretical research established a mathematical formalism and analytical models to describe structural characteristics that influence yarn behavior. Mechanical studies of staple fiber yarns provide insights into the deformation and rupture phenomena of yarns composed of synthetic or natural fibers, aiding in the determination of manufacturing process parameters. Several models exist to predict the rupture forces of yarns with high twist; however, the mechanical behavior of intermediate and low twist yarns is more complex, as it requires understanding the frictional interactions between fibers within a yarn. The proposed model addresses these interactions using the Euler-Eytelwein model, with lateral force transmission through the yarn based on Love's theory of elasticity for a rod bent into a helical form. An experimental study is conducted on synthetic fibers and yarns, selected for their clean and uniform structure that aligns well with the model's geometrical assumptions-ideal for an initial experimental approach. Tensile properties are obtained by using the Automatic Single-Fibre Test System FAVIMAT+ to measure the linear density of individual aramid fibers and capture their complete stress-strain profiles during tensile testing. Friction characteristics are obtained from a specific method. Pertinent tensile and friction criteria are chosen supplying essential mechanical parameters for model input. Yarn samples are tested using an Instron tensile testing machine with specialized clamps to impose and measure specific twist levels, ensuring controlled torsional conditions throughout testing. Tensile tests on yarns across varying twist levels are conducted to facilitate direct comparison with the model, assessing its accuracy in predicting the mechanical response of the yarn under different torsion conditions. Following this initial study with synthetic fibers, future work will compare results with natural fibers, such as flax. Although the model may require adjustments to account for the variability of natural fiber properties, this step will enable a broader validation of the model across different fiber types.

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Keywords: fibre, yarn, modeling, friction

Comprehensive Stab-Resistant Protection through Synergistic Effect of Boron Carbide (B_4C) Ceramic Particles and Shear Thickening Fluid-Treated P-Aramid Fibers

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Stab-resistant armours are essential for police and security forces. However, the mechanisms of fabric failure during stab and bullet impacts are dissimilar due to huge difference in associated energy densities. This research aims to design a stab-resistant body armour using coating of hard boron carbide (B_4C) ceramic particles and shear thickening fluid (STF) on p-aramid fabric. The effects of thickener type used for coating, size of ceramic particles and particle to binder ratio on stab resistance have been investigated. The efficacy of coating was evaluated by checking adhesion between ceramic particles and fabric, bending and shear moduli. Dynamic stab resistance tests were conducted following NIJ 0115.00 (level 1) standard at 24 J energy. Results indicate that acrylic co-polymer based thickeners are not suitable for stab resistance applications due to the stiffness and rigidity they impart to the fabric which deteriorate the stab resistance performance. In contrast, an oil-water emulsion-based thickener maintains flexibility of the fabric coated with ceramic particles. While increased ceramic particle content enhances stab resistance, poor adhesion to the fabric creates a practical challenge. A comprehensive solution was developed, by strategically combining ceramic particles coated and STF impregnated p-aramid fabrics, which utilises the synergistic benefit of both approaches. When ceramic coated and STF impregnated fabric layers are placed at the strike face and rear side respectively, the fabric panel significantly outperforms its counterparts with individual treatments.

Keywords: Boron carbide, NIJ 0115.00, Kevlar, Shear thickening fluid, Stab resistance

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Predicting the Elastic Modulus of Recycled Carbon-Fiber Needlepunched Nonwoven Materials Based on 'Process-Structure-Property' Relationship

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Recycled carbon fibers (rCFs), often destined for landfills or incineration, offer a sustainable alternative for various applications, reducing reliance on virgin carbon fibers. Among these, needlepunched nonwoven materials made from rCFs provide opportunities for second-life applications and are increasingly used in composite materials due to their lower cost and ease of manufacturing. However, the elastic modulus of these nonwovens-typically three to four orders of magnitude lower than their constituent fibers-remains challenging to predict due to their complex structure. The current work presents a comprehensive theoretical framework to predict the elastic modulus of rCF-based needlepunched nonwovens by establishing a 'process-structure-property' relationship. The framework integrates constituent fiber properties, the three-dimensional (3D) morphological characteristics of the nonwoven, and the proportion of fiber length in the thru-thickness direction. 3D orientation descriptors were obtained for two distinct rCF-based needlepunched nonwovens using X-ray micro-computed tomography. Extending the 'Paper Physics' approach to three dimensions, the predictive model incorporates 3D orientation averaging and fiber length distributions. Experimental validation showed good agreement between predicted and measured elastic modulus values in both the machine and cross-machine directions. The findings underscore the dramatic reduction of the elastic modulus-from hundreds of GPa for carbon fibres to tens of MPa for the nonwoven materials-and demonstrate the viability of the proposed framework. This work bridges the gap between the needlepunching process and the mechanical performance of rCF-based nonwoven materials, offering insights into optimizing these materials for sustainable composite applications.

Keywords: recycled carbon fiber, elastic modulus, theoretical modelling

*Speaker

Simulation of Heat/Fluid Diffusion in Weft-Knitted Textiles

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Controlling the heat and fluid diffusion behavior of textiles is important for the functionality of advanced fabrics. The structure of the fabric may direct heat away from heat-generating elements or may focus a fluid towards sensors that are monitoring the fabric's environment. We present a method for simulating the diffusion of heat and fluid in a weft-knitted fabric. Our method is based on the yarn topology graph that is produced by the TopoKnit system. TopoKnit is capable of generating a graph, given a stitch pattern, that captures how the yarn in a weft-knitted fabric flows through the fabric and how it connects with itself at yarn intertwinings. We use this yarn topology graph as the foundation for performing flow simulations for the associated knitted fabric. Given the combined capabilities of generating yarn topology graphs from stitch patterns and computing heat/fluid diffusion over these graphs, we have developed an optimization framework that searches the space of stitch patterns, in order to produce a fabric with user-defined flow characteristics. This paper presents our initial simulation and optimization results which show that our method is capable of designing 10 x 10 stitch swatches that have user-prescribed diffusion characteristics. The desired flow is specified with source and sink points in the swatch. Our simulations demonstrate that knitted fabrics may be produced that direct heat/fluid in user-specified directions.

Keywords: weft, knitted textiles, computational modeling, flow simulation, design and optimization

*Speaker

Theoretical Framework for Optimizing the Filtration Efficiency and Pressure Drop across Nonwoven materials for Fog Harvesting and Coalescing applications

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The complex three-dimensional structure of nonwoven materials makes them highly versatile for numerous applications. With their irregular and disordered fiber networks, these materials possess unique capabilities for restricting particle and moisture movement in the air, positioning them as ideal candidates for filtration, fog harvesting, and coalescing systems. Although the wetting and wicking properties of nonwoven materials have been widely explored both experimentally and theoretically, the potential of microfiber nonwovens for extracting water from ambient fog has gained attention only recently. In fibrous materials, the effectiveness of fog harvesting or coalescing depends on a balance between the fibers' ability to capture droplets, the loss of collected water due to convection, and pore clogging within the material. Additionally, the pressure drop caused by the drag within the fibrous structure also plays a crucial role in their performance. This research aims to establish a theoretical framework to identify the design principles governing the filtration efficiency and pressure drop of nonwoven materials in fog harvesting and coalescing applications. Through parametric analysis of various design factors, the study aims to propose optimized designs that enhance the efficiency of fog harvesting and coalescing while reducing pressure drop, minimizing convective water loss, and preventing pore clogging. These design principles are expected to be applicable to the development of advanced filtration media for efficient air-water separation in a range of industrial uses.

Keywords: Coalescing, Fog harvesting, Nonwovens, Analytical Modeling

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Modeling of the woven fabric geometric roughness

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Surface roughness is defined as a parameter determining the spatial arrangement of the surface in relation to the micro-geometry of the surface relief. The micro-geometry of the surface relief is given by the sum of the deviations of the surface irregularities from the ideal geometry. The ideal surface in this case is a smooth surface. Basic information about irregularities and their deviations can be expressed from the profile that is created as the intersection of the cutting plane perpendicular to the surface of the evaluated structure. The basic objective experimental method for determining the feel of a textile (mainly fabric) and experimental definition of the fabric surface relief based on geometric roughness is the Kawabata Evaluation System (KES). The principle of measuring surface characteristics is based on obtaining the surface profile using a touch sensor - a sensor as the main part of the measuring device. Theoretical modeling of surface roughness and prediction of geometric roughness of a fabric is based on the analysis of the structural component of the fabric surface roughness and uses the design parameters of the fabric from the perspective of both the areal and spatial geometry of the fabric. The prediction of geometric roughness of a fabric can be defined as the mean deviation of the fabric thickness in micrometers over the evaluated section of the weave/pattern. The theoretical profile of the fabric surface is defined based on the definition of the height of the protrusions and the height of the depressions of the surface of the structural cells of the yarn interlacing in the fabric. The theoretical profile and structure of the surface is determined by the distribution of the structural cells of the interlacing in the weave/pattern and their geometry. The distribution and number of structural cells contained in the weave/pattern area can be determined based on the relative frequency of individual structural cells of the interlacing of threads in the fabric based on the weave/pattern size. From the point of view of geometry and assessment of the roughness of the fabric surface in relation to the interlacing and the structural cells of the interlacing themselves, it is necessary to determine the degree of their influence on the final unevenness of the surface profile.

Keywords: roughness, woven fabric, thickness, geometry, interlacing, surface.

*Speaker

Improving the technology for producing compression hosiery products by using of natural raw material

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The development and research of knitted products with functional properties, in particular, medical compression knitted products, is one of the current trends in knitwear technology. If to take into account the hot climatic conditions of Uzbekistan, as well as Central Asia as a whole, two main points in this direction emerge: firstly, the demand for this type of product is increasing for the prevention of varicose veins, and secondly, consumer demand is high for an assortment of natural fibers. The article is dedicated to research-investigation on development of compression hosiery using natural and synthetic raw materials for hot climatic conditions. Compression knitwear based on fleecy knitting structures has been designed by using of hosiery machines. Variants of knitwear structures of different fleecy knitting structures patterns have been developed. One of the used raw materials is cotton yarn – a natural type of raw material and another one is spandex and latex – synthetic threads. The technological parameters, physical and mechanical properties of the samples were determined. The necessary recommendations on the using of new variants of knitwear structures are offered. Samples of structures are recommended for a range of compression knitting products to prevention therapy of varicose veins. The scientific significance of the research results is explained by improving the technology of obtaining compression hosiery products with low consumption of raw materials and high quality parameters, by determining the influence of the rapports and structural elements of the fleece knitted fabric structures used in the compression hosiery production on its technological parameters and physical-mechanical properties, and by recommending new rapports of knitting fabric structures for producing compression hosiery.

Keywords: compression knitwear, fleecy structure, technological parameters, physical, mechanical properties, breaking strength, elongation, deformation.

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Yarn with Enhanced Moisture Management Performance

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This study presents a novel yarn structure engineered to enhance moisture-wicking performance through utilizing innovative yarn covering techniques. The proposed structure features a helically shaped covering yarn designed to reduce inter-fiber spacings in core staple fiber-spun or filament yarns, thereby forming enhanced microchannels with superior capillary action. This design significantly increases wicking height and facilitates efficient sweat dispersion by push-pull mechanism.

To evaluate its effectiveness, various core and cover yarn combinations were studied. Core yarns included hydrophilic viscose staple fibers and draw-textured polyester yarn, while covers were made of polyester and polypropylene in both filament and staple fiber forms, with different linear densities. Single and double covering structures were examined, with the optimal surface helix angle achieved at 300 twists per meter. Among the tested combinations, single-covered polyester 75D DTY yarn for both core and cover exhibited the highest wicking distances, reaching up to 8.2 cm - substantially outperforming control polyester DTY yarn without a covering structure and double-covered yarns. The wrapping structure, optimized for ideal twist, emerged as the primary driver of increased wicking height.

Customized drying tests were developed to evaluate water evaporation rates alongside wicking performance of developed yarns. The single-covered polyester DTY/DTY yarns demonstrated the shortest drying times and the highest evaporation rates, although no direct correlation was observed between wicking performance and drying time due to variability in exposed surface areas and testing conditions. The innovative yarn structure achieved at least a 50% improvement in wicking performance without requiring chemical treatments, providing a sustainable and scalable solution for moisture management.

This research marks a step toward eco-friendly advancements in yarn technology, offering improved moisture management in textiles without compromising environmental considerations. Future studies will focus on fabric development to optimize drying performance, dyeing compatibility, hand feel, and drape.

Keywords: yarn, moisture management, yarn covering, wicking, evaporation rate, sustanability

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Development of Functional Fabrics with Complex Structures for Medical Applications

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The growing demand for specialized textile products in medical and rehabilitation contexts highlights the need for advanced functional fabrics with enhanced properties. This research focuses on the development of functional fabrics with complex structures, using modern weaving technologies and innovative fiber blends, such as cotton and Modal. By optimizing geometric and technological parameters, the study achieves fabrics with variable thickness, improved air permeability, and massage properties, meeting the requirements of bedridden patients. Experimental results demonstrate that fabrics with complex structures ensure better blood circulation, superior moisture management, and enhanced comfort. The research also includes an economic analysis, showcasing the potential for significant cost reductions and profitability, with an estimated annual profit of 58,000,000 sum per weaving machine. The study aligns with Uzbekistan's strategic goals for textile innovation and sustainable development.

Keywords: functional fabrics, complex structures, weaving technology, medical textiles, Uzbekistan, sustainability, air permeability

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Investigation of the Performance of Denim Fabrics Woven from Different Regenerated Cellulose Yarns

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Denim is a type of fabric and garment that can be used in every aspect of life and never loses its popularity. Denim is generally known as a fabric woven with cotton yarn dyed by indigo dyestuff in the warp and weft directions. However, this traditional approach has been changing in recent years with the use of yarns made from regenerated fibers in the warp or weft direction of the fabric. Regenerated fibers are produced using chemical pulping techniques, and it is possible to find regenerated fibers made from different raw materials in the market.
This research examines the various performance properties of fabrics produced by using three different types of regenerated cellulose yarns in the weft direction. The three regenerated yarns used are Saxcel, Ecocell, and Tencel.
The four types of yarns were produced for this study, all spun using the ring-carded technique at a count of Ne 12/1. The warp yarn was selected as Ne 12/1 100% cotton. The remaining three yarns were used as weft. Additionally, as a reference, Ne 12/1 100% cotton yarn was also used in the weft. Therefore, 8 different fabrics were woven with 4 different raw material compositions and 2 different weaving types.
Three different washing procedures as rinse, stone, and enzyme were applied to the 8 raw fabrics obtained, resulting in 32 samples . The CIELab values, tensile, tear, and seaming strengths, air permeability, moisture transfer capabilities (MMT), and stiffness (bending rigidity and stiffness test) of these samples were measured.
In particular, when examining bending rigidity, it was found that fabrics made with regenerated yarns could be more drapable. In parallel with this, improvements in tear strength and weft-direction tensile strength were observed, indicating a reduction in rigidity. Additionally, the air permeability of fabrics using regenerated yarns increased.

Keywords: denim, regenerate, saxcell, ecocell, tencel

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Data-based analysis and visualization of textile knitted constructions using a vector space model

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Determining the permeability properties of knitted textile constructions is essential for numerous technical applications. In particular, light, air, and water permeability are crucial in fields such as architecture and the mobility sector, where specific material properties are required. To systematically quantify and predict these properties, a six-dimensional vector space model was developed. The six dimensions are derived from experimental measurements and include surface properties such as thickness, fabric weight, material composition, and porosity, as well as surface permeabilities (light, air, and water permeability). The developed vector space model enables a mathematical representation of textile permeability characteristics, allowing for an objective comparison of different knitted structures. Each textile sample is represented as a point in this six-dimensional space, where the spatial distance between two points corresponds to the difference in their permeability properties. This approach facilitates the clustering of textiles with similar permeability behavior and give correlations between material parameters and permeability characteristics. For validation, various textile structures were experimentally examined and mapped into the vector space. The resulting dataset enables a systematic analysis of textile structures and a direct comparison of their permeability characteristics. An interactive visualization tool displays the data as a 3D scatter plot, making the relationships between the six dimensions more accessible. Additionally, the program allows for a targeted selection of structures based on predefined permeability requirements. After entering the target values, the tool automatically identifies the best-matching, previously tested textile. This facilitates material selection for specific applications and supports the development of textiles with tailored properties. The results demonstrate that the developed vector space model provides a robust framework for analyzing knitted textile structures. The combination of experimental data, mathematical modeling, and interactive visualization enables efficient optimization of knitted constructions for application-specific requirements, such as textile facades, adaptive shading systems, or breathable seat covers.

Keywords: knitted textiles, permeability properties, vector space model, surface characteristics, light permeability, air permeability, water permeability, material characterization, 3D visualization, fabric structure modeling, technical textiles

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Low-Stress Mechanical Properties of Cotton and Polyester Fabrics using the Kawabata System

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The Kawabata technique is well known for its objective evaluation of fabric hand (or "feel") and the mechanical properties of fabrics. This is achieved using the Kawabata Evaluation System for measuring fabric properties (KES-F). The system was developed by Professor Kawabata of Kyoto University in the early 1980s and provides a scientific approach to measuring textile properties related to how fabrics feel and behave. The elastic and inelastic components of low-stress tensile, shearing, bending, and compressional deformations are measured using the Kawabata Evaluation System for Fabric (KES-F). In this report, we investigate the low-stress mechanical properties of cotton and polyester fabrics. Two sets of samples were used for this study: the first set consisted of 100% cotton with varying density (g/m^2), while the second set consisted of 100% polyester, also with varying density (g/m^2). All samples measured were 20 cm $\times$ 20 cm. All measurements were performed using the KES-FB1 tensile-shear tester. Tensile properties are important parameters in evaluating the functional performance of textiles. Therefore, they were measured in both the weft and warp directions of the samples. It was observed that, for all samples, weft elongation was higher in respect to the warp elongation. This observation was confirmed by the higher values of Tensile Energy per unit area (WT) in J/m^2, which correspond to the work required to stretch the fabric in the weft direction. This is due to the fact that the weft yarn is more extendable and, therefore, more energy is required for the extension. Additionally, the effect of increasing cotton density differs between the weft and warp directions. In the warp direction, elongation increases as cotton density increases, whereas in the weft direction, no clear linear relationship was observed. Interesting results were also obtained for the samples with varying polyester density. In the warp direction, the elongation was increased as the polyester density decreased.

Keywords:

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Correlation of quality indicators with normal and Poisson's distributions in grading woven fabrics

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The majority of the quality indicators of woven fabrics reflect the properties of the raw materials used and the given texture. The origin and reasons for the fluctuations in quality indicators are known. Deviations from the stated values are primarily the result of coincidences of boundary values of fibres properties and to a lesser extent of variations in the machine mode of modern textile equipment. In essence, both the variations in fibrous multitude after multi-stage processing and technological variations are controlled, deterministic processes. The measured qualitative indicators form numerical series with a normal distribution. A primary and clear indicator of the structure of woven fabrics is the area mass with its longitudinal and transverse variations on the fabric.
Defects in woven fabrics have contrastingly different probabilities. The possibilities of a warp or weft thread breaking and a knot forming are rare events. Defects represent the material connection between the surface of the fabric and the sporadic coincidences of machine failures with anomalies in the fibrous multitude. Enumeration of defects yields number series with a Poisson's distribution.
The combination of the quality indicators with a normal distribution and the defects with a Poisson‘s distribution gives the generalized quality assessment of the fabric. The balance between statistical ratings of deterministic properties and rare defects is based on verified internal correlation and justifies the credibility of the final rating.
The subject of this article is the linear correlations between the cross-sectional surface masses and between the breaks of the warp and weft threads of woven fabrics. The goal of the development is a parallel application of aggregate characteristics of numerical data from qualitative indicators with normal and Poisson's distributions.

Keywords: textile, fabrics, QMS, Gauss and Poisson distribution

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7- Surface Functionalization and Coating, Dyeing technologies and systems

Dyeing of natural fibers with extracts from wood – a strategy for fully bio-based and sustainable textiles

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Extracts from special types of wood can be effective substances for dyeing of natural fibers. Wood types with high content of natural colorant are e.g. brazil wood, quebracho wood and logwood. Obviously, dye extracts from wood should be only used if the wood type is broadly available and not from an endangered species. Under this consideration, dye extract from logwood can be used for dyeing purposes. Logwood is gained from trees growing mainly in Central and South America. It is also used for charcoal production. One main colored component of logwood is Hematoxylin which is oxidized to Hematein. Suitable mordants for application of logwood are aluminum salts and iron salts. While with alum mostly blue colors can be realized; with iron mordant colors as brown, grey and black can be realized. This actual study focusses mainly on the evaluation of logwood extracts combined with different combination of iron sulphate as mordant. For environmental reasons aluminum ions should be avoided. Parameters like dye and iron mordant concentration are investigated for the dyeing of wool and cotton fabrics. The iron sulphate is applied by pre-mordanting and meta-mordanting processes. By combining the two components logwood extract and iron sulphate in different concentration and order a broad range of different color shades from brown, grey to black can be realized on the fabrics. The fastness properties against washing, rubbing and light exposure are determined. Especially for light fastness good values from mostly 3 to 4 are reached. For some recipes even grades 5 to 6 are reached, which is an excellent light fastness for natural dyes. Washing and rubbing fastness are good for low dye concentration but decrease for higher dye concentration. In conclusion, by using logwood extracts for dyeing of natural fibers fully bio-based dyed fabrics with fine fastness properties can be realized.

Keywords: dyeing, logwood, wood extracts, light fastness, mordanting

*Speaker

Modification of hemp fibers under UV irradiation with nano-TiO_2

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Hemp fiber exhibits poor adhesion between hydrophilic lignocellulosic fibers and hydrophobic polymer matrices, primarily due to the polar nature of natural fibers, which reduces compatibility with nonpolar thermoplastics. Non-cellulosic components negatively affect fiber processing and properties. Heterogeneous photocatalysis using nano-TiO_2 is promising due to its low cost and non-toxicity. Nano-TiO_2 generates reactive oxygen species under UV light, oxidizing organic molecules. This study investigates the impact of nano-TiO_2 treatment on hemp fibers under UV light.
100% hemp woven fabric was used. Titanium dioxide Aeroxide®TiO_2-P25 (Degussa, Germany) was utilized. The experiments were conducted in a UV-C cabinet.
Fabric samples were immersed in the treatment solution and processed with a foulard for 100% pick-up, followed by 1 hour of UV exposure. Hydrophilicity was measured using AATCC 79. Tensile strength tests followed ISO 13934-1 standards. SEM analysis was conducted at 1000x magnification, and FTIR analysis covered 500-4000 cm^{-1}.
The treatment significantly enhanced hydrophilicity, with untreated samples showing > 300s and treated samples 1.55s. This aligns with findings of amphiphilic properties in nano-TiO_2-treated samples under UV light (15,16).
A 20% increase in tensile strength was observed due to nano-TiO_2 particle retention on the fiber surface (11,17-20).
SEM images confirmed successful deposition of nano-TiO_2 on treated fibers.
FTIR indicated that treatment preserved hydrophilic peaks (3336 cm^{-1}), with changes in peaks associated with lignin (1400 and 1600 cm^{-1}), demonstrating the removal of non-cellulosic components (19,21-24).
Nano-TiO_2 treatment under UV light significantly enhances the hydrophilicity and tensile strength of hemp fibers while maintaining hydroxyl content and adhesion properties. SEM validates successful incorporation, contributing to improved mechanical performance.

Keywords: hemp fiber, nano-TiO_2, UV irradiation, surface modification

*Speaker

Obtaining functional textile surfaces via plant extract

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Cellulosic fibers, which have common usage in the textile industry due to their excellent properties, provide a great medium for microorganisms. In order to prevent these microorganisms from reproducing on the textile surfaces, the antibacterial and antifungal finishing treatments that protect users from pathogenic or odor-generating microorganisms can be carried out. The treatments can be carried out via different compounds such as cationizing agents, triclosan, metals and metal salts, oxidizing agents, amines, antimicrobial dyes, plant extracts, etc.
The increase in UV levels reaching the earth, due to damaging the ozone layer, causes sunburn, the onset of herpes simplex, skin cancer etc. In order to minimize the effect of harmful UVR, the development of UV-protective clothing and coverings is essential. Textiles inherently provide a barrier against solar radiation, due to their physical characteristics that can influence the final UV Protection Factor (UVPF). There are several agents giving textiles photoprotective activity, which can be of inorganic nature, such as copper oxide, zinc oxide, and titanium dioxide, or even organic, such as phenolic compounds present in plant extracts. In the study, the functional activity saves to the textile surfaces with methanol extract of *Salvia verticillata* subsp. *amasiaca.* The plant has gained particular attention due to their biological properties such as antimicrobial, antiviral, antioxidant, enzyme inhibitory, and anticancer effects. In the study, firstly the methanol extract of *Salvia verticillata* subsp. *amasiaca* was prepared and then 100% cotton fabric was coated with the plant extract, and in order to compare the results it also coated without using extract. The coated fabric samples were examined with antibacterial (against *S. aureus* and *E. coli* bacteria) and UV protective activity. The results showed that the fabric samples coated with prepared extract gained high antibacterial activities (SA: %99.50, EC: %91.95) and UV protective activity (UPF: +50 factor).

Keywords: UV Protection, antibacterial activity, natural plant, S. verticillata subsp. Amasiaca, functional textile surface

*Speaker

Antibacterial textile finishing of cotton by in situ green synthesis of silver nanoparticles

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Textile materials, like cotton, are widely employed in several fields such as industrial, healthcare and fashion. The global demand for textile products is still increasing because of population growth and economic development. Nowadays, textiles integrated with various nanoparticles are used in many innovative applications such as biomedical, sports and transportation areas. Among nanoparticles, silver nanoparticles (AgNPs) are very popular nanoobjects due to their outstanding antimicrobial properties. However, for biomedical usage, a green approach to synthesising AgNPs is recommended to avoid any possible toxicity. In this work, the cotton's surface functionalization with green silver nanoparticles is developed. An *in-situ* green strategy is performed to attach the AgNPs onto the surfaces of cotton. Firstly, textile samples are immersed in an aqueous solution with known concentrations of silver nitrate. Then, the specimens are dipped in the solution of biopolymers which are used as both reductant and capping agents for enabling the growth of AgNPs. The treated and untreated materials were characterized using Fourier transform infrared spectroscopy (FTIR), Raman scattering, Energy-dispersive X-ray (EDX), scanning electron microscopy (SEM), thermogravimetric analysis (TGA), and Datacolor 650 spectrophotometer to investigate their chemical properties, morphology and colour changes. Finally, preliminary antimicrobial assays were assessed to confirm the antibacterial properties of the finishing.
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Keywords: cotton, green synthesis, silver nanoparticles, antibacterial finishing

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A Novel Natural Dyeing of Cotton Knit with Immature Citrus grandis Osbeck for Bio-active Textiles

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This study was performed to investigate dyeing properties and fastness of cotton knit with hot water extract of immature Citrus grandis Osbeck (CgO) and to identify its antimicrobial activity, UV protection, and deodorization activity. Immature CgO fruits were extracted in hot water to final solid dye powder to dye a cotton 100% jersey under the condition of 80℃ and 60min with repeated dyeing and to investigate dyeing behavior and color characteristics along with the dyeing fastness. To assess skin-friendly functions of dyed fabric, antimicrobial activities, UV protection properties, and deodorization activities were quantitatively investigated. As results, the dye absorption behavior of immature CgO extract on cotton might be in accordance to Freundlich isotherm and the surface of dyed cotton showed light and pale shades of Yellow under the dye concentrations of 10_˜100% owf even though it gave gradually higher saturations and less lightness as dyeing repeated. The dyeing fastness to perspiration, rubbing and had washing were shown as excellent with grade 4-5 while fastness to light was graded as poor with 3 or less, which means that light fastness needs to be improved in a future study. Among four differently dyed specimens (10%+single dyeing, 10%+5-repeated dyeing, 50%+single dyeing, 50%+5-repeated dyeing), all of then exhibited excellent antimicrobial activities with bacterial reduction rate against *S. aureus* and *K. pneumoniae* of higher than 95% except the specimen of 10%+single dyeing. As for UV cut ratio %, all of dyed cotton jersey presented 97% or higher and they showed 99% or higher of deodorization efficacy, which implies the dyed cotton could be utilized for skin-friendly bio-active textiles.

Keywords: natural dyeing, Citrus grandis Osbeck, cotton knit, bio, active, antimicrobial activity, UV protection, deodorization activity

*Speaker

Water and Fire Repellent Technical Shoe for Airline Employees

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Most of the companies use animal or synthetic leather in the inside of their shoes. But this does not prevent any damages come from the outside water or deformation damages for example. For the airline employees whom has to wear their shoes in the extreme environments that is the idea has started for this novel study. To protect to inside of the shoe a neoprene coating has been applied to the interior lining. Neoprene has is a synthetic rubber which has a soft texture and has high durability. It has high elongation properties and after stretching their formation will not be deformed. It can be designed for the selected performance, for this study water-repellency, fire-retardancy and air permeability. Also, neoprene has a long-life cycle so it has high efficiency.

Keywords: coating, water repellency, air permeability, technical textile

*Speaker

Functional and Sustainable Fluorine-Free Silane Coatings to Achieve Super-Hydrophobic Fabrics

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The textile industry has undergone significant transformations over the years, particularly with the advent of advanced materials that enhance the functional properties of fabrics. One such advancement is the use of functional silane-derived nanohybrid materials, which have emerged as a promising solution for developing hydrophobic coatings on various textiles. Traditionally, fluorine compounds have been used for water repellency. Although effective, many fluorinated agents are difficult to degrade and pose environmental risks, prompting restrictions on their use. This highlights the need for fluorine-free alternatives, despite the effectiveness of existing fluorine-containing formulations.(1) Functional silanes are instead organosilicon compounds that contain reactive functional groups that can bond to various substrates, including textiles, to modify their surface properties. The ability to tailor these materials for specific applications makes them ideal candidates for fabric treatments. In particular, this study explores an efficient and eco-friendly method for achieving highly hydrophobic surfaces on cotton and polyester fabrics using modified silica sols. The resulting surface properties of the treated fabrics were evaluated through static and dynamic water repellency tests, along with assessments of resistance to common water-based liquids, abrasion resistance, moisture adsorption, and air permeability. Scanning electron microscopy was utilized to analyze the micro- and nano-morphology of the functionalized surfaces.(2) Overall, this research promotes sustainable practices in textile finishing while enhancing the performance of polyester and cotton fabrics. By leveraging the unique properties of silanes, these coatings offer enhanced durability, performance, and environmental sustainability, promising a future of high-performance, eco-friendly fabrics that meet the demands of consumers and industries alike.

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Keywords: sol, gel, alkoxysilanes, functional fabrics, hydrophobicity, nano, hybrid coatings

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(Multi)functional bio-based hybrid materials as sustainable coatings for tailored high-performance textiles

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Functional coatings technologies come from the need to protect or significantly enhance the performance of the covered materials on which they are applied. As far as textiles are concerned, these functional layers offer a multitude of benefits, making them more durable, versatile, and preventing the leaching of microfibers on the environment. In particular, they may also enable implemented properties, such as antimicrobial, conductive (for wearable technology), waterproof, stain/UV resistant, flame retardant, and phase-change (for thermal regulation). Moreover, coatings can improve textiles sustainability by enabling their recyclability at the end of life, and by reducing the need for conventional chemical treatments. In this framework, bio-based hybrid materials have emerged as attractive functional coatings for high-performance textiles, merging the benefits of renewable resources with modern innovative material synthetic techniques, for the development of (multi)functional hybrid and nanostructured materials with superior qualities. A part other advanced functionality, these materials provide higher mechanical strength, durability, and biocompatibility, while minimising reliance on non-renewable resources. Furthermore, the addition of bioactive substances, such as antibacterial agents, hydrophobic compounds, antioxidants, UV-absorbing and conductive molecules to them, may give raise to (multi)functionality in high-tech textiles.

This communication describes the development of such novel hybrid nanostructured materials using various chemical synthetic strategies, such as the use of a combination of suitable bio-based polymers with synthetic (blended) polymers or functional nanomaterials/molecules. Green and eco-friendly synthetic procedures, based on bio-based, natural, or waste reactants, were additionally employed in order to create more sustainable (multi)functional hybrids or nanostructured textile coatings in accordance with the circular economy concepts. Finally, the chemical-physical and morphological properties of all precursors, materials, functional coatings and treated textiles are described.

Acknowledgment: MICS Extended Partnership (PE00000004) and Ecosistema SAMOTHRACE (ECS00000022) PNRR, and FOE2022 Future Raw Materials projects are gratefully acknowledged.

Keywords: functional coatings, sustainable textiles, circular economy, hybrid materials, nanostructured coatings, smart surfaces, high performance textiles

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Evaluating Different Organic Solvents as Stress-Inducing Agents for Enhancing Pyocyanin Production in Pseudomonas aeruginosa

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Bacterial pigments are gaining increasing attention as sustainable, versatile alternatives to synthetic dyes, providing eco-friendly options across diverse industries. In the textile sector, these pigments hold particular promise not only for reducing environmental impact but also for imparting fabrics with novel and functional properties. Pyocyanin, a striking blue pigment produced by many strains of *Pseudomonas aeruginosa*, exemplifies these benefits; it is both biodegradable and readily extractable, making it a practical candidate for industrial applications. Beyond its aesthetic appeal, pyocyanin possesses potent antimicrobial properties, effectively targeting bacterial species such as *Staphylococcus aureus* and *Escherichia coli*, as well as fungal pathogens including *Fusarium graminearum* and *Candida albicans*.

As secondary metabolites, pigments like pyocyanin are typically synthesized as protective mechanisms in response to environmental threats, including competing bacteria and fungi, UV radiation, and various stressors encountered by the bacterial species. This study began with an exploration of different culture media—namely nutrient broth, peptone water, and brain-heart broth—to optimize conditions for pigment production. Samples of *Pseudomonas aeruginosa* were cultured over seven days at 27$\circ$C with continuous stirring, revealing that nutrient broth supported the highest levels of pigment production and was thus selected for further experimentation.

To simulate environmental stressors and enhance pyocyanin production, toluene, acetone and ethanol were introduced as inducing agents, aiming to stimulate the pigment's natural protective response within *Pseudomonas aeruginosa*. Of the different experimental conditions tested, the introduction of these organic solvents after 24 hours of bacterial growth allowed verifying that blue pigment production was visible after 7 days.

Keywords: Bacterial pigments, textile dyeing, toluene, pyocyanin

*Speaker

Novel Textile Dyeing Process: The use of Natural Deep Eutectic Solvents (NADES)

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Textile dyeing is recognized for its substantial environmental impact (1, 2). In response to this challenge, there is an increasing focus on eco-friendly alternatives, including the use of natural dyes derived from plants that not only provide coloration, but also impart unique functional properties to textiles(3). However, these types of dyes typically exhibit poor color fastness when exposed to washing and light. To address these limitations, heavy metal-based mordants are usually employed, which, in turn, contribute to water contamination issues. In this study, the main objective is to establish a multifunctional dyeing method that incorporates Natural Deep Eutectic Solvents (NADES) as sustainable alternatives for both dye dispersion and the extraction of natural dyes (4-6). The adoption of NADES is expected to reduce water, solvent, auxiliaries, and energy consumption in industrial operations, supporting environmentally friendly practices while maintaining textile quality.

This research presents a comparative analysis of dyeing processes employing both natural dye extracts and synthetic dyes. Two methodologies were examined: one utilizing the conventional water-based process with standard auxiliaries, and an alternative employing only NADES. Two specific NADES were studied: one widely documented in the literature, composed of choline chloride and malic acid, and a novel formulation developed by our group, consisting of an alcohol and a sodium salt. Cotton, wool, and polyester were the fiber types analyzed, with samples evaluated for color strength, coordinates, and color fastness, alongside assessments of NADES' physicochemical properties.

The results demonstrate the feasibility of using NADES for dyeing with synthetic and natural dyes across the different fiber types. To date, there is a limited number of documented applications of NADES in water-free dyeing processes especially with natural dyes in textiles. This study contributes to the growing knowledge regarding sustainable dyeing practices and the potential of NADES in dyeing process while reducing environmental impact.

Keywords: textile dyeing, sustainable dyeing, NADES

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Exploring Knife Coating Strategies for Diverse Algal Biomasses and Coating Architectures

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Innovative approaches to textile finishing are emerging. There has been a strong focus on incorporating algae-based solutions into textiles to imbue them with functional characteristics (e.g. antioxidant), while fostering sustainability. The present research seeks to develop and test new coating approaches that integrate algal biomass (*Tetraselmis chuii*) and its extracts into fabrics through knife coating, an algae known for its antioxidant traits, among others. The developed functionalized fabric solutions are to be tested at the laboratory and industrial scales, to assess feasibility, performance and scalability of the process. The outreaching goal is to create eco-friendly/sustainable, scalable alternatives for existing textile functionalization processes while empowering the recognized benefits of the use of such algae in our solutions.
We worked with three distinct 100% cotton substrates: two knitted Jersey fabrics (K1 and K2) and one woven taffeta fabric (WF), while aiming at user's protection from various everyday exogenous hazards while maintaining a high level of comfort. Hence, we applied a functionalized layer (compact and/or porous layer) to each substrate, incorporating a bio-based polyurethane polymer matrix combined with various algae biomass. The applied knife coating method is a widely used technique in the textile industry to apply uniform layers of material onto fabric substrates. The architecture of the coating -single- or multi-layer - plays a crucial role in determining the final characteristics of the textile, including flexibility, breathability, and abrasion resistance. Standard protocols were employed to test the abrasion, washing fastness and sea water fastness as well as the fastness to perspiration, both alkaline and acidic. Antioxidant assays were additionally done. From the results obtained, a mass loss below 1% after 2000 abrasion cycles can be highlighted, as well as higher antioxidant performance after 5 washing cycles (approximately 20% higher), when compared to the coating without algae functionalization resulting from the ABTS method.

Keywords: textiles, coating, functionalization, sustainability

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An Environmental Route for Textile Surface Treatment to Enhance its Dyeability

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Sustainability and a green environment are international imperatives today to mitigate the environmental impact of numerous industrial sectors. The textile industry is among those most reliant on chemicals in its primary wet processing stages. Consequently, it necessitates innovative finishing techniques to enhance product quality and reduce environmental impact. The principal objective of this study is to examine the effects of chemical-free finishing and treatment processes on natural fibres and natural/synthetic fibre blends. Laser technology, as an example, has been employed in this work as a surface treatment method to enhance the dyeability of selected fabrics. Several laboratory tests were conducted to assess surface morphology, colour depth, and dye stability following laser surface treatment. The results indicated a substantial improvement in dye absorption rates and an increase in dye stability against variables such as light, washing, and friction after laser treatment. This qualifies that chemcial free treatment methods are effective and sustainable alternative to conventional, chemical-based methods.

Keywords: textile industry, sustainability dyeability, wettening, surface treatment

*Speaker

Improved Dyeing Conditions in Hair Dyeing by Using Amino Acids and Saccharides

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Studies have been carried out on novel hair dyeing techniques using amino acids and saccharides as dye precursors, which are chemically modified and used to dye hair. This method was successfully used to dye human hair and wool. However, in the early stages of the study, the dyeing system needed to be heated up to temperature and treated for long time to obtain satisfactory deep dyed hair. Then, it was necessary to lower the dyeing temperature and reduce the dyeing time. Therefore, as a result of intensive studies, it was found that adding organic acids such as citric acid and sodium periodate facilitated the formation of dye substances and made the dyeing process cooler and shorter. Furthermore, the effect of these additions was revealed that easy-to-obtain, general-purpose saccharides such as glucose, fructose and sucrose, which had been previously ineffective, can also be used as the dye precursors. This study examined the relationships between dyeing conditions, such as the type of saccharides / heating sequence of dyeing solution and dyeability of hair using easily obtainable glycine as an amino acid. In addition, when D-glucose was used as a saccharide, the dyeing results were not consistent, being deep brown or not dyed. Therefore, the reason for the phenomenon was tried to clarify. It was found that heating the dyeing solution just prior to hair immersion to 25°C and over enabled hair to be dyed at a lower temperature of 30°C for a shorter dyeing time of 45 min.

Keywords: hair dyeing, Amino acid, saccharide, sustainability, biobased material

*Speaker

Surface grafting of textile as a tool for fabrication of functional fabrics

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This talk will describe new strategies for chemical surface modification of textile, specifically seeking processes which are modular, inexpensive, technically simple and would not damage the fabric, while providing durable functional coatings. One of the methods is based on a two-step process that includes surface grafting of bifunctional small linker molecule, 10-undecenoyl chloride, via esterification reaction and a subsequent covalent attachment of functional materials to the double bond end-group via UV-mediated thiol-ene click chemistry. The covalent grafting can be accomplished in a rapid manner within several minutes leading to uniform and thin functional coatings. The modified fabrics were characterized using contact angle measurements, Fourier Transform Infrared and X-ray Photoelectron Spectroscopy analyzes. The developed approach allows preparation of woven, knitted and non-woven textile based on natural and synthetic polymers with controlled hydrophobicity/hydrophilicity, oil-water separation ability and pH regulation. In addition, preparation of hybrid antibacterial, antiviral and electro-conductive fabrics based on organic conjugated polymer will be presented. Polyaniline-coated fabrics were prepared via in situ polymerization of aniline monomer and the influence of the aniline concentration on the electrical resistivity of the modified fabrics was evaluated. Antibacterial properties were examined for *S. aureus* and *S. epidermidis* types of bacteria.

Keywords: surface functionalization, cotton fabric, hydrophobic cotton, covalent surface grafting, anti, bacterial textile

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Circular bio-based technical textiles with innovative bio-inspired non-toxic functionalisation

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EU's industry is pushed to convert into a net-zero industry and accelerate the transition to climate neutrality. As an important part of the manufacturing industry, the textile sector must make disruptive innovations in sustainable textiles. This is the context of the BioFibreLoop project that focuses on circular and technical textiles for active-, outdoor- and work-wear made from biopolymers (lignin, cellulosic material, PLA) with bio-inspired non-toxic functionalisation. The BioFibreLoop consortium comprises 13 partners from 9 European countries, and it is coordinated by DITF Denkendorf. The project guiding principles are summarised in three key concepts: **Safe:** BioFibreLoop is making a breakthrough in non-hazardous chemical textile functionalisation with a 100% reduction of hazardous chemicals, replacing them with biomimetic functionalisation laser technology. in this way, consumer needs can be addressed with high-added value and smart functionalities in fabrics and garments; **Sustainable:** Only bio-based materials from renewable and sustainable sources are used and the products are designed for durability, to reduce the landfill material; **Circular:** The project ensures a complete circular lifecycle by recycling garments made from these bio-based materials. At the end of life, functionalised biopolymers are recycled through dissolution-based processes for cellulosic materials and mechanical or thermomechanical methods for PLA and lignin-based textiles.

To achieve these objectives, the project partners are developing mono-material fabrics (woven, knitted, non-woven) that will be coated with a lignin layer. This coating imparts thermoplastic properties to the fabric, enhancing the effectiveness of biomimetic functionalisation, which is applied through hot embossing using a laser-textured Titanium Master Plate. The project also investigates methods to remove the lignin layer from the garments to optimize the following recycling process. Digital twins and process models will enable the fast and effective development of the BioFibreLoop products. NTT's role is focused on the preparation of PLA-based non-woven textiles using air-laying and carding technologies. These materials will be mechanically recycled to produce again non-woven products for fabric padding. Finally, design principles to determine safe and sustainable processes and product parameters are being defined and the life cycle and overall safety and sustainability assessments of the product lines will be analysed to ensure their circularity and reduce their impact on human health and the environment.

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Keywords: laser, based textile functionalization, biomimetic, Bio, based textiles, textile industry, recycling, digital twins, safe and sustainable by design framework, circular process, zero hazardous chemical

Enhancing Acrylic Fiber Functionality Through Surface Modification

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The project focuses on the surface modification of acrylic fibers to optimize dye uptake, improve process efficiency, and enhance functional properties. Acrylic fiber, predominantly composed of acrylonitrile, exhibits a positive charge, necessitating the use of cationic dyes for effective coloring. These dyes bond electrostatically to the negatively charged sites on the fiber, creating strong adhesion and vivid color outcomes. However, challenges such as low dye penetration due to the fiber's chemical composition and high crystallinity often hinder process efficiency.
This study aims to address these challenges through the development and optimization of surface modification techniques. Laboratory-scale plasma technology processes are used to modify the fiber surface, followed by evaluation of the integration of these modifications into pilot-scale wet spinning processes. Key factors such as fiber moisture content, fiber quantity, process parameters and positioning of surface modification mechanisms were investigated to determine their impact on dyeing efficiency and color retention.
Comprehensive analyses, including color homogeneity, depth, and color difference tests, are conducted to evaluate the industrial benefits of the modified fibers. The project also explores environmentally friendly strategies to reduce chemical consumption and waste, contributing to sustainable and cost-effective dyeing practices.
By enhancing dye uptake efficiency and ensuring compatibility with existing production systems, this research aims to offer innovative solutions for the textile industry. The findings have the potential to not only improve the quality and durability of dyed acrylic fibers but also provide significant economic and environmental advantages. The project aligns with global sustainability goals and paves the way for the adoption of greener practices in the textile sector, ultimately contributing to competitive and sustainable production. This project was developed within the framework of university-industry cooperation.

Keywords: surface modification, fiber functionality, process efficiency, plasma technology, acrylic fiber

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Depolymerization of Colored PET Fibers using Phase Transfer Catalysts (PTC)

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Polyethylene terephthalate (PET) fibers are among the most widely produced fibers due to their excellent physicochemical properties, including chemical stability, dimensional stability, and heat resistance. However, approximately 70% of used PET fiber products are incinerated or disposed of in landfills, contributing to significant environmental problems, necessitating the development of recycling technologies for PET waste fibers. Chemical recycling methods, such as depolymerization, which convert PET waste fibers back into monomers (Terephthalic acid, TPA), have been widely studied. However, most PET waste fibers are dyed, and it has been reported that the recovery yield of monomers (TPA) from dyed fibers is lower than that from undyed PET fibers during depolymerization. Therefore, strategies to improve monomer recovery yield during the depolymerization of dyed fibers are required. Phase transfer catalysts (PTC) are substances that enhance the transfer of reactants between immiscible phases and are known to improve the efficiency of the hydrolysis-based depolymerization process by facilitating the reaction between aqueous NaOH and solid PET fibers. In this study, the effect of PTC on the depolymerization of dyed PET fibers was investigated. It was observed that the catalytic effect increased with the length of the alkyl chain in the PTCs. The use of PTC in the depolymerization process improved TPA yield by more than 10% across all samples, including virgin PET fibers, dyed PET fibers, and decolored PET fibers, without causing any damage to the TPA. Notably, depolymerization of decolored PET fibers with PTC achieved a TPA yield of 82-89%.

Keywords: decolorization, depolymerization, phase transfer catalyst (PTC)

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Antimicrobial viscose nonwoven fabric with ZnO, Cu nanoparticles and vinyltrimethoxysilane

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The coronavirus SARS-CoV-2 pandemic has become a particular driving force for taking action in the fight against the pathogens Efforts to prevent their spread are based, among others, on the development of textile materials with antiviral and antibacterial properties. Much attention has been paid to metal/metal oxide nanoparticles exhibiting antimicrobial properties. Zinc oxide (ZnO) and copper (Cu) nanoparticles have been used in the textile industry as bioactive modifiers.
In this study, a modified viscose (Vi) nonwoven fabric was developed by application of compositions of 2.5 wt.% ZnO (ZnONPs), Cu (CuNPs) nanoparticles, their equilibrium mixture and vinyltrimethoxysilane (VIN).
To characterize the physic-chemical effects of the modification the scanning electron microscopy with the X-ray spectroscopy analysis by dispersive energy (SEM/EDS) and atomic absorption spectroscopy (AAS) was performed.
All modified nonwoven fabrics exhibit antiviral properties against human coronavirus HCoV-229E. The antiviral activity (Mv) amounts 2.22, 2.14 and 2.69, respectively for ZnONPs, CuNPs and their mixture. They are also non-toxic against non-tumorigenic, immortalized human keratinocyte cells (HaCat) and human lung adenocarcinoma cells (A549).
All modified nonwoven fabrics have strong antibacterial activity against Gram-negative (Klebsiella pneumoniae) which is higher than 6. Antibacterial activity against Gram-positive (Staphylococcus aureus) bacteria is strong (higher than 6) for fabrics with ZnONPs and CuNPs and significant (higher than 2) for fabric with nanoparticles mixture.

Keywords: viscose nonwoven fabric, zinc oxide and copper nanoparticles, silane, antibacterial and antiviral properties, toxicity

*Speaker

Enhancing cotton fabric with silver and zinc oxide nanoparticles for antibacterial and antiviral properties

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In the wake of the coronavirus pandemic, the development of new materials with enhanced antibacterial and antiviral properties for the textile biomedical sector and personal protective equipment has become one of the critical area of research. Creating a textile with antiviral properties is a complex process that requires considering the textile's structure and composition, selecting bioactive modifiers, and employing effective application methods.
We investigate innovative approaches to modify textile materials and create new bioactive composites that can effectively reduce microbial threats. For this purpose we have functionalized the cotton (CO) woven fabric with silver nanoparticles (AgNPs) synthesized by chemical reduction method and commercial zinc oxide nanoparticles (ZnONPs), as well as their mixture using dip-coating method.
The modification effects were rated using scanning electron microscopy with energy-dispersive X-ray spectroscopy (SEM/EDS), atomic absorption spectroscopy (AAS), thermogravimetric techniques (TG/DTG). The wettability and surface free energy were determined by the goniometric method. The bioactive properties were studied against Gram-positive (*Staphylococcus aureus*) and Gram-negative (*Klebsiella pneumoniae*) bacteria. The antiviral properties against the human coronavirus HCoV 229E was tested and the toxicity against HaCat - non-tumorigenic, immortalized human keratinocyte cell line and A549 - a human lung adenocarcinoma cell line was evaluated using MTT test.
The functional CO woven fabrics modified with AgNPs, ZnONPs and AgNPs/ZnONPs are non-toxic and characterized by antibacterial and antiviral properties. Our studies highlights the potential of innovative material science to health security.

Keywords: antiviral and antibacterial textiles, cotton, silver nanopartcles, zinc oxide nanoparticles

*Speaker

8- Industrial textiles, Technical Textiles, Protective Textiles

Development of vascular cool sportswear with advanced liquid sweat management

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Many hydrophilic synthetic fabrics claim to move moisture away from the body to the garment's outer layer, however, most do nothing more than absorb water within inter-yarn space, resulting in heavy, sticky and wet discomfort during exercise and after-chill effect. This research proposes the development of vascular cool fabric by mimicking the branching structures of the blood vascular system for advanced liquid sweat management properties for sportswear. Like the blood vascular system that efficiently distribute blood and lymph fluid throughout the body, the screen-printing process prints a vascular-like water repellency finish on the double side of the fabric, but simultaneously remain absorbent bridge channel in the fabric surface. As the wearer begins to sweat, the printed areas remain dry against the skin while connected wicking channel spread sweat to a wider area of the fabric where it can evaporate and dry quickly by edge effect. Physical measurement indicated that, vascular biphilic fabrics exhibited higher evaporation rates per unit wet area than the pristine fabric. The vascular pattern with 3-branch miniaturization sizes and a hydrophilic/overall ratio of 60_˜63% performed best, with sweat diffusing most rapidly during sweating when compared to other pattern designs. Wear trails validated that skin humidity was measured to be 3_˜5% lower when wearing vascular cool T-shirt than that wearing the control fabric (viz. no vascular pattern). Less wet fabric against the skin validates a drier, more comfortable experience. The vascular cooling technology greatly reduces the amount of cling force by minimizing the amount of wet fabric that comes into contact with the skin. This promising method have the ability to move sweat away from the skin and exhibit significant performance advantages over untreated cotton, cotton blends, and synthetic fabrics.

Keywords: biphilic surfaces, vascular capillary structure, evaporative cooling, edge effect, thermal comfort

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The Impact of Fiber Composition on the Cut and Abrasion Resistance of 3D Weft-Knitted Fabrics

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This study investigates the influence of fiber composition on the resistance of 3D weft-knitted fabrics to cutting and abrasion. For this purpose, six different 3D weft-knitted fabrics, consisting of outer (protective), connecting, and inner layers, were produced on an E20 circular interlock knitting machine. The protective 3D weft-knitted fabrics were designed by varying the percentage of high molecular weight polyethylene multifilament (HMWPE) from 49% to 24% and basalt multifilament yarns from 0% to 23% in the outer layer, while the percentages of polyester in the inner layer and polyamide in the connecting layer were kept constant. The straight cut and abrasion resistance tests were conducted to evaluate the resistance of 3D weft-knitted fabrics to these mechanical risks, in accordance with EN ISO 13997:1999 and EN 388:2016, respectively. Analysis of the cut resistance test results revealed a positive relationship between cut resistance and the percentage of basalt in the 3D weft-knitted structure. It was determined that the highest cut resistance (25.8 N) among all the knitted fabrics was achieved in the sample with the highest percentage of basalt (23%) and the lowest percentage of HMWPE (24%) in the outer layer. The abrasion resistance test for all 3D weft-knitted fabrics was stopped after 16,000 cycles, as no holes were detected in the samples. Consequently, no correlation was found between the percentages of HMWPE and basalt and the number of abrasion cycles. Although there is no correlation between abrasion resistance and the fiber composition of the 3D weft-knitted fabrics, all the designed knits met the highest abrasion resistance level (Level 4 = $\geq$8,000 cycles) in accordance with EN 388:2016.

Keywords: cut resistance, abrasion resistance, mechanical risk

*Speaker

Investigation of the properties of multifunctional polyester yarn with biodegradable and flame retardant properties

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Today, the increase of industrialization, the increase of mass residential areas and the development of technology have increased the risks of fire; the use of heat and flame-protective textiles has made it inevitable.Flame retardant yarns are manufactured to meet this need to reduce the ignition and combustion risks of textile products. It is produced by halogen-free flame retardant additive technology based on phosphorus chemistry during yarn drawing process.
As a result of increased environmental awareness, there has been a parallel increase in interest in environmentally friendly products alongside developments and demands in technical textiles. Polyester, a polymer derived from petroleum, is not biodegradable and is therefore a significant source of waste for the planet. In light of this, research has been carried out into alternative polymers.
In this study, flame retardant polyester yarns were rendered biodegradable. The yarns were produced using the melt spinning method. At the industrial scale, polyester yarns were added biodegradable masterbatch comprising 2-3% and a flame retardant masterbatch comprising 10-12% to the polyester yarn. Subsequently, DTEX167F48 biodegradable yarns were produced via the false twist texturing method.
The impact of biodegradability on the mechanical properties of flame retardant yarns was examined. A comparison was made between the physical and thermal properties of biodegradable flame retardant polyester yarns and flame retardant polyester yarns . The yarns were used to make woven fabrics and tested for biodegradability. The accelerated biodegradation test was performed according to ”ASTM D5511-18-Standard Test Method for Determining Anaerobic Biodegradation of Plastic Materials Under High-Solids Anaerobic-Digestion Conditions” and the flame retardancy test was performed according to the French M1 standard.
As a result, the potential of polyester yarns with both flame retardant and biodegradable properties in the textile sector has been evaluated. The use of flame retardant biodegradable yarns will be contribution to sustainability.

Keywords: polyester yarn, biodegradable, flame retardant, multifunctionality, sustainability.

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Determination of reliability indicators of thread connections of textile bands for manufacturing of modular system

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Analysis of the range of existing types of military equipment proved the relevance of using modular systems for the purpose of placing and adjusting them on mobile equipment. Reasonable choice of textile bands with high indicators of strength and types of seams for their connection is appropriate. It has been established that belt bands and thread connections during their operation are negatively affected by stretching, contamination, multiple bending, abrasion, tearing, ripping, the effect of light and weather, moisture, etc., as a result of which the values of their quality indicators gradually decrease. Improvement of modular systems is carried out by using modern bands and appropriate types of seams made of multifilament threads. Based on the analysis of the assortment of modern textile wear-resistant bands presented on the market of Ukraine, samples of polyester and polyamide fibers were selected for further research. In accordance with the operating conditions, significant physical loads affect textile bands when they are caught during movement by objects in the surrounding environment. The expediency of conducting experimental studies to determine the reliability indicators of thread connections of textile bands is substantiated. The operating conditions of modular systems are simulated in the laboratory. Experimental studies to determine the breaking load were carried out in an accredited analytical and research testing laboratory according to a known methodology in accordance with current regulatory documents. The results of tests of samples of the modular system are presented, taking into account different types of seams connecting the layers. The obtained data was processed by methods of mathematical statistics and graphs of the dependence of elongation on the load of samples of textile tapes were constructed.

Keywords: experimental studies, reliability, belt braids, moving machinery, thread connections

*Speaker

A new evaluation method of measuring the stab depth of stab resistant textiles

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A main problem of materials, which are currently used for stab resistant applications, is the missing friction interaction between the yarns, why a knife can penetrate theses fabrics easily. To guarantee the safety of the wearer, many layers have to be combined which leads to a high weight of the safety vests and consequently a lower comfort for the wearer. To improve such body armour panels, several stab measurements have to be done and analysed. In this context, the boundaries of the method are shown. Normally just the stab depth of these measurements is determined, but for example the impact energy, which is absorbed by a trauma, isn't taken into account. Standard stab resistance tests are carried out on body armour panels according to the German Test Standard with a standard knife which falls from a specific height, depending on the required energy level. Therefore it is driven by a defined weight onto the test sample, which is lying on a box with ballistic plasticine. Test samples out of several aramid layers, like they are used in practice, are tested. The penetration depth in the plasticine is measured after removing the plasticine on one side of the penetration channel. The deformation depth is determined by measuring the deepest point of the stab impact, where the trauma impact isn't taken into account. This means that the hole, which is caused by the stab test, has to be dug out carefully and the exposed hole has to be measured using a ruler. In practice, this measurement method is, however, quite difficult to implement and lead to frequent discarding of the stab. When digging, it may happen that the stab hole is touched and so falsifying the measuring result or becomes unusable. While three samples should be measured according to the standard and to ensure reproducible and meaningful results, it becomes quite difficult and expensive to get enough test material in case of the discard of many measurement results. Therefore a new method to determine the stab depth was developed, which allows the analysis of the depth of the knife during the impact and additional to this, the trauma volume and depth of the impact. Also the deformed fabric layer is fixed stable for further measurement or the comparison with simulation results.

Keywords: stab resistance, stab depth measurement, body armour panel, trauma

*Speaker

Ballistic and stabbing performance of female body armour

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Ballistic protection materials made from 3D warp interlock fabrics (3DWIFs) could be used for both ballistic and stabbing performance. Several previous studies have demonstrated the effectiveness of 3DWIFs with para-aramid yarns for ballistic performance and 3DWIFS with high modulus polyethylene yarns and with para-aramid yarns (4) for stabbing performance. However, the two dynamic events (ballistic and stabbing) imply different material behaviour of the 3DWIFS due to the different penetrator geometries and impact velocities. Considering the 3D WIF made with para-aramid yarns, the (0,90°) of ply orientations of the final structure has revealed better performance for ballistic impact and the (0°) of ply orientations of the final structure for the stabbing performance. By the same, the material response of the 3D WIF made with para-aramid yarns subjected to ballistic and stabbing impact have been totally different according to its initial state: flat or deformed.

The objective of this paper aims at defining the material behaviour of 3D WIFs submitted to different impact events and then provide a clear description of the different energy absorption contribution. Thanks to this comparison of material behaviour during dynamic event, some product parameters linked to the definition of the 3D WIF can be highlighted.

Keywords: impact protection, ballistic and stabbing impact, 3D fabrics

*Speaker

Effect of the Number of Layers on the Tensile Properties of Sandwich-Structured Fiber Composite Dilatant Compound

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We focused on developing a "dilatant compound," a viscoelastic-plastic material that exhibits dilatancy-where viscosity increases with increasing shear rate. By integrating fibers into this compound, we created a "fiber composite dilatant compound," which enhances dilatancy through shear interactions between fibers and the dilatant compound. This composite material is flexible during slow deformation and highly rigid during rapid deformation. However, its practical applications are limited because the dilatant compound does not revert to its original shape after deformation due to plastic deformation and has adhesive properties on its surface. In this study, we fabricated a "sandwich-structured fiber composite dilatant compound" by layering the dilatant compound within an anisotropic stretch-woven fabric. The elastic force of the stretch-woven fabric allows the material to return to its original shape after deformation, thus addressing plastic deformation. Moreover, since the surface is composed of stretch-woven fabric, the problem of surface adhesion is eliminated. Tensile tests were conducted on the sandwich-structured composite material to evaluate its mechanical properties. Specifically, we examined the increase in the tensile load relative to the tensile speed and investigated the effects of varying the number of dilatant compound layers on the material's tensile properties. The results indicate that both the tensile speed and the number of layers significantly influence the tensile behavior of the composite. These findings provide valuable insights into optimizing the structure and composition of fiber composite dilatant compounds to enhance their performance in practical applications.

Keywords: dilatancy, stretch woven fabric, fiber composite material, tensile test

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Computationally optimized multilayer fabric system toward improved thermal performance

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Thermoregulation is a crucial aspect of functional textiles where thermal resistance plays a major role in heating the body's clothing microclimate. That mostly depends on the air gaps, fabric properties and alignment, and the environment, thus regulating comfort. Therefore in the current study, a skin-multilayer clothing-environment system was designed to propose a heat transfer model. The model considers the thermal interaction among human skin, air gap, a three-layer fabric system, and cold environments, allowing heat conservation analysis. The skin is a heat source while conduction, convection, and radiation were considered as the mechanism of heat transfer. Based on the model, a system was suggested indicating optimized heat conservation in the microclimate of the body-clothing system to ensure better thermal performance in cold weather. The results indicate that the thermal resistance of the multilayer fabric was of great importance to skin temperature consistency. The airgap thickness of the body-clothing microenvironment and between fabric layers act as enhancing parameters for thermal resistance. Based on this analysis, an optimized skin-multilayer clothing-environment system was developed, where thermal insulation of the fabric itself and airgap play a crucial parameter. Thus a design for optimizing the thermal resistance of clothing is proposed, which can solve issues in human thermal comfort and energy efficiency.

Keywords: computation, modeling, thermal resistance, heat transfer.

*Speaker

Optimization of Different Filter Fabrics and Designs on Energy Efficiency and Microfiber Retention Capacities in Heat Pump Tumble Dryers

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Heat pump tumble dryers are devices known for their low energy consumption and garment protection. The heat pump system heats the air, circulates it through the drum, and cools the moist air to condense it into water. Tumble dryers use a lint filter to remove microfibers from the airflow. However, due to the limited filtration capacity and efficiency of lint filters, microfibers are released into both terrestrial and aquatic ecosystems. In addition to their inefficiency in retaining microfibers, lint filters in heat pump tumble dryers also affect airflow, reducing energy efficiency. To address these disadvantages, there is a need for lint filters in tumble dryers that are more effective at retaining microfibers while minimizing impact on airflow. This study aims to modify both the filter fabric and the design of lint filters used in heat pump tumble dryers. The specifications of alternative filter fabrics and their impact on the airflow in dryers were evaluated as potential replacements for the current filter fabrics. Based on these findings, the optimal filter fabric specifications were identified, and structural design modifications were made to the filters. Experiments conducted with the newly designed filter showed a reduction in airflow obstruction within the tumble dryer. Consequently, the use of this newly designed filter improved the energy efficiency of the tumble dryers.

Keywords: heat pump tumble dryer, lint filter, microfiber retention, airflow optimization, energy efficiency

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Advanced Microplastic Fiber-Capturing Woven Filters for Domestic Laundry Machines

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Microplastic pollution represents a growing threat to global ecosystems and human health. Among its sources, synthetic textile fibers released during domestic laundering stand out as a significant contributor. These fibers, commonly referred to as microplastic fibers, originate from materials such as polyester and polyamide and are discharged into wastewater during washing cycles. As these pollutants evade standard treatment systems, they enter aquatic environments, where they persist and accumulate, disrupting ecosystems and posing long-term risks to marine biodiversity and the food chain.

This study addresses this issue by focusing on the development of advanced filtration systems integrated into domestic washing machines to capture microplastic fibers directly at their source. Existing filtration technologies often lack the capacity to efficiently retain these pollutants, necessitating more innovative and effective solutions. In this research, four novel filter prototypes with varying weave structures (plain, twill) and densities (33x33, 33x17) were designed and evaluated. Unlike external filters, these systems are embedded components of washing machines, designed to enhance microfiber retention without compromising washing performance.

The filtration efficiency of the prototypes was assessed through controlled testing in both air and water environments. The results demonstrated that structural parameters such as weave design and density play a critical role in determining microplastic fiber capture efficiency. Filters with optimized configurations exhibited superior performance, effectively reducing microplastic fiber emissions at the point of generation. These findings underscore the potential for integrated filtration systems to significantly mitigate the environmental impact of domestic laundering and the outcomes offer a scalable and sustainable solution for reducing microplastic fiber pollution, paving the way for more environmentally responsible household technologies.

Keywords: microplastic pollution, microplastic fiber retention, domestic laundry, sustainable filtration systems

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Hybridity of Non-Woven, Polystrene Plastics and Cellulosic Based Packaging and Comparison of Their Performances

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Packaging of a product has an important place in reaching the end user.In addition, with the increasing population and consumption, packaging is becoming a sector where the concepts of sustainability and recycling gain importance every single day. Moreover, many countries are working to make their waste management more environmentally by detailing their current packaging content regulations.In terms of reducing the use of plastic, serious bans have begun to be imposed on polystyrene group plastics in particular.This study seeks an answer to the question of whether non-woven plastozoid (LDPE-4) and EPS (PS-6) raw materials based packaging design, molded cellulosic raw material (PAP21) based packaging design, honeycomb (PAP21) based packaging design, including PS6, LDPE4, PAP20, PAP21 raw materials, are sustainable by using them in the packaging of cooking devices. Especially, built in hobs products can be exposed to many difficult conditions in the field. According to packaging test standards, stacking tests using a static load (ISO 2234), vertical impact test by dropping (ISO 2248), compression and stacking tests using a compression tester (ISO 12048), vibration tests at fixed low frequency (ISO 2247), horizontal impact tests (ISO 2244), conditioning for testing (ISO 2233), different designs were evaluated.Non-woven plastozoid (LDPE-4) and EPS (PS-6) raw materials based packaging design, molded cellulosic raw material (PAP21) based packaging design, honeycomb (PAP21) based packaging design have significant positive and negative sides. Resilience, maximum deviation, drop heights, impact surface, vibration effects, water condensation, cost effect, container loadings, cosmetic damage to the product etc. on the designs have been carried out and the results have been analyzed.

Keywords: technical textiles, nonwpcems, packaging textiles, moulded cellulosic fiber, honeycomb, plastozoid, expandable polystyrene

*Speaker

Influence of selected additives on the biodegradation rate of polylactic acid films and their composites

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The excessive reliance on materials derived from petrochemicals has created an urgent need to reduce their use due to their harmful effects on the ecosystem. Recently, the scientific community, has been doing extensive research on ecological preservation, waste reduction, and use of different biodegradable materials as an alternative to petroleum products. This research aims to investigate the influence of various additives and their combinations on the degradation of polylactic acid (PLA) films and their composites reinforced with ramie fibers. The PLA and its blends, integrated with an impact modifier (lotader AX8900), plasticizers (triethyl citrate TEC and polyethylene glycol PEG), and their composites, were subjected to biodegradation in a soil environment. To quantitatively assess the degradation, the samples underwent testing for mechanical properties, morphological traits, thermal characteristics, and alterations in chemical structure via Fourier transform infrared spectrophotometry. In the case of pure PLA films, a 22.5% reduction in strength was noted, along with a 33% increase in elongation, whereas for PLA blends incorporating lotader and lotader/TEC, the tensile strength diminished by 66% and 37%, respectively, while elongation decreased by 98% and 94%. A notable decline in tensile strength of the composites was recorded during the initial 20 days of soil burial, followed by a more gradual decrease until the 60-day mark. It was observed that the additives, namely lotader, PEG, and TEC, accelerated the degradation rate of PLA, leading to a tensile strength deterioration of up to 66% in the case of PLA-lotader films. For ramie-PLA composites, the initial decline in tensile strength was more pronounced within the first 20 days, although it subsequently diminished. The findings indicate that the incorporation of additives within PLA and its composites can contribute to rendering the material more environmentally friendly by enhancing the degradation rate, thereby presenting a viable alternative to conventional materials.

Keywords: polylactic acid, composites, biodegradation

*Speaker

Behaviour of textile materials at vibrations

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The damage to the human body caused by exposure to various sources of vibration depends largely on the intensity of the vibrations generated by the tools used, the daily duration of exposure and the protective equipment used. Textile materials, especially spacer fabrics, confirm their performance characteristics and high potential as a substitute for the commonly used polyurethane foams, as a protective material against health problems resulting from vibration transmission. Different materials used for protection differ in stiffness, natural frequency and damping properties to achieve different vibration isolation characteristics. In addition to protection properties, materials must provide good comfort, thermal conductivity, air permeability, moisture wicking and flexibility. To analyze the ability of a system to protect against vibrations, its natural frequencies must be measured to avoid the possibility of resonance during operation. The magnitude of the natural frequency for each material provides information about its stiffness. The higher the natural frequency, the more stiffness can be expected. The shape of the frequency curves indicates how well the sample dampens the vibrations, the smoother the curve, the higher the damping capacity of the material. The studies carried out by the authors have confirmed that knitted fabrics can serve as vibration isolators to protect people and offer greater comfort compared to the alternative materials used to date. Conversely, the same materials can also be used as transmitters, i.e. for medical applications, if necessary, by allowing the vibrations to pass through, and massage the body. To evaluate this possibility, the vibration transmissibility of the materials was experimentally measured to assess the internal damping and stiffness for spacer-knitted materials using a single-degree-of-freedom system, and the results showed that yarn nature mainly influences this characteristic. This article summarizes the key aspects of vibration theory, the methods used for vibration measurement and the performance of the materials tested.

Keywords: vibrations, natural frequencies, transmissibility, knitted materials.

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Role of thermal insulation in protective clothing on heat strain in firefighters

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According to the US Fire Administration, only 4% of emergency calls to fire departments in 2020 were related to live fires, and 64% of calls were associated with a wide range of non-fire scenarios, including mass shootings, medical emergencies, hazardous materials, search and rescue operations, and civil unrest. Between 2019 and 2024, 122 incidents occurred in the USA where firefighters were shot and killed while responding to non-fire scenarios. After firefighters became targets of violence, fire departments requested funds to make ballistic vests standard personal protective equipment. Research studies indicate the potential harmful impact on firefighter heat strain when adding additional layers and thickness to the turnout gear. Wearing ballistic vests with turnout gear, therefore, may increase the risk of heat strain to the firefighters. While each layer in a firefighters' PPE system contributes in a different way to the overall level of protection, all layers also increase the risk of heat strain due to increased thermal insulation. Heat strain is the total reactions of the body when it is exposed to a high-temperature environment that can cause hyperthermia, heat stroke, dehydration, etc. Therefore, the firefighter turnout gear contributes to a significant amount of heat strain during their occupational tasks as ballistic vests are multilayered and non-breathable, impeding proper ventilation of the metabolic heat and sweat through the fabric to the environment. Therefore, the research outlined an empirical approach to quantify heat strain by assessing the thermal insulation of six firefighting clothing combinations emphasizing how ballistic vests affect heat transfer in the torso area. Results demonstrated that a substantial increase in thermal insulation occurred when ballistic vest was added to the firefighting gear. This study also investigated the comparative analysis of the tested ensembles to emphasize the need for optimized solutions to balance safety and heat strain mitigation for firefighters.

Keywords: firefighter, ballistic vest, turnout gear, thermal insulation, heat strain.

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9- Composites and Membranes

Sustainable composites from banana plant waste

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In view of the growing concern about global pollution, sustainable composites made from food waste products are emerging as a key direction for the development of new materials. Banana plants are cultivated primarily for fruit production, and after the fruits are harvested, the plants become waste. However, banana plants contain a significant amount of fiber, which can be used for industrial applications. While banana fibers are not of sufficient quality for clothing manufacturing, they can be useful for technical applications, such as composites. In this work, several types of banana fibers were used for composite reinforcement, sourced from different parts of the banana plant: outer bark, middle bark, inner bark, and midrib. It was found that fibers from different parts of the banana plant exhibit distinct properties, and the mechanical properties of composites made from these fibers also varied. Two types of polymer matrices-bio-based epoxy resin and unsaturated polyester resin-were used for composite manufacturing. Various surface treatments were applied at different stages of material development to enhance the properties of the nonwovens and composites. These included alkali treatment to improve the mechanical properties of the fibers, water-repellent treatment to enhance the hydrophobicity of the nonwoven surfaces, and gamma radiation to further improve the mechanical properties of the composite. The results showed that composites made from outer bark banana fibers exhibited superior mechanical properties and water absorbency compared to others. Additionally, the epoxy-based composites demonstrated significantly higher mechanical properties and hydrophobicity compared to polyester-based composites. The developed composites have potential applications in various technical fields, such as packaging materials, construction panels, and more.
Acknowledgment: This work supported by Research Council of Lithuania, project S-MIP-24-103 "Development of Sustainable Nanocomposites from Banana Fiber Reinforced Biopolymers Enriched with Bio-Nanoparticles Derived from Natural Wastes".

Keywords: banana plant wastes, sustainable composites

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Analytical approach for an eddy current testing system with depth-resolution for the non-destructive testing of carbon fiber structures

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Carbon fiber reinforced composites possess excellent mechanical properties such as high stiffness and strength in relation to their weight. However, their anisotropic nature and the multi-step production process consisting of textile manufacturing, preforming and matrix material injection lead to several defect sources. Non-destructive testing can decrease the amount of waste and simultaneously provide feedback to optimize process parameters. One of the technologies that are frequently employed is eddy current testing (ECT) because it can evaluate both textile preforms and infiltrated composites. However, current ECT cannot provide reliable information on the depth of defects and thus the affected reinforcement layer cannot be determined. Multi-frequency ECT in theory allows to generate depth-dependent signals but currently there is lack of evaluation methods to process these signals. Here we propose and validate a method based on an analytical approach to reach a depth-resolved image of the sample. To leverage the frequency-dependent penetration depth, an ECT device, which acquires signals at 30 different frequencies is used. Several carbon fiber reinforcement configurations with different defect sizes and orientations are setup and measured. The validation is carried out on carbon fiber textile stacks of a thickness of up to 1.4mm.

Keywords: fiber, reinforced composites, non, crimp fabrics, non, destructive testing, eddy current testing

*Speaker

Optimization of the interaction between SMA-actuator and fiber composite through braiding technology

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Soft robotics is a growing field of interest, with solid-state joints being a key functional element. To create these joints on a textile basis, shape memory alloy (SMA) wires can be integrated into fiber-reinforced composites. For optimal performance, the actuator needs two zones: a force introduction area and a segment with high flexibility. In the case of SMA wires, the interface with the composite matrix is crucial. This interface can be tailored in various ways, such as coating the wire or using textile techniques like braiding. Varying the braiding density allows the sheath to be adjusted for different zones. Low-density braiding forms a porous sheath that bonds well with the matrix, creating a strong force introduction zone. High-density braiding forms a tubular sheath, isolating the actuator from the matrix and allowing free contraction. By combining these methods, a sheath with a property gradient can be created, improving the actuator's interaction with the composite.

An alternative method is friction spinning, where the wire is wrapped with loose staple fibers, which can be compared to braided structures.

Tensile tests are used to evaluate the performance of these constructions. Wire segments with the sheath are embedded in an epoxy block, and in a quasi-static pull-out test, shear stress at the interface and friction forces during extraction are measured. The data helps identify suitable braiding parameters for different functional zones, and allows comparison between textile manufacturing methods. With a braided sheath featuring a property gradient, the actuator potential of SMA wires is enhanced, allowing for greater displacements.

Keywords: soft robotics, composite, shape memory alloy, braiding, friction spinning, actuator

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Enhancing Asphalt Pavement Durability: Experimental and Simulation-Based Development of Textile-Reinforced Asphalt Base Layers

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The increasing axle loads from heavy traffic and rising temperatures due to climate change are placing immense stress on the asphalt base layers of roads, often preventing them from reaching their intended 30-year lifespan. Current construction techniques and empirical design methods are proving insufficient, resulting in premature damage and costly repairs. This study explores the development of textile-reinforced asphalt base layers using a combination of experimental testing and simulation-based approaches, with the aim of improving the durability of asphalt pavements through the integration of high-strength tensile reinforcements.
In contrast to conventional low-strength textile inserts, this research focuses on enhancing the mechanical resilience of the entire asphalt base layer. The approach targets crack prevention in the lower tensile zone by introducing advanced textile reinforcement structures made from profiled carbon rovings. These structures are specifically engineered for immediate absorption of high tensile forces via mechanical bonding and their superior tensile strength. The proposed reinforcement technologies have the potential to double the service life of asphalt pavements without increasing layer thickness, promoting more durable, sustainable infrastructure while significantly reducing maintenance costs.
This paper will present key findings from experimental and simulation results, alongside novel production methods for the textile-reinforced asphalt base layers.

Keywords: textile reinforcement, asphalt pavement durability, simulation, based design, carbon rovings, infrastructure sustainability

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Wool fibers for the composite reinforcements

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Natural fiber-reinforced composites (NFRCs) have gained significant attention for their array of advantages, including biodegradability, low density, and cost-effectiveness compared to synthetic fiber-reinforced composites. The surge in interest is driven by a global shift towards sustainability and eco-conscious practices across various industries. However, the flammability of natural fiber-reinforced composites is a major challenge that needs to be addressed. Wool fiber, known for its natural flame-retardant and self-extinguishing properties, has been widely used in the textile industry to produce apparel, but its use in composite production has been limited. In Europe, approximately 75% of the wool produced by sheep farms is also unsuitable for use in the textile industry. This wool is classified as special waste and requires sterilization before it can be disposed of. Each year, around 150 million tons of this unused wool is generated, and this amount increases when adding wool from other end-of-life products, such as carpets, as well as waste from the textile industry. This study explores the feasibility of using wool fibers for composite reinforcement, primarily for applications where fire resistance is required. In this work, wool woven fabric was used as preforms, and a bio-based resin was applied through resin infusion techniques to produce the composites. The prepared composite samples were subjected to experimental investigations of thermal insulation, tensile, interlaminar shear, and three-point bending. The results obtained from the experimental investigations indicate that wool fiber has promising potential as a reinforcement material in composite applications, mostly where thermal insulation is critical.

Keywords: wool, thermal insulation, composite, sustainability, natural fiber

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Pipe Nodes for media transport - Weave technology for the integral manufacturing of thick-walled pipe nodes for media transport

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Pipe nodes used to transport various gaseous and liquid media are conventionally manufactured using welded steel, concrete or as fibre composite components through filament winding or centrifugal casting processes. Main areas of use of fibre composite pipe nodes are plant constructions, especially chemical plant constructions, air conditioning systems as well as in the vehicle and aviation sector because of their exceptional media resistance and mechanical performance while structurally being extremely light weight.
A disadvantage of fibre composite pipe nodes manufactured by winding or centrifugal casting processes other than a low internal pressure resistance is the disproportionate use of the reinforcement and matrix material (oversizing of material). Significant improvements to the faced challenges were made by 3D-weaving the reinforcement element. Due to technical limitations of the shuttle weaving machine and challenging binding patterns media transport using woven and subsequently infiltrated composite pipe nodes is not possible.
An innovative approach to produce 3D-woven pipe nodes for media transport involves the modification of a weaving machine to implement an otherwise impossible orientation of warp threads. This new way of pipe node manufacturing combines multiple advantages of the previously mentioned manufacturing methods and allows the production of pipe nodes with subsequent consolidation that provide evenly distributed fibre reinforcement, optimized matrix input and a minimal internal pressure resistance of 100 bar as well as a high structural stability.
This research includes the machine modification to allow a specific warp yarn arrangement, the binding pattern development by transformation of a 3D-model to a multilayer 2D binding pattern, the production of the pipe nodes as well as the simulation of the internal pressure resistance.

Keywords: pipe nodes, composite, carbon fiber, glass fiber, 3D, Weaving, weaving machine modification, nodal structure, integral, media transport

*Speaker

Conductive nonwoven fabric reinforced cement composite

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In winter, the low temperature and ice accumulation on pavements can not only affect the structure of cement but also people's lives. However, the traditional methods for removing ice and snow can lead to damages on the pavement and are not enough efficient. By converting electrical energy into heat, electrically conductive cement composite (ECCC) can solve these problems. In most ECCC conductive fibers or particles randomly dispersed in the cement are used. Relying on the contact between conductive materials, the conductive network can be formed so that the cement can gain conductivity. However, the distribution of conductive networks is uncertain, and mechanical properties may be affected if involved high volume of conductive fibers or particles. In this study, an ECCC with a single layer of conductive nonwoven fabric made of 20/80 stainless steel /polyester fibers was used as the conductive component combined with 5 layers of nonconductive nonwoven fabrics made of recycled fibers used as reinforcement material. The electrical, thermal, and mechanical properties were evaluated. Furthermore, the finite element analysis method was employed to simulate the heating performance of ECCC in different environmental conditions.

Keywords: electrically conductive cement composite, ECCC, nonwovens, stainless steel fibres, recycled fibres, self heating

*Speaker

Locally deformable Multi-Matrix 3D Composites from TPU

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An innovative approach for new, functional fiber-reinforced composites is the development of thermoplastic multi-matrix preforms for the production of complex-shaped composite components. These multi-matrix composites (MMC) demonstrate significant potential for applications in soft robotics, medical devices, and aerospace engineering, which profit from seamlessly integrated joint functionalities. A key focus for their production is the development of different types of hybrid yarns, enabling the integration of stiff and elastic matrices within one composite component. Elastic zones are achieved locally incorporating hybrid yarns made of glass and thermoplastic polyurethane (TPU) filaments, while a hybrid yarn made of glass and stiff thermoplastic polymer (for example polypropylene) filaments form the stiff part. The advantages of the thermoplastic MMC approach include tailored deformation mechanics, and versatile processing for textile-based reinforcements as well as recyclability and shorter consolidation times compared to traditional (multi matrix) composites. This research emphasizes the integration of hybrid yarns into complex geometries using advanced textile techniques such as Tailored Fiber Placement and 3D knitting, enabling localized control over stiffness and flexibility. Numerical analysis and experimental testing further validate the mechanical performance and structural integrity of these composites in practical applications.
Special attention is given to the use of thermoplastic elastomers for sustainable and adaptive composite solutions, highlighting their potential to transform the design and functionality of fiber-reinforced materials in technical and biomedical fields.

Keywords: multi, matrix composites, TPU, glass fiber, hybrid yarn

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Micromechanical Testing on Single Fiber Model Systems

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Power transformers and switchgears are key components high-performance composites used in power grids. Their availability and robustness have a decisive influence on the reliability and profitability especially for the future expansion of power grids. Their mechanical but also dielectric composite strength is strongly determined by the fiber-matrix interphase as the origin of micro-scale damage. To improve the dielectric and mechanical performance of these glass fiber (GF)/epoxy (EP) composites, it is critical to achieve a strong bond between the fiber and the matrix. The most commonly used technique is to modify the interphase is the application of sizings on the fiber surface. Sizings consist mainly of aqueous polymer dispersions, silane coupling agents, lubricants and other additives. By choosing an appropriate sizing formulation, better mechanical properties of the composite can be achieved with high levels of stress transfer. This study focused on a fundamental investigation using model sizing formulations designed for composites with enhanced dielectric strength. Fibers with different diameters (9, 17 and 24 μm) were produced at the IPF on a continuous pilot spinning line. The fibers were treated with different epoxy compatible film formers with (i) different glass transition temperatures Tg, (ii) different solids contents and (iii) with and without a silane as coupling agent. The increase in sizing content was associated with an increase in fiber surface area. This tendency was not observed for formulations without silane. Single fiber tensile strength results indicated a healing effect of the silane on the fiber surface. The fiber-matrix interaction was evaluated using the single fiber pull-out (SFPO) micromechanical test. Fibers with different diameters were used to investigate the influence of the embedded fiber area on the success of the fiber pull-out test. Finally, the surface of the pulled-out fiber was evaluated by scanning electron microscopy (SEM).

Keywords: glass fiber reinforced composites, interphase design, sizings

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10- Fashion, Design and aesthetic aspects of clothing

The Influence of Acquisition Goals for Garment Industry Products on Meeting the Unique Needs of Customers

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The innovative development of global industrial production and e-commerce systems for garment industry products has contributed to changes in consumer purchasing intentions. This shift demands the development of technologies that predict consumer choice trends to meet these evolving needs. The aim of this study is to identify the most significant factors influencing the selection of garment industry products by consumers under modern conditions. The article presents the results of a statistical study on the relationships between the goals of acquiring garment industry products and production, marketing, and personalization factors. An assessment of the significance of these factors was conducted, taking into account the reasons for purchases (daily needs, special occasions, vacations, sports, purchases for family members), as well as the gender and age of the consumers. To identify the features of personal identification and consumer intentions regarding garment industry products, a survey of 1,114 Russian respondents from 89 regions of the Russian Federation was conducted. Contingency tables were constructed for the data, and regression analysis was used to assess the significance of the results. Statistical data processing was conducted using SPSS Statistics software, along with Python, Pandas, Numpy, and Scipy libraries. The reliability level of the results obtained was 95%. During the processing of the experimental data, respondents' answers were categorized by purchase goals as follows: 27.3% for daily needs, 21.4% for special occasions, 19.5% for family members, 16.6% for vacations, 12.6% for sports, and 2.6% for other reasons. The results of the study revealed a significant relationship between the goals of purchasing garments and several socio-demographic factors, the most important of which turned out to be the price category of goods. Data showing the relationship between consumption motives and how respondents perceive their future in terms of social activity hold scientific and practical interest. Significant correlations were found between the reasons for acquiring garment industry products and the unique characteristics of the consumer's personality. The study revealed significant correlations of data between the reasons for purchasing clothing, footwear and accessories and the characteristics of the unique personality of the consumer, taking into account their gender, age and psychological characteristics, appearance, and features of social and work activity. Predicting consumer preferences is crucial for creating an innovative production system for apparel industry companies. This serves as the foundation for intelligent digital product design that fully meets the requirements of each individual client.

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Keywords: consumption goals, digital design, garment and footwear industry products, unique consumer qualities

Investigation of clothing requirements for individuals with war-related injuries

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Individuals with war-related injuries often face significant challenges due to changes in body geometry, increased skin sensitivity, or limitations in self-care due to amputations or other physical impairments. In addition, the use of adapted medical devices such as prostheses, orthoses and wound dressings becomes a routine part of their daily lives. This study investigates the specific clothing needs of these individuals with the aim of improving comfort, functionality and ease of use. Data was systematically collected and categorised through structured interviews with individuals who had sustained a range of war-related injuries. The analysis focused on key aspects such as changes in body geometry, the design and placement of openings in garments, ways of dressing and undressing, and issues related to sensory sensitivity, including reactions to different fabrics and garment structures. By addressing these unique needs, the study aims to significantly improve the quality of life for individuals with war-related injuries, enabling them to regain confidence and participate more actively in social and professional environments. Ultimately, this research highlights the importance of inclusive design in clothing and advocates for a more considerate, empathetic and supportive approach to developing garments for people with specific medical and physical needs. The findings provide valuable insights for designers, manufacturers and healthcare providers working to create adaptive clothing that meets these complex and diverse needs.

Keywords: war, related injuries, clothing requirements

*Speaker

Image-to-Text and Text-to-Image Generation: Artificial Intelligence in Clothing Design

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Fashion is a creative design industry encompassing clothing, footwear, and accessories, characterised by exploration and the pursuit of innovation. The design process involves multiple stages, from inspiration to production, and a designer's success depends not only on technical skills but also on the ability to develop creative solutions to uncertainties regarding customer expectations. Currently, digital technologies that predict trends and customer expectations play a significant role in design. Artificial intelligence (AI) based digital technologies have been instrumental in fostering innovative ideas in fashion industry. AI applications such as machine learning and computer vision have brought transformative changes to fashion design. However, apart from efforts to create databases for image generation of original fashion products, there is insufficient research in this area, which represents a significant gap. Previous AI applications were generally limited to data analysis and trend forecasting. With advancements in machine learning and deep learning, particularly Generative Adversarial Networks and Natural Language Processing, designers can now able to process visual and text-based data to create original designs. These technologies have revolutionised clothing design. However, there are doubts about the extent to which AI technologies capture the compositional structure of human language. Some researchers have identified limitations of OpenAI's DALL-E 2 regarding composition, common sense, and relational understanding. Moreover, it has been observed that image generators do not always consistently deliver visuals of high quality. Recent advancements in AI, particularly with tools like ChatGPT and DALL-E, suggest that these technologies could bring substantial changes to the way fashion design processes are carried out. ChatGPT stands out for its ability to produce creative and contextually meaningful text, while DALL-E translates abstract design ideas into visual representations. This research aimed to investigate how ChatGPT's "Image to text generation" and DALL-E's "Text to image generation" capabilities contribute to these stages of the fashion design process. A qualitative research method was employed in this study, utilizing content analysis and experimental methods based on data obtained from secondary sources. In the application phase, ChatGPT was performed garment analysis and generated prompts from reference fashion images; these prompts were then used by DALL-E to create new fashion visuals. The findings indicate that ChatGPT provided accurate information regarding garment types and details but revealed a need for more information on fabric types and accessories. It was also noted that the prompts prepared for DALL-E needed to be more detailed and specific to improve visual outcomes. The study emphasizes that while ChatGPT and DALL-E offer significant opportunities for

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innovation and sustainability in clohting design, they cannot completely replace human creativity.

Keywords: Artificial Intelligence, Image-to-text generation, Text-to-image generation, Clohting design, ChatGPT, DALL E

Problems and Prospects of Visualization of Clothing Forms in the CLO3D Environment

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The article explores the functional capabilities of CLO3D software, a significant tool in advancing the fashion industry. It addresses challenges in designing women's clothing, focusing on the simulation of 3D body model parameters and virtual sewing materials. The study examines digital body parameters, which are critical for ensuring that clothing visualization in CLO3D aligns with real-world outcomes, and conducts a comparative analysis of these parameters with various dimensional typologies. The research revealed that CLO3D's 3D figure models include dimensional markers that both align with and differ from Russian and European standards. Significant discrepancies were noted in dimensional parameters, even with similar measurement methods. The analysis examined interdimensional parameters across varying heights and body fullness. Since these differences affect clothing fit, a women's skirt was chosen to evaluate the conformity of the design to the virtual garment. A conical skirt was developed, adapting 3D figure model parameters below the waistline to a typical mannequin size. Virtual skirt models were analyzed based on silhouette angles, transverse diameters, and skirt widths. The impact of fabric density and thickness on the skirt's shape, particularly in cotton fabrics, was studied.Comparative analysis between real and virtual skirts revealed significant differences, highlighting the need to optimize digital design parameters. Incorporating expert knowledge into CLO3D can align virtual designs with real-world results, accelerating decision-making processes and improving the quality of clothing design.

Keywords: CLO3D, virtual environment, clothing shapes, figure size parameters

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3DP technology and its creative potential in the fashion industry

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The fashion industry is very well known for its rapidly changing trends on the one hand, but also for its unsustainable practices on the other. 3D printing, also known as additive manufacturing technology, once limited to prototyping and industrial applications, has found fertile grounds in fashion industry, revolutionizing the way in which the designers create and produce fashion items. This technology has gained a lot of attention in fashion due to its versatility, precision, and ability to produce complex designs that are difficult or impossible to achieve with traditional manufacturing methods.
3DP (3D printing) technology is opening up new possibilities in material creation, design process and production stages since it has the ability to bring digital fashion designs to life with a remarkable precision.
In this article are explored several creative uses of 3D printing in fashion. Using fused deposition modelling (FDM) 3D printers, are proposed fashion items, namely clothing and accessories. Were utilized different design approaches, two different types of filaments (PLA – polylactic acid and TPU – thermoplastic polyurethane), a combination of 3D printed structures (different models of prints on different types of fabrics) and/or individual printed elements that have the role to embellish existing garments. It was concluded that, with the right material (filament/ fabric) selection, with the appropriate design process (taking accountability of filament properties), 3D printing can offer a technological platform for reaching creative and sustainable potential in fashion industry.

Keywords: 3D printing, sustainability, creativity, fashion industry

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Development of a geometric approach for pattern making women's clothes with kimono sleeves with inserted wedges

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Fashion has repeatedly revived kimono sleeves in various variations, especially when soft, rounded, and voluminous forms of clothing are a trend. A structural feature of this type of sleeve is the merging of the main structural parts—the front and sleeve into one, and the back and sleeve into one piece. In fitted and semi-fitted silhouettes with this type of sleeve, the range of movement of the arm is more limited. Such a restriction of arm movement often disrupts the inner seam of the sleeve in the armpit area. For the sake of body comfort and free movement of the arms, the need arises to change the construction of the kimono sleeve by inserting an additional piece, a wedge, in the underarm area. It is interesting to note that such wedges are also observed in outerwear designs, in which freedom in the upper part and in the sleeve is structurally provided. From this fact, it should be concluded that the inserted gussets in the sleeves have not only a functional role but also a decorative design solution.

The presented investigation examines the design and constructional features of kimono sleeves with inserted gussets in the underarm area of women's garments. An analysis of commonly used gusset shapes in different types of pattern designs is made. On the basis of analysis, a geometric approach for pattern making of women's clothes with kimono sleeves with two-piece structured wedges is developed.

The developed geometric approach ensures an aesthetic appearance of the garment and freedom of arm movement through the curvilinear contours of the gussets of the front and back. Aesthetics are also a result of the integrity of the shape without unnecessary elements and elegance achieved only by the silhouette of the garment. Another benefit of the kimono sleeves with wedges is the minimizing of cutting waste in comparison with other types of kimono sleeves.

Keywords: pattern making, kimono sleeves, wedges, minimizing waste

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11- Comfort evaluation and sense evaluation

Moisture absorption and transfer in hydrophilic/ hydrophobic textile composite

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The comfort properties of textiles are mainly determined by air permeability, water absorption and moisture transfer through the textiles. With increased body sweating, it is especially important that excess moisture is quickly absorbed, but not transferred to the outer layers of clothing. In this work, ten variants of hydrophilic cellulose-based knitted fabrics and two variants of hydrophobic synthetic woven fabrics of different structures, raw materials and surface densities were made. Knits of pure cotton yarns, and combinations of cotton and viscose yarns with modal, elastane, polyester and polyamide yarns were investigated. The knitted fabrics were knitted in single jersey, single plated, Milano rib, tuck-stitch and fleece patterns; the woven fabrics were woven in plain weave. Physical properties such as dynamic and static water absorption and drying speed were determined for the materials tested. The ability of the material to absorb moisture is an essential feature that determines comfort. The dynamics of moisture absorption are fundamental, i.e., how quickly moisture is absorbed and how widely the moisture stain spreads across the surface of the materials. Analysis of the static and dynamic water absorption of ten cellulose-based hydrophilic knitted fabrics and two synthetic hydrophobic woven fabrics showed that the best moisture absorption and comfort performance of the textile materials could be achieved by using cellulose-based double-layer knitted structures consisting of a cotton-based fleece knitted structure for the inner layer and fully hydrophobic synthetic dense and thin woven fabrics for the outer layer. In a study of the drying speed of the materials, it was found that fabric knitted in a fleece pattern using combinations of cotton, modal and elastane yarns absorbed the most moisture. Therefore, the best performance of textile materials is achieved when hydrophilic and hydrophobic textile layers are used together.

Keywords: textile, knitted fabric, woven fabric, comfort properties, moisture absorption

*Speaker

Determination of the Effect of Softening Finishing Processes on Comfort Properties of Knitted Fabrics

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The comfort properties of fabrics are influenced by several factors, including fiber structure, yarn production method (such as ring or open-end spinning), fabric structural properties (such as thickness, weight, and stitch density), as well as wet finishing processes like bleaching, dyeing, and softening. Among these, softening has become increasingly significant in textile wet treatments due to its ability to enhance fabric softness, fullness, and elasticity. The tactile quality, or "hand feeling," of fabrics plays a crucial role in the success of textile marketing strategies. For this reason, finishing processes are widely employed in the textile industry to improve the palpation properties of clothing products. According to Tomasino, the primary factor in selecting a softener is the desired fabric hand feeling, and different performance characteristics can be achieved by adjusting the level of softener application.
In this study, the effect of softeners applied at different concentrations on the comfort properties of knitted fabrics was systematically analyzed. The effects of three different types of commercial softeners on the water vapor permeability and thermal conductivity properties of fabrics with different fiber contents and various knit structures were investigated.
The correct determination of parameters such as softener type and application amount are critical for the development of high-quality textile products that meet user expectations. As a result, this study reveals the effects of softening finishing processes on the comfort properties of knitted fabrics. It is thought that the data obtained will contribute to the literature on how the selection and application of appropriate softeners can optimize garment comfort.
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Keywords: comfort, finishing, softener, hand feeling

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Design of technical fabrics based on numerical modelling

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The aim of this study is to design and optimize technical fabrics, particularly for sportswear and industrial applications, using numerical modeling. The research focused specifically on air permeability, a key factor in fabric breathability, which is crucial for enhancing comfort and performance in both athletic and industrial environments.
Building on previous studies in porous media and fabric permeability, certain challenges regarding the accuracy of existing models and their applicability to real-world scenarios remained unresolved. This study employed computational fluid dynamics (CFD) simulations to more effectively analyze and optimize fabric structures. Four types of fabric weaves (Plain Weave, Basket Weave, Filling Rib, and Twill) were analyzed with varying densities. CAD models of these fabrics were created, and CFD simulations were conducted to assess permeability and airflow. Permeability was calculated using Darcy's law, and advanced meshing techniques were employed to simulate laminar flow through the fabrics.
The study resulted in the development of precise models capable of predicting and optimizing air permeability while significantly reducing experimental tests, time and costs. These innovations are expected to improve the design of high-performance fabrics for sportswear and industrial applications.

Keywords: Technical Textiles, Air Permeability, CFD, Optimization

*Speaker

Method for integrative investigation of the Microclimate for Personal Protective Clothing

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The microclimate within personal protective clothing (PPC) is a critical factor influencing wearer comfort, thermal regulation, and physiological safety, particularly in high-demand environments. Despite the importance of these parameters, comprehensive methodologies for assessing PPC microclimate holistically are underdeveloped. This study introduces an integrative, multi-step method designed to thoroughly evaluate the thermal and moisture regulation properties of PPC, emphasizing ergonomic fit and fabric performance under simulated conditions.

The proposed method combines laboratory-based thermal resistance and moisture transfer testing with dynamic, real-time monitoring of microclimate variables, including temperature and humidity. Utilizing a thermal manikin, skin-surface temperature sensors, and airflow analysis tools, we measured the interaction between the body and the PPC microclimate across prototype garments. Results indicate that specific combinations of fabric composition and garment structure features enhance PPC microclimate control by improving airflow, moisture wicking, and reducing heat accumulation. These design adjustments were shown to lower physiological strain on the wearer, reduce sweat retention, and improve comfort by limiting high-pressure contact points. The integrative assessment framework provided by this method enables detailed insights into how PPC materials and designs influence microclimate properties.

This comprehensive approach to microclimate investigation in PPC establishes a foundation for more effective, evidence-based garment design. The method outlined here not only supports PPC manufacturers in enhancing comfort and performance but also offers a replicable framework for future studies aiming to optimize protective clothing for various occupational settings.

Keywords: anthropometrics, human body scanning, ergonomics, microclimate, personal protective clothing

*Speaker

Tactile perception of sheep wool fibers as a function of geometrical and mechanical fiber properties and possible applications of regional wool fibers

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The common perception is that sheep wool fibers with a fiber diameter greater than 22 to 25 μm cause a prickling sensation on the human skin. Therefore, the breeding goal was to reduce the fiber diameter with currently fibers smaller than 18 μm are being called superfine wool fibers. On the contrary, most regional breeds of sheep have a greater fiber diameter and because of that there are mainly held for food supply and landscaping purpose. Since their wool is not further processed it is treated as hazardous waste and needs to be disposed at the owner's cost which makes sheep farming economically more and more challenging. One obvious solution for using the existing fiber resource would be to reduce the fiber diameter. But not every breed of sheep and climatic conditions are suitable to reduce fiber diameter sufficient enough to avoid a prickling sensation.
However, there are studies indicating that there are more key determinants than just the fiber diameter who have an influence on the tactile perception such as fiber structure, curvature, bending properties, yarn and fabric characteristics. Understanding the behavior of regional wool fiber properties under the influence of a changing temperature and humidity and the functioning and perception of the human skin under those conditions is a crucial part in order to extend the common assumption that a prickling sensation depends solely on the fiber diameter. A distinct cause-effect relation between regional wool fibers, its products and the tactile perception of the human skin is key to evaluate areas of application. And not only applications but also the different manufacturing processes from raw wool to a finished fabric are subject to necessary adjustments in order to change the tactile perception of wool fibers other than the superfine ones.
By pointing out possible applications for regional wool fibers the degree of usage of unexploited resources can be increased. A greater usage and acceptance of regional wool fibers can support and help to establish a textile value chain and sustain the genetic pool of the different breeds of sheep which can be found throughout Europe.

Keywords: regional wool, fiber properties, tactile perception

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Sensorial comfort properties of hybrid knitted fabrics for EMR shielding

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The actual topic is the development of textile products with EMI shielding, which ensure the creation of a flexible protective screen for a person. "Classic" textiles do not protect against electromagnetic interference, but they can be successfully transformed into a protective material after changing the composition of raw materials, creating a new production process or adapting technologies that can make it electrically conductive. Basic textile production methods, such as weaving, knitting, non-woven, or a combination thereof, can be used to produce fabric that shields electromagnetic radiation. The main task of this research is the c design and investigation of new hybrid knitted materials with contained stainless steel wire for shielding against EMR with good comfort properties . The stainless steel wire is a conductive element of future materials that has been used separately and together with conventional (cotton) yarn. In this study the knitting on 8 gauge flat-bed machine has been chosen as main technology. The metal wire (stainless steel 0.12 mm) is used separately or together with 30x2 tex cotton yarn. Two sets of samples with different interlooping are produced which are differ by steel percentages and positioning in the structures. This paper deals with the mechanical properties, such as tensile, shearing, compression and surface properties of hybrid knitted fabrics for EMR shielding. Mechanical properties of the fabrics were researched with KES-F Kawabata equipment. These properties are very important in determining the sewing and wearing behaviour of textiles. The obtained results will be discussed in relation to the effect of the presence and location of stainless steel wire in the structure of knitted fabrics on the complex of sensorial comfort properties.

Keywords: sensorial comfort properties, Kawabata Evaluation System, EMR, hybrid knitted fabrics, stainless steel

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An Investigation on Comfort Properties of Needle-Punched Poplar/PLA Blend Nonwovens

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Nonwovens are highly preferred in technical textiles due to their versatility in raw material selection, allowing for tailored performance characteristics and enhanced adaptability to sustainable goals, such as recyclability, biodegradability, and resource-efficient production processes. In this study, nonwoven fabrics were developed using needle-punching technology, utilizing a blend of poplar fibers and polylactic acid (PLA) to explore their comfort properties. For this investigation, key characteristics of thermal conductivity, water vapor permeability and air permeability have been selected. These properties are crucial factors to determine the potential of these nonwovens in applications requiring comfort and sustainability. Needle-punched samples were prepared using a reference fabric composed of 100% pure hollow PLA fibers and a 50:50 blend of poplar and hollow PLA fibers for comparative analysis. Due to its comparatively large hollow lumen as well as eco-friendly nature, poplar fibers offer great potential for improving thermal comfort. Blending poplar fibers with PLA enhances sustainability while opening new avenues for the use of renewable materials in high-performance textile applications. This study makes a significant contribution to the development of environmentally friendly textiles by revealing the potential of poplar fiber in terms of comfort properties.

Keywords: poplar fiber, PLA fiber, hollow, comfort, thermal, needle punched nonwoven

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Wickview – a new test equipment for assessment of moisture and liquid transport in broader scope of textile applications

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The transport of moisture and liquid in fibrous assemblies, like yarns and fabrics, is crucial for thermophysiological comfort in functional textiles, including activewear, protective clothing, and health and hygiene products. Understanding these complex liquid transport processes has involved both standardized and non-standardized testing methods. One key tool, the Moisture Management Tester (MMT), was developed in 2002 to objectively measure moisture spreading and transfer between fabric surfaces. In 2009, the American Association of Textile Chemists and Colorists (AATCC) established Test Method 195, which uses the MMT to assess moisture management properties in textile fabrics. However, this standard primarily addresses clothing comfort by measuring basic moisture spread over time and distance. In applications like patient support systems and incontinence products, moisture behavior differs: patient support systems involve slow application of small liquid quantities, while incontinence products handle larger fluid amounts applied at a rapid rate. These variations require tracking liquid movement in multiple directions. Wickview, a new system equipped with integrated cameras, uniquely captures and records video and images, measuring multidirectional liquid movement through fabrics or fabric layers. This work demonstrates Wickview's capabilities in evaluating applications such as patient support and incontinence products. With its comprehensive parameter measurements and visual tools for studying liquid transport, Wickview broadens the scope of quantitative machine measurements, offering enhanced insight into moisture and liquid dynamics across various textile applications.

Keywords: Wickview, MMT: incontinence, patient support

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Effects of Mid-Layer Friction on Outer Garment Deformation during Arm Movement

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This study investigates the relationship between the type of mid-layer garment and the deformation of an outer garment (jacket), focusing on the impact of the frictional properties of mid-layer fabrics. Three men's shirts with identical patterns were created as mid-layers using fabrics with different frictional properties: SA (plain weave, shirt fabric), SB (satin weave, blouse fabric), and SC (velour fabric with a raised pile). Additionally, a single type of men's jacket (JD: plain weave muslin) was created as the outer garment. The mid-layer and outer garment were dressed on a mannequin, and a single-arm forward raising movement was performed. The maximum principal strain at the shoulder (10 points) and back (17 points) of the jacket was measured using a non-contact optical 3D deformation measurement system (ARAMIS). Measurements were repeated five times for each sample, and average strain differences were analyzed using Tukey's multiple comparison test. The frictional properties between mid-layer and outer garment fabrics were evaluated using a surface friction tester (NT-01, KATO TECH CO., LTD) to measure the mean friction coefficient (MIU) and static friction coefficient (SFC). Results showed significant differences in back deformation, with a trend of SA, SC > SB for maximum principal strain, aligning with the SFC trend (SC > SA > SB). Shoulder deformation showed no significant differences, likely due to the lifting of the jacket. These findings suggest that the frictional properties of mid-layer garments, particularly SFC, play a critical role in determining the deformation of outer garments during movement. This emphasizes the importance of fabric selection for improving garment comfort and performance.

Keywords: outer garment deformation, mid-layer garment, maximum principal strain, static friction coefficient, garment comfort

*Speaker

Evaluation of the air gaps between clothing and body during set of motions using 4D Scanning

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This works presents preliminary results of evaluation of 4D scan data from the MOVE4D Scanner. A human performed series of separated motions with the hands with and without clothing and was scanned with 10Hz frequency for 3 seconds. The scans were processed from point cloud to homologous mesh using the build in software from IBV in the Move4D scanner system. Finally the point cloud with clothing was compared with the mesh and the point cloud from the naked human for selected positions. The difficulty in the comparison is that the human is not able to repeat exactly the same position, but the analysis provide promising results for future comfort related evaluations.

Keywords: 4D Scanning, air gap, clothing

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12- Quality testing, Measuring Technology of textiles and textile products

Towards Efficient Color Quality Control of Textiles for Fashion E-Commerce: Adjustment of Initial Color Design Factors in Digitalized Manufacturing Process

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Currently, digital textile printing (DTP) is being widely used in the fashion industry. However, the issue of color reproduction is prominent in DTP because it entails a complex process compared to conventional dyeing. In DTP, multiple color reproduction media having different color gamuts are employed before color is imparted to the textiles - that is, RGB gamut for the digital space and CMYK gamut for printers, resulting in a large discrepancy between the intended color and the final textile color. Also, as the focus of the fashion market has shifted from offline to online, the mismatch between the color of the textile product observed online and that encountered offline, which occurs due to their different color gamuts, became a plaguing issue. This study quantitatively analyzed the color discrepancies of digitally printed textiles between online and offline, and determined the color factors of the design to reduce these color discrepancies in the early design stage. A total of 192 online and offline textile samples with wide-ranging colors were produced, and the colors of which were measured spectroradiometrically and spectrophotometrically, respectively. It was found that the color reproducibility of textiles significantly decreased when the medium transition from online to offline was made with a lightness discrepancy of 8.45 lΔL*10l, a chroma discrepancy of 24.63 lΔC*ab,10l, and a hue discrepancy of 18.35 lΔhab,10l on average. Meanwhile, the overall color discrepancy between the two types of samples was 28.98 ΔE*ab on average. This overall color discrepancy was visually perceived as 8.76 ΔE*ab by the human eye, which still indicates a large color difference. The low color reproducibility, especially in terms of chroma and overall color, was particularly affected by the C*ab,10 of the initial design. The chroma and overall color reproducibilities decreased with the increment of the C*ab,10 of the initial design.

Keywords: color reproducibility, color reproduction media, color gamut, digital textile printing (DTP), fashion E-commerce

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Simple, Direct and Accurate Measurement of Directional Liquid Transport across Fabric Thickness

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Directional liquid transport property, sometimes also known as 'transplanar wicking', is one of the crucial properties affecting the thermal and moisture management capability of textiles. Although many test methods for this property have been proposed in the past, a simple and direct measurement of wetness on both side of the fabric is still missing. By applying gravimetric analysis, a novel Directional Liquid Transport Fabric Tester (DLTFT) was developed to provide simple, accurate and reproducible measurement of the liquid content on both faces of the fabric after exposed to a defined volume of liquid droplet. Two filter papers were used to absorb liquid moisture from both sides of the wetted fabric under controlled pressure, and a new indicator called normalized transplanar ratio is proposed. The results showed that DLTFT was highly sensitive and reproducible in differentiating different fabrics and liquid transport properties of fabrics are pressure-dependent. Correlation analysis showed that measurements from DLTFT have positive correlation with MMT results and are able to test fabrics that cannot be accurately differentiated with existing test methods. This instrument is useful for fabric evaluation in textile product development and quality control.

Keywords: One-way liquid transport, Transplanar wicking, Gravimetric analysis, Surface water content

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Visual perception of the ageing color of textiles

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The concept of a ”sustainable lifestyle,” aimed at fostering a circular and sustainable society, is attracting increasing attention. Among the challenges addressed is the issue of excessive clothing consumption, highlighting the importance of valuing each garment and wearing it for a more extended period. A primary reason people discard clothing involves damage such as ”shrinkage,” ”fraying,” and ”tearing.” Other common reasons include ”stains,” ”yellowing,” and ”fading,” which affect not only parts of the garment but sometimes its overall color. These issues go beyond mere appearance, impacting consumers' trust and satisfaction with the quality of the products. The authors have been conducting research focusing on color changes in textile products, with particular attention to the perception differences between ”yellowing” and the colors ”white” and ”yellow.” This study further investigates the visual impression of the aging color of textiles. For the visual evaluation, 588 color samples were prepared, covering the entire range of hues in shades close to white, with systematically varied levels of lightness and chroma. These samples were used to conduct a visual assessment of color perception. In the visual assessment, participants were asked to judge the hue of each sample by selecting from ”white,” ”red,” ”yellow,” ”green,” or ”blue.” They were also asked whether the sample appeared to reflect signs of aging or yellowing. Based on the evaluation results, the study analyzed trends in color perception. The results of this research will not only deepen our understanding of how aging and yellowing are perceived as color but will also suggest new approaches to sustainable clothing.

Keywords: color, perception, aging

*Speaker

Using Computer Vision Methods for Raw Cotton Quality Control

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Cotton is an important textile fiber used in many industrial processes. Because it is so widely used in fabric production, controlling the quality of cotton is crucial to ensuring the competitiveness of the final product. Impurities such as leaves, stems, and small foreign objects can negatively affect cotton quality, making processing more difficult and costly. Effective quality control is essential for optimizing the production process and reducing costs.

Researchers at ITA RWTH Aachen have studied innovative methods for analyzing digital images to detect foreign objects in cotton. They also explored techniques for measuring the geometric parameters of impurities within these images. This data is used to assess the physical and mechanical properties of impurities, which is essential for evaluating the quality of textile raw materials and for separating impurities from cotton during processing.

Computer vision technologies for cotton quality control are more accurate and efficient than traditional methods, reducing human error and making the process more automated. These technologies can lead to new standards in the industry, improving product quality and reducing environmental impact. As part of this research, software was developed that can detect and measure impurities in cotton. This software can be used in industrial quality control systems, making the process faster and more precise, while also lowering costs and increasing productivity. As the software continues to improve, it has the potential to become an essential tool for enhancing cotton quality and competitiveness in the textile industry.

Keywords: quality control, raw cotton, computer vision

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DNA-Based Authentication of Alternative Plant Fibres in Textiles

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Alternative plant fibres, such as hemp, banana, and pineapple, are gaining prominence in the textile industry due to their ecological advantages over traditional fibres like cotton and flax. These fibres are renewable, biodegradable, and require fewer resources-such as water, fertilisers, and pesticides-making them potentially more sustainable. Their adoption has the potential to significantly reduce the environmental impact of textile production and align the industry with global sustainability goals. However, the increased use of these fibres demands accurate product labelling and compliance with regulatory standards to mantain consumer trust and support regulatory oversight. Traditional identification methods, such as microscopic and chemical analyses, often struggle to reliably differentiate these fibres from others like flax or cotton, especially in processed textiles. As sustainability and transparency become more critical in global textile markets, DNA-based molecular biology techniques are emerging as a promising solution for authenticating and tracing plant fibres in textiles.

In this context, this work aimed to develop a DNA-based tool capable of identifying and differentiating emerging fibres in the textile industry. Both chemically treated and untreated fibres from hemp, banana, pineapple, flax, and cotton were analysed using an optimised DNA extraction protocol Foodproof® Sample Preparation Kit III (Ref^{a} S 400 06. 1, BIOTECON Diagnostics GmbH, Alemanha) and primers designed based on conserved regions of the *matK* and *rbcL* genes. Specific primer pairs were successfully developed for each of the target fibre species-hemp, banana and pineapple. The primers showed high specificity and did not cross-react with other common fibres like flax and cotton, confirming their effectiveness in distinguishing between different fibres. Using these newly developed primers and an optimised polymerase chain reaction (PCR) protocol, amplification was successfully carried out across multiple textile samples of hemp, banana, and pineapple fibres subjected to different chemical treatments (such as bleaching and dying), validating the method's potential for genetic identification of these species across the value chain.

This study confirms the effectiveness of DNA-based methods in distinguishing alternative fibres from other plant fibres, highlighting the importance of DNA-based methods for fibre authentication in the textile industry. As such, this method supports the textile industry's efforts to build consumer trust, maintain compliance with regulatory standards, and promote the use of sustainable materials.

Keywords: molecular biology, natural fibres, sustainability, textile industry, traceability

*Speaker

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Polarimetric Inspection of Carbon-Based Composite Materials

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Carbon-based composite materials are very popular, but their visual inspection remains difficult due to the very low reflectivity of carbon. A major insight consists of using imaging polarimetry, since carbon exhibits a strong polarization response
Nowadays, operating such an inspection is easier, since new polarimetric cameras able to sense linear polarization have been released for ten years: recent models have proved cost-effective and rather easy to implement with common software frameworks. Nevertheless, implementing adequate lighting and efficient digital post-processing are mandatory conditions to get information with moderate polarimetric noise. Before studying carbon samples, we demonstrate how to efficiently calibrate a polarimetric setup able to sense linear polarization. We then verify that linear polarization is sufficient to get information about carbon fibers and that circular polarization can be omitted, which makes the implementation much more straightforward.
Then, we consider carbon fabrics used as composite material reinforcements. We study their polarimetric response and show fiber orientation can be estimated with excellent accuracy. Finally, we then consider full composite samples including an epoxy matrix. We will demonstrate that seeing the first layer of the carbon reinforcement through the opaque matrix is possible with good accuracy. Our technique allows us to see coating defects as well as the multilayer structure appearing at the edge of the samples.

Keywords: carbon, based composite materials, polarization imaging

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Analysis of the optically and with the tactile sensation analyzer (TSA) device measurable parameters of textile, paper and wooden surfaces related to the haptics perception

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The tactile sensation of the textile, paper and wooden surfaces is determined by their micro and macro structure, and from the material, which in this case is the same. In this study a 3d images of the surface of textile woven and knitted materials from cellulose based fibers and for different types of paper are analysed. The same samples are investigated using Tactile Sensation Analyser (TSA) produced by the company Emtec. The results for the surface evaluation and the TSA are analized using principal component analysis (PCA) and correlation between these are investigated. The goal of the investigation is for the researchers to get understanding if the identical chemical basis cause similar reactions in the skin independent on the different mesostructured, and if yes, to identify for which parameters is responsible the material and which are material independent.

Keywords: haptics, sensing, surface, optical evaluation, tactile sensation analyzer, digitalization

*Speaker

13 - Textile based sensors, smart textiles

Smart Textiles for Energy Harvesting and Self-Powered Sensing from Human Motion

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The rapid progress of wearable technology needs the investigation of sustainable energy sources like triboelectric nanogenerators (TENGs). Nonetheless, the development of flexible, breathable, and washable wearable TENGs presents a considerable problem. This paper presents an innovative twill weave structured triboelectric nanogenerator (TW-TENG) created by a straightforward, economical, and scalable weaving method. The TW-TENG is composed of commercially available silver-plated nylon yarn (SNY) and cotton yarn, serving as triboelectric positive materials. The relevant layer consists of a highly elastic polymer, polydimethylsiloxane (PDMS), infused with BaTiO3, serving as a triboelectric negative material. The distinctive self-resilient architecture of the TW-TENG enables it to generate an output voltage of 430 V, a short-circuit current of 10.1 μA, and a power density of 1,851 mW/m^2. The remarkable output power capability of the TW-TENG, in conjunction with human movement, indicates potential applications in smart textiles in the foreseeable future.

Keywords: triboelectric nanogenerator, weaving structure, energy harvesting, sensing, smart textiles, human motion

*Speaker

Functional Textile for Sustainable and All-Weather Energy Harvesting from Moisture

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Harvesting energy from the environment or human activities is increasingly seen as a viable approach to meet the growing energy demands of wearable technologies. Although notable advancements have occurred over the past decade, energy harvesting technologies based on piezoelectric, triboelectric, photovoltaic or thermoelectric principles encounter substantial challenges in wearable applications. In addition to the intricate manufacturing processes, they all necessitate an external energy source such as mechanical, solar or thermal energy as input, thereby constraining the applications in wearables. Flexible textiles that can generate electricity from moisture would be an excellent solution for providing sustainable and all-weather energy to wearable and portable electronics. In this work, an innovative functional textile featuring high-efficiency moist-electric conversion properties was developed based on the elaborate integration of moist-electric functional materials and textiles, capable of generating direct current output for driving wearables including LED light, electronic watch and portable calculator. This work will provide scientific insights and new knowledge on designing, fabricating, and evaluating new functional textiles for sustainable and all-weather energy harvesting.

Keywords: functional textile, energy harvesting, moisture

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Rewritable Photochromic Textiles for Sustainable Applications

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Fiber-based photochromic wearables have attracted substanial attention in sustainable pattern display, information security encryption, and optical data recording/storage. Molybdenum trioxide (MoO_3) is one of the popular photochromic materials that possesses good photochromic performance. However, it faces considerable challenges in preparing photochromic textiles based on MoO_3 with scalability, long color retention property, and great stability. In this work, we developed a kind fiber-based photochromic wearable by combining cotton fabric with MoO_3-based polymer network and polyacrylate adhesives. The prepared photochromic wearable shows excellent fatigue resistance and good reversibility ($>$ 20 cycles), fast light response (color saturation at the UV dose of 100 kJ m^{-2}) and outstanding color retention ability ($>$ 30 days). In addition, this photochromic textile can maintain rapid light response and excellent color retention even after repeated washing (10 cycles). Moreover, photochromic fabric can resist the deterioration of acid solution and alkali solution as well as keep clear patterns under sunlight and indoor light irradiation. As an application demonstration, fiber-based photochromic wearables were used for the sustainable application of rewritable patterns and information security encryption.

Keywords: photochromic wearables, color retention, MoO_3, sustainable patterning, information security encryption

*Speaker

TexSens: Towards a Flexible Textile-Based Sensor Array for Accurate Pressure Measurements Using Multi-Dimensional Weaving

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Accurate pressure measurements are crucial for wearable applications, such as compression wear, sleep position classification, and gait pattern analysis. Conventional pressure sensors are mostly rigid and work with bulky connectors, presenting challenges for flexibility and integration. Textiles are ideal base structures for human body measurements due to their flexibility, and versatility, allowing seamless integration of both sensors and connectors.
The proposed sensor arrays are produced using MDW (multi-dimensional weaving) technology from Jakob Müller AG, which allows the integration of up to four functional fibers in addition to the warp and weft yarns during the weaving process. The prototype was manufactured in one step including the electrodes, the piezoresistive layer, and the connectors to the electronics. Pressure data from individual sensor elements demonstrate a nonlinear but reproducible relation between raw sensor readings (ADC counts) and the applied load on a single sensor element. Comparison between different sensor elements revealed variations in sensitivity and resistance, suggesting that the manufacturing process, particularly the consistency and repeatability of electrode fabrication and the surface resistance between electrodes and piezo-resistive fibers, could be improved. Further improvements will also include adjusting the textile base structure, optimizing the electrical and piezoresistive properties of the functional yarns, the geometry of the sensor elements, and the supply of the measurement signals to the electronics. Also, robustness to washing and the effect of bending will have to be investigated.
From the preliminary prototypes, we can conclude that the MDW technology holds significant potential for the cost-effective manufacturing of textile-based sensors, with the resulting prototypes exhibiting good reproducibility, and high sensitivity.
Acknowledgment The study is supported by the Swiss Innovation Agency, Innosuisse project no. 118.027 IP-ENG.

Keywords: smart textiles, sensors, pressure

*Speaker

Electrically conductive textiles for health applications by carbon nanotube coatings on cotton

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Recently, the demand for wearable conductive materials-featuring comfort, flexibility, lightweight, and stretchability-has prompted the growth of the electronic textile field. A research segment aimed at creating wearable electronics for various applications (e.g., sensors, energy harvesting, electromagnetic shielding, and energy storage) is focused on using carbon nanotubes (CNTs). However, applying CNT coatings uniformly to textiles poses challenges due to nanotubes' agglomeration. The sol-gel technique, which produces ceramic-based carbon composites with high electrical conductivity, has proven effective in overcoming this issue.

In this study, non-functionalized CNTs with different aspect ratios were used to prepare two stable, homogeneous solutions for textile applications. CNTs were mixed with an amino-functionalized sol-gel precursor and a thermo-degradable surfactant that facilitated the dispersion and distribution of CNTs by acting on the π-π stacking interactions and maintaining their structure and conductive properties. The use of a polyurethane thickener led to CNT-based pastes, which were applied to cotton fabrics using the knife-over-roll method, producing electrically conductive textiles. Different chemical-physical techniques were employed to confirm the process's success and assess the morphology and chemical composition of coatings. Electrical properties were evaluated by surface resistance measurements, demonstrating that a shorter CNT aspect ratio leads to higher conductivity at the percolation threshold. The electrically conductive CNT-based cotton fabrics, integrated with an optoelectronic system, acted as elements of signal transmission of biomedical data by reliably monitoring heart rates through photoplethysmography.

This work highlights the successful combination of CNTs, the sol-gel process, and cotton fabrics, resulting in efficient and unobtrusive smart textiles suitable for various applications, including healthcare and sports.

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Keywords: carbon nanotubes, sol, gel, electrically conductive textiles

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Wearable Patterned Triboelectric Textiles for Energy Harvesting and Self-powered sensing

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In recent years, the development and application of smart electronics have trended towards miniaturization, wearability, and multifunctionality. Among these advancements, triboelectric nanogenerators (TENGs), which convert ubiquitous mechanical energy into electrical energy, have garnered significant attention. In practice, TENGs can harvest energy from everyday human activities. This paper aims to develop a novel type of patterned triboelectric energy textile, combining contact-sliding and freestanding mechanisms (CF-p TENG), capable of self-powering by harnessing green, sustainable, and renewable energy from human motion or even directly from wind energy. Unlike existing rigid and bulky energy devices, the proposed sustainable energy textiles will be based on flexible and lightweight materials, making them ideal for daily use. CF-p TENG will have broader and more versatile applications as smart wearables, as they do not require repetitive impact forces or bulky elastic supports. Fabrication methods and processing parameters, from yarn spinning and fabric making to pattern creation and garment assembly, will be meticulously designed and optimized to produce sustainable energy textiles with enhanced performance. The prominent output power performance of CF-p TENG together with human motion and textiles show their great potentials for viable applications in wearable electronics and smart textiles in the near future.

Keywords: triboelectric nanogenerator, energy harvesting, sensing, smart textiles, human motion

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Innovative Smart Textiles with Corrugated Flexible Triboelectric Nanogenerators for Enhanced Energy Harvesting and Self-Powered Human Motion Sensing

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With the rising demand for sustainable energy solutions for wearable electronics, triboelectric nanogenerators (TENGs) have emerged as an environmentally friendly and renewable option. In this work, a flexible corrugated triboelectric nanogenerator (C-TENG) has been developed, featuring high elasticity, durability, and efficient energy output for powering devices and enabling self-powered sensors. The structural design of the C-TENG has been optimized for enhanced electrical performance, ensuring stable operation even under mechanical stress or after washing. This device is capable of generating enough energy to power multiple LEDs, illuminating up to 250 LEDs with a simple hand press, and can generate a short-circuit current of up to 700 microamps when stepped on. Additionally, the C-TENG has been successfully integrated into smart insoles and intelligent carpets, showcasing its ability to detect human motion and monitor foot traffic. This research provides a novel approach to TENG design, paving the way for future applications in energy harvesting and intelligent sensing technologies.

Keywords: triboelectric nanogenerator, energy harvesting, smart carpets, wireless intelligent system, selfpowered sensing

*Speaker

Design and Performance Evaluation of Flexible Printed Piezoresistive Strain Sensors for Parachute Canopy Measurement

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Canopies and parachute lines experience high stresses during the opening phase. The study aims to measure the strain on these components to enhance our understanding of these materials and their life span. To avoid altering the parachute structure and affecting data accuracy, measurements are conducted non-intrusively. This necessitates designing and implementing a discreet and robust interface between sensors and textiles. Additionally, this project involves developing an electronic measurement device capable of recording data from embedded sensors.

Different types of sensing technologies can be used to measure the strain or stress experienced by textiles ranging from optical fibers and metallic yarns to piezoresistive films or polymers. This study aims to develop flexible printed piezoresistive strain sensors at the surface of the textile components of a parachute canopy, with a focus on the meridional ribbons (textile elements that link two parachute canopy panels) since they bear the most intense strain.

The characterization of the sensors in static and dynamic strain is crucial for understanding the sensing capabilities of the system (sensor + substrate + connections) and for adapting the data processing and analysis based on the sensing system's gauge factor (GF). The GF represents the ratio of the relative change in electrical resistance to the mechanical strain, quantifying the sensitivity of a strain sensor. This study demonstrates the performance of printed piezoresistive sensors in measuring strain in textiles.

The study also seeks to assess the repeatability and sensitivity of the sensors in measuring small elongations on different parachute components by analyzing how different process and testing parameters affect the resulting GF. Factors such as ink properties, the interface between the sensor and the textile substrate, the number of testing cycles (fatigue), and the speed of the applied stress are expected to have an impact on the GF.

Keywords: smart textiles, parachute canopy, piezoresistive sensors, strain measurement

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Functionalized Smart Sensing Materials: Sustainable Chemical Advances Powering Next-Gen Wearable Devices

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Smart sensing materials for wearable technology are essential for advancing personalized healthcare, fitness, and overall well-being. These materials can continuously monitor vital signs such as heart rate, body temperature, blood pressure, and hydration levels, ECG providing real-time data for early detection of health issues. Their lightweight, flexible nature makes them comfortable for long-term use, ensuring seamless integration into daily life. By offering continuous, non-invasive monitoring, smart wearables empower users to manage their health proactively, enabling fitness tracking, stress management, remote health monitoring and up to medical interventions. Additionally, smart sensing wearables play a crucial role in, promoting healthier lifestyles.
Advancements in nanotechnology have revolutionized smart coatings for wearable devices, enabling precise real-time monitoring of physiological parameters such as pH, and different target analytes. Different nanostructured materials can be incorporated into coatings to create highly sensitive, responsive, durable and flexible sensing substrates enhancing the interaction between the sensor and biological fluids, improving accuracy and stability. pH-responsive coatings can dynamically adjust and report changes in acidity levels, making wearable health monitors more reliable, compact, and adaptable to personalized healthcare needs.
This communication will show in detail the design, synthesis, and characterization of hybrid nanomaterials and multifunctional, innovative, and smart nanocomposites based on functional nanoparticles and nanofillers dispersed in polymeric matrices and/or in combination with suitable eco-friendly additives. The developed advanced formulations will be used as coatings of various substrates for applications as highly efficient products and smart technologies in opto-electronic devices and sensors, for biomedicine, textiles and other transversal sectors powering next-gen wearable devices, thus covering personalized healthcare, including diagnostics and therapies, and sustainability, including energy conservation, and use or bio-based or secondary raw materials as reactants.
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Keywords: smart coatings, hybrid materials, wearable devices, sensing materials, sustainability, healt monitoring, functional nanomaterials

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Advanced Polyamide 6/ Branched Carbon Nanotube Composites for Melt-Spinning of Bicomponent Filaments: Electrical Conductivity and Strain Characteristics

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The rapid advancements in smart textiles and wearable electronics have sparked renewed interest in the role of conductive filaments. These filaments are key components enabling the integration of electronic functionalities into textile platforms, paving the way for innovative and versatile wearable devices. Flexibility and stretchability are critical for wearable electronics, as they must conform to the body's dynamic movements. Conductive filaments capable of withstanding high mechanical strains while maintaining electrical conductivity are essential for realising these advanced functionalities.
In line with these developments, our research focuses on creating advanced Polyamide 6 (PA6) composites reinforced with branched carbon nanotubes (bCNTs) to melt-spinning bicomponent filaments. These composites are designed to enhance both electrical conductivity and strain characteristics, aligning with the demands of wearable electronics and smart textiles.
This study determines the optimal concentration of bCNTs required to achieve the percolation threshold for forming a continuous conductive network within the PA6 matrix. This network is crucial for providing electrical performance for smart textiles, where conductivity is vital for sensing, heating, or actuation functions. Moreover, incorporating bCNTs significantly improves the strain-handling capacity of the composites, enhancing mechanical properties such as tensile strength and elongation at the break-essential for the durability of wearable textiles under repetitive body movement. We have employed melt spinning as the fabrication method to produce uniform, high-quality bicomponent filaments. The study also examines how CNT dispersion and morphology affect the overall performance, emphasising the importance of CNT functionalisation for better compatibility with the PA6 matrix. Our results demonstrate that these advanced PA6/CNT composites offer superior electrical and mechanical properties, making them ideal for multifunctional smart textile applications, particularly wearable electronics.
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Keywords: smart textiles, nanomaterials, melt spinning, carbon nanotubes, electrical conductivity, strain

*Speaker

Stress evaluation by using a textile heat fluxmeter

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Stress is a psychological or mental health issue that affects one person in four. Prolonged negative emotional stress can potentially lead to deterioration in health, a decrease in quality of life, and an increase in healthcare utilization. Due to these effects of stress in daily life, it is important to monitor the psychological state of individuals experiencing it in real time and treat them appropriately. For this reason, several methods are proposed to detect stress: standardized questionnaires, biochemical analysis, facial expression analysis (FEA), measuring physiological changes. The questionnaires lose their reliability when applied frequently and may also be unreliable because they may not be filled out sincerely. FEA remains subjective and requires the intervention of medical personnel. Although biochemical analysis is a widely used and reliable measure, its major limitation lies in the inability to detect stress in real-time. Following all of these limitations, it is found that the most reliable method for identifying individuals' stress levels is recording their biophysiological signals. These represent a non-invasive and non-intrusive method, allowing real-time monitoring. For this purpose, the most relevant biophysiological activities are identified like cardiovascular, respiratory, muscular, cervical, electrodermal, and thermal. Although several studies have utilized skin temperature as a stress indicator, focusing on thermal activity, they often neglect the heat exchanges between the individual's body and the environment, which are of utmost importance. Therefore, the novelty of this study lies in the utilization of a textile heat fluxmeter (THF) capable of considering the heat exchange between the human body and the environment for stress detection. The paper outlines the conceptualization of THF, the calibration method for sensor sensitivity, and the experimental design for stress detection. Thus, this study aims to provide a comprehensive understanding of the relationship between heat flux and stress for practical applications in stress monitoring and management.

Keywords: textile, heat fluxmeter, sensor, stress

*Speaker

Innovative Textile-Based Electrochemical Sensor for Ethanol Detection in Sweat: Integration of Catalysts and Molecularly Imprinted Polymers

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The development of textile-based biosensors capable of quantifying biometric data in biological fluids is a major topic of research. The ultimate goal is to provide information about an individual's medical state anytime and anywhere. Alcohol is considered the most commonly used addictive substance worldwide, being one of the main causes of death in road accidents. This work demonstrates a method to produce a novel textile-based screen printed electrode (SPE) sensor for electrochemical sensing of ethanol in sweat, exploring different textile substrates (100% polyester (S1), 100% recycled polyester (S2), and 50% recycled polyester 50% hemp (S3)) and different conductive inks, namely silver ink (DuPont 5025) to produce the electrical contacts and the reference electrode, and carbon ink (DuPont BQ242/Elantas 9553) to produce the working and auxiliary electrodes.The electrochemical performance of Elantas 9553 and DuPont BQ242 inks was compared, with DuPont BQ242 identified as the most suitable ink for the working electrode. Among the substrates, sample S3 demonstrated superior properties, with higher peak currents (peak current ratio of 1.2) and smaller peak potential separation (602 nV), demonstrating better electrochemical behavior than commercial SPEs. Techniques like Cyclic Voltammetry, Impedance Spectroscopy, and Square Wave Voltammetry were used to assess sensor performance. The produced Textile-Based SPE maintained approximately 95.5 % of the initial current response after 4 months, demonstrating that the SPE has good stability. The sensors' repeatability intra and interday was studied, with an RSD of 1.58% and 3.57%, respectively. Following characterization, the working electrode was functionalized with the sensing element capable of detecting ethanol. Different catalysts were studied and a molecularly imprinted polymer was produced to recognize and adsorve ethanol, obtaining an average adsorption degree between 18.8% and 33.5%. These textile-based SPEs present a valuable alternative to conventional rigid sensors, which are typically single-use and less durable than the flexible ones.

*Speaker

Keywords: textile based sensors, screen printing, electrochemical sensors, cyclic voltammetry, metal oxide, molecularly imprinted polymers

Investigation of the Effect of Sintering Process on the Performance of Textile-Based Wearable Pressure Sensors

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Textile-based pressure sensors are emerging in various fields, including human health monitoring, capturing human movements, examining human-machine interactions, and robotic applications. Each application area necessitates different performance specifications for these pressure sensors. In this study, flexible and wearable textile-based pressure sensors were produced using a conductive paste containing silver nanoparticles via a pad printing method. To ensure efficient operation within the pad printing machine, a formulated silver conductive paste was printed onto a polyamide-based taffeta label fabric. Following the printing process, the produced sensors underwent a sintering process at various temperature and duration to optimize the performance of the sensors. The sintering conditions employed in this study were 120°C for 30 minutes, 150°C for 15 minutes, and 150°C for 30 minutes. Among various sensing mechanisms, a capacitive sensing mechanism was selected for the printed pressure sensors. Accordingly, a nonwoven fabric was incorporated as an insulating material between the textile-based pressure sensors, creating a sandwich structure. The performance of the produced pressure sensors was measured using a digital multimeter. Changes in capacitance of the printed pressure sensors were recorded by applying finger pressing to their surfaces. The sensitivity and performance of the textile-based pressure sensors subjected to different sintering processes were evaluated based on capacitance variations. As a result of the evaluations, it was determined that the pressure sensor with the best performance was the sensor exposed to the sintering process at 150°C for 30 minutes, and the best conductivity was also obtained in the same sensor structure subjected to this sintering process (150°C, 30 minutes). This study concludes that the sintering process is critical for conductive structures containing nanoparticles. Additionally, considering the performance of the proposed pressure sensor, there is significant potential for its application in critical areas such as human health monitoring, tracking physical activities, and human-robot interactions.

Keywords: textile based sensor, pressure sensor, pad printing, sintering process, silver paste

*Speaker

Electromechanical properties of Polypyrrole/Silver nanowire Composite yarn for Wearable Application

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Electronic textiles (E-textiles) were commercialized through weaving, knitting, and embroidering using conductive yarns. Since recent years have witnessed intense efforts and innovations in the design of flexible conductive yarns for developing next-generation electronic textiles. But to date, it is still a great challenge to guarantee stretchability under deformation of conductive yarn.

In this study, we fabricated conductive composite yarns by in-situ polymerization of polypyrrole (PPy)/silver nanowires (AgNWs) on the surface of various fibers such as polyester (PET), polyamide (Nylon), viscose rayon and Lyocell, shown good candidates in previous studies. Stretchable yarns were fabricated thru the manufacturing process using composite conductive yarns.

The addition amount of AgNWs was designed differently, and the electromechanical properties of each sample were compared. The PPy/AgNWs yarns has demonstrated high electromechanical performance, including stability under repeated stretch-release deformation.

These results provide a promising approach to the development of various stable conductive yarns by introducing conductive components on the surface of existing fibers.

As-manufactured conductive composite yarns showed the strechability and demonstrate the potential as functional sensors for E-textiles

Keywords: stretchable conductive yarn, polypyrrole, silver nanowire, electromechanical performance

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Analysis of Durability of Silver-Plated Conductive Threads for Electronic Textiles

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Metal-plated conductive threads are increasingly recognized as essential materials in wearable electronics. Among them, silver-coated nylon is the most widely used types and is typically fabricated by continuously coating silver nanoparticles onto the surface of nonconductive fibers. However, these coated particles are prone to deteriorate like detachment and oxidation that critically impact the usability, scalability, and longevity of electronic textiles. To investigate and address these challenges, commercially available silver-coated nylon threads were analyzed. Each threads have similar denier but having slight structural variations. The threads were exposed to various chemical and mechanical stress conditions to analyze the changes in electrical resistance and surface morphology and were assessed using a multimeter and scanning electron microscope (SEM), respectively. The silver content in each sample were correlated with the observed conductivity. All samples exhibited more severe changes in resistance with momentary deformation compared to continuous deformation under axial tensile stress. Notably, the Silver-tech (AMANN, Germany) sample displayed the most substantial resistance increase across all stress conditions, showing a fivefold increase in resistance change rate between momentary deformation (100 cycles of 10% strain, $\Delta R/R_0$=5.88) and continuous deformation (10% strain held for 10 minutes, $\Delta R/R_0 = 1.11$). This study aims to explain the causes of performance degradation in silver-coated threads and to manage these factors to improve durability. Through this research, we identified directions for enhancing the durability of silver-coated threads, which holds potential for increasing the practicality of electronic textiles.

Keywords: electronic textiles, conductive thread, wearable electronics, durability

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Highly Conductive and Flexible Cotton Fabrics Using Acid-Functionalized MWCNTs for Advanced Energy Applications

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Developing new materials with improved electrical conductivity and mechanical flexibility is essential for advanced applications in wearable electronics, energy storage, and sensing devices. Here we report an innovative method of converting ordinary cotton fabrics into highly conductive, durable, and flexible substrates by incorporating acid-functionalized multi-walled carbon nanotubes (MWCNTs). A uniform deposition of MWCNTs onto cotton fabrics using an optimized doctor blade process resulted in crack-free coatings that remain bendable under repetitive mechanical stress. Acid-functionalization not only enhances the stability of dispersion of MWCNTs but also promotes strong adhesion to the fabric, thus greatly enhancing the conductivity and durability of the coated fabrics. Composite fabrics produced under such conditions reveal a striking electrical resistance of as low as 2 Ω/sq. The coating remained stable during repeated washing cycles and bending series. The coating was also seen durable during in contact with liquid electrolyte. The scanning electron microscopy showed smooth coating on the surface of cotton. These conductive fabrics also exhibit high stability through repeated washing and flexing cycles, making them good candidates for long-term exposure to dynamic environments. This work provides a scalable and green approach to making highly conductive and flexible textile materials, thereby paving the way for their applications in next-generation wearable electronics and advanced applications. The results further underline the synergy between sustainable materials and advanced nanotechnology for emerging technological demands.

Keywords: MWCNT, coating, electrical resistance, cotton fabric, flexible, sustainable.

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A Comprehensive Characterization of Commercial Conductive Yarns for Smart Textile Applications

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The development of conductive yarns is growing rapidly due to their use in wearable electronic textiles for sensing, heating, and energy storage applications. These yarns can be integrated into fabrics using traditional textile fabrication techniques such as embroidery, weaving, and knitting. Their structural properties play a crucial role in the processability in fabrication techniques and atmospheric conditions, abrasion resistance, and sweat on the overall performance of the conductive yarn. However, an efficient evaluation of these properties of commercial conductive yarns remains limited. This work focuses on characterizing 15 commercially available conductive yarns with varying structures, materials, and fabrication techniques to evaluate structural properties, processability in embroidery, abrasion resistance, and heat exchange performance using a Newton thermal manikin under controlled environmental conditions. Structural properties such as thick/thin places and hairiness were measured, along with their effects during embroidery. Changes in resistance due to abrasion were also evaluated to predict variations in electrical performance during wear. Additional tests were conducted in a climate chamber with temperature variations from 5°C to 45°C and a thermal manikin operating in dry and wet conditions to check the real-time effect during wearability. Highly twisted yarns with low hairiness demonstrated superior processability and resilience during embroidery and abrasion tests, maintaining stable electrical properties. In contrast, lower-twist yarns frequently experienced breakages and entanglements due to reduced structural integrity. Most materials displayed consistent resistance across varying conditions, ensuring reliability for wearable applications. However, one material exhibited significant variability, highlighting repeatability issues. Resistance changes during wet conditions depended on the sample's proximity to sweating pores. These findings provide a framework for the selection and characterization of conductive yarns, offering valuable insights for their integration into textile-based wearables and advancing the field of smart textiles.

Keywords: conductive yarns, wearable textiles, smart textiles

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Individual warning using electrical signals – State of the Art Review

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There are many professions and situations, where humans cannot see, listen, or understand that the environment becomes dangerous for them. For instance, loud machines of craftworkers or reduced visibility because of the geographic terrain or climate can be reasons that the persons cannot see an incoming train or car and get injured. Similar is the situation for the firefighters, who have to operate in hot and dangerous conditions and have to be able to understand when they have to leave their current position in order not to overheat or get other damages. In all these situations, another type of warning than voice is required – which can be an electrical signal, generated within the clothing.
While electric stimulation for medical and lifestyle purposes is widely used, this type of stimulation is not yet applied for electric warning purposes in practice. Recent research focused on basic research aspects of electric warning: types, number, and positioning of electrodes for warning, parameters of the applied current, types of textiles, and mechanical properties of the placing and holding mechanisms.
This work has the goal to give an update on the state of the art of this research work, summarize the results and open problems, and provide directions for future developments. The review specifically covers three aspects of textile-based systems for electric stimulation: investigations about human body geometry and its changes, related to the electrode placement, the types of electrodes and currents, and the influence of environmental conditions.

Keywords: clothing, sensors, warning, individual warning, state of the art review

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Effects of Knit Textile Structures on Rivet-Embedded Interconnects in Wearable EMG Armband

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Wearable electromyography (EMG) systems require reliable and durable electrical interconnects between surface EMG (sEMG) sensors and associated circuitry within textile-based systems. Rivet-embedded interconnects offer a promising solution by providing stable mechanical and electrical contact while maintaining wearability. However, the effectiveness of these interconnects depends on the textile structure used. This study evaluates the impact of three different knit textile structures — single jersey, interlock, and spacer knit — on the performance of rivet-based interconnects in wearable EMG armbands. The evaluation focuses on the impact of physical properties of the knits, such as thickness and loop density on the integration of the rivet, electrical resistance of the interconnect, and EMG signal acquisition. Due to its high elasticity and lower structural integrity, single jersey fabric experiences a reduction in thickness under strain, potentially leading to rivet loosening, increased contact resistance, and detachment. In contrast, interlock fabrics provide greater mechanical stability, maintaining thickness, which reduces rivet displacement and ensures more consistent electrical contact. Spacer fabrics, with their compressible three-dimensional structure, exhibit significant thickness variation under stretching, which may increase the risk of rivet loosening or inconsistent signal transmission. These structural characteristics directly impact the electrical resistance of the rivet interconnects. EMG signal stability would be monitored before and after washing to evaluate the performance of rivet interconnects embedded into the knits. The findings of this study would provide key insights into designing durable, high-performance wearable systems by selecting knit fabrics that enable reliable and low-profile interconnects. These results would have broader implications for e-textile development, particularly in ensuring stable and repeatable electrical contacts.

Keywords: E-textiles, knit structures, rivet interconnect, wearable EMG armband

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Textile-based sensors for soft robotic applications

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In the early 2010s, researchers began exploring textiles as a key material for enhancing wearable soft robotics, particularly for actuators and sensors. Textiles offer several advantages, including low weight, breathability, cost-effectiveness, and versatile mechanical properties, which are essential for creating assistive devices that transmit forces without limiting user movement. Textile-based soft sensors, in particular, have gained attention for their potential in motion tracking within soft robotic systems. These sensors are integrated into wearable devices to ensure that the appropriate assistive forces are applied at the right time. Textile-based soft sensors, such as strain and pressure sensors, are commonly attached to the actuator bodies. These sensors are made by incorporating conductive materials like threads, yarns, and fabrics into the textile structure. Their function relies on changes in electrical output that occur when the fabric is stretched or subjected to pressure. This ability to detect mechanical changes makes them ideal for monitoring and controlling movement in soft robotic systems. For instance, these sensors can provide real-time feedback on the user's motion, ensuring that the wearable device responds accordingly to support or assist the user's movements. While textile engineers have been developing these sensors for nearly two decades, their application in soft robotics has been less integrated. Research in textile-based sensors and soft robotics has largely progressed separately, limiting the full potential of these materials in wearable robotic systems. By combining textile-based sensors with actuators, soft robotic devices can achieve greater precision and reliability in real-world applications, particularly in rehabilitation and motion assistance. The integration of textile-based sensing technology into soft robotics offers a promising direction for improving the efficiency and functionality of wearable devices, enabling more adaptable and effective solutions for continuous home rehabilitation and daily life assistance.

Keywords: textile based, soft robotics, sensors

*Speaker

Structural Design and Optimization of Knitted Heaters for Uniform Heat Distribution

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Knitted heaters have attracted significant interest due to their flexibility and ease of integration into smart textile applications. They have been used in various applications aimed at enhancing thermal comfort, such as heat therapy, personal heating garments, and heated seats, providing therapeutic benefits like muscle relaxation, pain relief, and effective heat distribution. Despite the great potential of wearable heating garments, uneven heat distribution remains a big challenge, leading to comfort issues and inefficient energy usage. The main issue arises from the complexity of design and manufacturing processes, which prevent the achievement of uniform heat distribution. In this study, we present a model that links the generated heat and surface temperatures of a knitted heater to key design parameters such as size, configuration, material properties, and knitting structure, aiming to establish guidelines for achieving a desired temperature rise over a specified surface area. The knitted heaters were fabricated using four different lines (2, 5, 10, and 12) using a Stoll CMS 530 flat knitting machine with a gauge of E8. Conductive yarns from Shieldex® were used, with 235/36 dTex 1-ply for the heater sections and 235/36 dTex 2-ply for the leadwire. The resistance of the knitted heaters was measured using an Agilent Technologies N6705B DC power analyzer to supply power, while temperature data was collected with a FLIR E60 thermal camera. The resistance characterization results show a linear trend with respect to the length-to-width (L/W) ratio, while the ΔT–P curves for all lines exhibit positive slopes, indicating that temperature increases with power across all lined samples. In all cases, the observed and calculated ΔT values showed a slight gap that increased with more heaters or courses, indicating that additional conductive paths enhance heating more than the model predicts. This study presents an analysis of knitted heater structures, contributing to the development of more efficient designs with improved heat uniformity for smart textile applications

Keywords: knitted heaters, heat distribution, smart textiles, thermal comfort

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14- Artificial Intelligence (AI) in textile and clothing science

Artificial Intelligence (AI) in Textile/Clothing Engineering

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Artificial Intelligence, AI, is booming business. They are capable of extracting knowledge from large data sets. AI applications in textiles have been studied for more than 25 years. The techniques used include neural networks NN, classifier systems CS, genetic algorithms GA and fuzzy logic FL.

This presentation explains the basics of these techniques and examples, in order to understand their strengths and limitations. The relationships between material properties, machine settings and production outcomes are complex and subject to strong interactions. In addition, targeted production outcomes include multiple parameters eg. product properties, productivity and cost. Statistical regression requires prior definition of type of relationships, cannot cope with correlated independent variables, considers one dependent variable. Neural networks do not exhibit such drawbacks. However, establishing the model requires large datasets. Finding optimal solutions of complex neural network models is not straightforward. Genetic algorithms can find such optimal solutions, even considering several parameters (eg. quality, productivity and cost) simultaneously, with adjustable balances.

An example will address fibre properties and setting of the ring- and rotor spinning machines as input and yarn strength and elongation, cost of the fibre blend and spinning productivity as output. The experimental data set contained almost 1400 spinning trials. The NN turns out to give lower error on prediction than multiple linear regression models. Optimization by GA allows to identify best spinning solutions, in terms of yarn strength and elongation, spinnability and raw material cost. The GA can also indicate which fiber properties and machine settings lead to these solutions.

Additional examples illustrate variants of the techniques, such as NN trained by unsupervised learning for product assessment subject to large subjectivity, such as assessment of carpet wear. GA's can also be used as a modelling technique, then called classifier systems. They have been successfully applied to the fibre-to-yarn data set, resulting into rules that can be easily interpreted, other than the NN black box model. With the current computational power and monitoring systems, that provide massive data sets, AI is reviving and expanding its applicability.

The examples explained in the presentation are meant to understand and inspire the huge potential in production analysis and optimization, design and quality control.

Keywords: Artificial Intelligence, AI, textiles, neural networks, genetic algorithms, modelling, optimisation

*Speaker

Textile-based, multifunctional coaxial sensor fibres for localized strain measurement of fibre-plastic composites

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Fiber-reinforced composites (FRC), particularly those using thermoplastic matrices like polyamide (PA) or polypropylene (PP) with glass fiber reinforcement, are increasingly popular for developing energy-efficient, high-performance, and recyclable parts. These composites offer low weight and superior mechanical properties, making them ideal for critical applications where efficiency and performance are essential. However, the complex manufacturing processes associated with these materials lead to high costs, making precise monitoring of their load states vital to maximize service life and reliability.
Conventional strain measurement methods, such as fiber-based resistive strain sensors, are widely used but fall short in providing detailed, localized information about strain distribution within the composite. This limitation is especially problematic for fiber-reinforced thermoplastic components, which can experience complex, localized strain patterns or defects due to their heterogeneous structure.
To overcome these challenges, this work presents an innovative coaxial sensor made of a conducting fiber core, surrounded by an insulating fiber sheath that serves as a dielectric layer, and coated with a nickel-based layer. This sensor integrates seamlessly into glass fiber-reinforced PA or PP composites and enables high-resolution strain-state tracking using time domain reflectometry (TDR). By measuring the time-resolved characteristic wave impedance of the sensor fiber, the system effectively captures local strain and bending states within the material.
To process and interpret the complex data collected, an advanced neural network is developed. The network is trained to correlate the impedance data from the TDR measurements with specific strain and deformation patterns in the composite material. Utilizing sophisticated machine learning algorithms, the neural network accurately identifies and quantifies localized strain variations and provides information on the load and stress conditions This approach provides real-time assessment of the load state, offering an effective solution for extending the lifespan and optimizing the performance of fiber-reinforced thermoplastic components in demanding applications.

Keywords: fiber, reinforced composites, structural health monitoring, non, destructive testing, time domain reflectometry

*Speaker

Using gradient boosting regressor to estimate the drape coefficient of fabrics based on the data of a novel test instrument

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As the textile industry increasingly digitizes through advancements in artificial intelligence and machine learning, accurate simulation of fabric properties, such as drapeability, has become critical for design and garment visualization. Fabric drape – the degree of fabric deformation under its own weight – is traditionally assessed subjectively despite the growing need for objective measurements to support 3D simulations in fashion technology. Cusic Drape Tester is a traditional test device commonly used to measure the static drape coefficient of fabrics. While effective, this method presents challenges due to its time-consuming, labor-intensive nature and high material consumption. This study proposes a novel and efficient approach to measure fabric drapeability using the Tactile Sensation Analyzer (TSA), originally designed to evaluate fabric hand and tactile comfort. TSA offers a quicker and less resource-intensive alternative to traditional methods. In this study, a range of fabrics representing different garment categories was tested to develop predictive models for drapeability based on TSA measurements. Firstly, the drape profiles of the fabrics were obtained using the Cusic Drape Tester, and image processing was used to calculate the drape coefficients. Then, the surface structure and out-of-plane deformation behavior of fabrics were measured using TSA. In the final stage, Gradient Boosting Regressor (GBR) was employed to create regression models linking TSA parameters with fabric drape coefficients. Gradient Boosting Regressor is an ensemble learning technique that builds a strong predictive model by combining the outputs of several weaker models. It operates by sequentially adding decision trees to minimize the error of previous trees, making it particularly effective for complex, non-linear relationships. Its ability to adjust for residuals iteratively leads to improved predictive performance compared to traditional methods like linear regression. Our results showed that the out-of-plane deformation behavior of fabrics is a significant predictor of drapeability. The GBR model achieved an R-squared of 0.82, explaining 82% of the variance in drape coefficients, suggesting a strong relationship between the TSA parameters and drapeability. The model also demonstrated a Mean Absolute Error (MAE) of 4.89 and a Root Mean Squared Error (RMSE) of 6.22, indicating high predictive accuracy with minimal average deviation from the actual drape coefficients. Consequently, the GBR model effectively eliminates the need for the conventional Cusic Drape Tester. TSA demonstrates potential not only in the objective assessment of tactile properties but also in accurately predicting fabric drape.

*Speaker

Keywords: fabric drape, gradient boosting regressor, regression, ensemble learning, performance metrics, Cusic drape tester, tactile sensation analyzer

Optimizing the Blending of Recycled Cellulosic Textiles Using Machine Learning Techniques

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The textile industry faces significant challenges in sustainability, particularly in recycling post-consumer cellulosic materials while maintaining quality. Effectively blending a higher proportion of recycled fibres with unused fibre is crucial for enhancing the quality and performance of textile products while minimizing environmental impact. This research aims to leverage machine learning techniques to optimize the blending process, ensuring that the resulting yarns meet industry standards.
This study employs a data-driven approach, utilizing machine learning algorithms to analyze the properties of recycled and virgin fibres. Key features such as fibre length, strength, and fineness are extracted from extensive datasets. Various regression models, including Random Forest and Gradient Boosting, are trained to predict the optimal blending ratios that yield desirable yarn characteristics. Hyperparameter tuning is conducted to enhance model performance, and cross-validation techniques are employed to ensure robustness.
The anticipated outcome is a predictive model that accurately forecasts the properties of blended fibres, facilitating the development of high-quality yarns. This research is novel in its application of machine learning to the textile recycling process, providing a systematic framework for optimizing fibre blends based on empirical data. Future work will involve validating the model predictions against practical lab results to refine the blending process further. Additionally, the integration of SHAP (SHapley Additive exPlanations) analysis will be explored to enhance interpretability and provide insights into feature contributions, guiding future research directions.
This project represents a significant advancement in the sustainable practices of the textile industry, demonstrating the potential of machine learning to optimize fibre blending processes and improve the quality of recycled textiles.
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Keywords: recycled textiles, fiber blending, machine learning, fiber length prediction

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Actual path correction in tailored fiber placement process through a machine-learning algorithm

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Due to their anisotropic behavior, fiber orientation plays a key role in the mechanical behavior of composite structures. Tailored Fiber Placement (TFP) technology takes advantage of this anisotropy, by enabling the design of variable-axial pre-forms, where the fiber roving is stitched over a based material in any direction, and later impregnated with the matrix material through infiltration. Despite the technology's accuracy when placing the stitching holes, the roving presents deviations when comparing the actual path with the target (or designed) path. From the designer's perspective, one can classify the sources of these deviations between controlled and uncontrolled. The first group covers material properties (e.g., roving type and density, base material, thread material) and manufacturing parameters (e.g., speed, stitching distance, and stitching width). The second group comprises local defects in the roving (e.g., waviness, excessive twisting), temperature/humidity, and roving tension (as a function of residual stress in the roving inside the bobbin, friction coefficients, amount of remaining roving in the bobbin, and possibly other factors). In this context, this study introduces a methodology for the application of a machine-learning (ML) algorithm, designed to reduce deviations from both sources. An experimental campaign was carried out to feed the ML training process, aiming to capture the influence of the most important parameters mentioned above, including also their cross-influence, and feed the training process of the ML. Two different ML algorithms were programmed. While the roving path prediction of the first one was based on the roving position, the second one aimed to predict the position of the stitching points and, subsequently, the path. The correction was performed by searching for a corrected version that minimizes the deviations between the target and the actual path. Both algorithms showed similar performance, being able to reduce the deviations by ca. 50%.

Keywords: machine learning, tailored fiber placement, digitalization

*Speaker

Novel Approach Based on Image Processing and Deep Learning for Similarity Comparison in Repeated Denim Productions

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The topic of this research is related to the introduction of a new artificial intelligence-based approach to control repetitive production in denim garment manufacturing. Thus, the similarity and repeatability of productions in repeated orders can be easily determined. The focus is on generating an output based on the similarity of input images. This is done by determining whether the images resulting from the repetitive production of the same products belong to the same product. There are some elements that make this work more difficult than classical image comparison. These include: (i) the images may have been taken under different environmental conditions, (ii) the images may have been taken at different zoom levels, (iii) not all of the product may be visible in both images (iv) the effects on the denim garment. To solve these problems, a deep learning based integrated control system is introduced in addition to the image processing approach. A four-step methodology was used in the study. First, the images were pre-processed using image processing methods. After pre-processing, transfer learning-based segmentation was performed to separate the product parts in the images. Convolutional neural network approaches were used to extract features for each product part. The final similarity ratios were calculated and the similarity ratios of the images were calculated using different similarity measurement methods. As a result of the evaluation on 50 sample images taken from production, it was observed that the proposed approach was able to make predictions with an accuracy of approximately 80% according to pairwise comparisons.

Keywords: image processing, denim production, deep learning, repetitive production

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Analysis of the ranges of the mechanical parameters of textile fabrics using the Fabric Analyzer (FAB) of Browzwear

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This work presents analysis of tested textile samples for clothing with the Fabric Analyzer (FAB) of company Browzwear. The Fabric Analyzer can perform tensile tests in different directions, bending test using axial buckling of the sample and lateral compression test. The device is developed to simplify the characterization of the textile fabrics for clothing simulation. In the current work large number of samples are tested. The extracted values for simulation with VStitcher software are analyzed. The goal is to be identified in which ranges of the parameters the FAB device provides reproducible results and how large are the deviations of the tested parameters for the common textile samples. This knowledge can be used in the development of simplified testing procedures, based on systems with artificial intelligence or similarity of the samples.

Keywords: material properties, fabrics, parameters

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Evaluation of Characteristics of the Body Motion Using 4D Scanning and OpenSim Software

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The ranges of the changes in the joint angles of the human body at daily motion are important for the design and functionality of the clothing. For specific working or sports activities, the human body takes extremal postures, which are not common for other activities and the ranges of the motion must be known before the clothing design starts. Considering the complex structural characteristics of daily life motion, the major challenge is to determine the ranges of the body part motion at specific activities in order to prepare the best clothing for these. This paper aims to analyze the joint angle in four characteristic landmarks namely, elbow, shoulder, hip, knee, and ankle with respect to most typical daily life activity. This study used the advanced 4D scanning technique, implemented by the Move4D body scanner for capturing the motion data, and adopted an open-access skeleton model to build dynamics and kinematics. By combining (connecting) the motion data with the respective model, the joint angle was analyzed via inverse kinematics algorithms in a multibody dynamic system OpenSim. The results identified a change in joint angle with respect to the natural degree of freedom of the studied joints. Concerning the chosen motion cycle the joint angle varies from 30 to 120, 20 to 270, 20 to 70, 10 to 30, and 10-50 degrees respectively for elbow, shoulder, hip, knee, and ankle. The most drastic changes happen in the elbow, knee, and ankle joints of the human body. The analysis also identified the characteristics of motion which resulted in smooth to inconsistent changes in joint angle. Thus, the current data is a potential addition to optimizing the functional clothing design (sport, exo-suit, defense, etc) solving the comfort and efficiency issues of textiles.

Keywords: Move4D, inverse kinematics, computation, motion capture.

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15- Additive manufacturing technologies in textile and apparel

Sustainable stretch: 3D printing flexible biodegradable filaments on natural fiber knitted textiles for improved elastic recovery

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Elastic recovery is the ability of a stretched material to return to its original size, a quality crucial for textile products. Textiles made from only natural fibers, such as cotton, have poor elastic recovery. Therefore, yarns made from Elastane, a flexible synthetic copolymer, are commonly embedded into these fabrics during the knitting process. While Elastane improves elastic recovery, it limits the ability of natural fiber textiles to be recycled or decomposed.
This paper proposes a sustainable alternative to Elastane-blended textiles by 3D printing flexible compostable filaments onto natural knitted textiles. The 3D-printed structures improve elastic recovery and allow degradation of the textiles in industrial compost facilities.
To test the impact of 3D printing structures on elastic recovery, we 3D printed a square grid pattern with varying thicknesses on 100% cotton knit fabrics. Three compostable flexible filaments were printed onto three fabrics made of different knit structures. We developed a special jig containing a thin foam sheet underneath the textile to enhance the adhesion of the printed material. All samples were tested using a continuous rate of extension (CRE) machine, according to the industry test ASTM D4964 standard for tension and elongation of elastic fabrics. In addition, we tested the degradation of the textiles using a home composting device. After selecting the best-performing material and knit structure, we 3D printed auxetic patterns to examine the effect of the geometry on the elastic recovery.
The results show that Biocirflex filament by Balena performs the best among the tested materials. Using this material, we created a case study of Yoga pants in which auxetic patterns are printed to enhance the elastic recovery of the knitted fabrics. This research aims to contribute to the fields of textiles and additive manufacturing by finding sustainable ways to create elastic textiles using 3D printing.

Keywords: knitted textiles, elastic textiles, additive manufacturing, FDM, 3D printing, compostable textiles, sustainable textile, auxetic patterns, elastic recovery

*Speaker

Thin layers on textiles via digital application

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Textile coatings and laminates are used in many industries, from transport to medicine. For coated textiles, an emulsion or solvent-based paste is applied to the textile, which requires drying and curing after application - an ernergy intensive process. For laminated textiles, not only does the membrane need to be manufactured seperately, but additional glues are needed, increasing the complexity the final product. In all these cases, the textile is always treated roll-to-roll, over the full width. However, in many cases, the coating is not needed on the full textile; especially in outdoor and medical textiles, a partial coating would be preferable.
We introduce a new method of applying thin layers of thermoplastic coating material in a fully digital process, which allows a patterned application of the coating material. This makes additional drying steps, the use of solvents and glues superfluous and results in a closed layer of variable thickness. For this process, a standard 3D printer with a modified nozzle is used, which provides small-scale proof-of-concept. Parameters for application and their influence on tensile properties as well as waterproofness are discussed. Examples of different textiles with a printed coating are shown.
The IGF project 21723N/1 "Thermoresponsive Mikrogel-Membran" of the Research Association Forschungskuratorium Textil e. V., Reinhardtstraße 14-16, 10117 Berlin was funded within the framework of the programme for the promotion of industrial joint research IGF by the Federal Ministry for Economic Affairs and Climate Action (BMWK) on the basis of a resolution of the German Bundestag.

Keywords: coating, membrane, waterproof

*Speaker

Investigate the Hot Air Welding Process Parameters for Long Lasting Attachment of 3D Prints with Textiles

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The application fields of 3D printed textile related products depend on the connection bond or stitch between the print preform and the textile. Hot air welding as one method of bonding the 3D printed thermoplastic preforms with the textile has investigated in this research. The hot air temperature, the air flow rate, the material feed rate and the air pressure are the main process parameter those considered for their combined and separate effect. The optimization result used to create long lasting connection. The prints were produced from poly lactic acid (PLA) using Original Prusa I3 MK3 3D printer on Kevlar twill woven fabric. The samples were subjected to a 180○ peel test according to the DIN EN ISO 8510-2 test standard of flexible bonded to rigid test specimen assembly for the full detachment of the prints from the fabric. The result revealed that the maximum strength is found at the expense of high air temperature, maximum air flow rate, minimum material delivery rate and minimum air pressure. This means maximum volume (l/min) of the hottest air flows on the slowly sliding 3D printed thermoplastic plates which then results in deep diffusion in to the textile porous and gaps between threads when fused by the rollers during delivery. The researchers of this study have considered the production cost by optimizing the process parameters without compromising the long lasting connection effect. In general, the delivery or feed rate is found the most significant of all factors in the bonding strength of the hot air sealed 3D printed plates with the textile. The micrograph analysis also showed the extent of the thermoplastic material diffusion and its bonding with the fibers of the Kevlar woven fabrics.

Keywords: adhesion, hot air welding, process parameters, 3D printing, material diffusion, peel force

*Speaker

16- Medical textiles, tissue engineering, implants

Knitted covers for compression therapy of amputated limbs

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Compression therapy can be applied to the treatment of amputated limbs in order to correct stump formation, to repair scars as well as to reduce phantom pain. It is a wide range of reasons for a limb amputation, like traffic accidents or industrial and home injuries, burns, diabetes, etc. The number of amputations increases especially during times of war. Conducted research showed, that compression covers knitted by combining elastomeric yarns with other functional yarns can be successfully used for compression therapy of amputated limbs. Twenty-four variants of knitted structures were developed for compression covers of amputated limbs by changing knitting pattern and two main knitting parameters: the feeding speed of the elastomeric inlay-yarn and the course density. Tubular compression covers were knitted on a circular weft-knitting machine. 20 tex cotton yarn and 4.4 tex textured polyamide yarn with 2.2 tex polyurethane core were used for the plated ground structure, and the same textured polyamide yarn with 2.2 tex polyurethane core was used as the elastomeric inlay-yarn. It was found that feeding speed of elastomeric inlay-yarn has insignificant influence on the compression when the cover is used in the limits of low elongation (up to 50 %). Therefore, this factor can be eliminated when designing weft-knitted compression covers. While the influence of the second parameter - the course density on the compression is significant. This influence has the linear character: as the loop density increases, the generated compression increases as well. This research also confirmed that, in the area of low elongations (for elastomeric knits up to the 50 %), generated compression linearly depends on the elongation, which appears due to the difference between the circumferences of a compression cover and a limb.

Keywords: compression therapy, amputated limb, knit, elongation.

*Speaker

An innovative approach based on electrospun wool keratin scaffolds added with gold nanoparticles for bone regeneration

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Recovery and valorisation of biopolymers obtained from cheap and renewable sources have an important impact on biomedical applications. Among all, keratin is a cysteine-rich protein that can be extracted from various sources, including low-cost, renewable and abundant biosources such as raw wool. Wool keratin is biocompatible, biodegradable, bioresorbable, non-immunogenic, does not induce inflammatory responses, and improves cellular adhesion. In regenerative medicine, one of the major issues is the repair and reconstruction of bone defects. This research work focuses on the development and characterization of scaffolds composed of keratin extracted from waste wool fibres added with gold nanoparticles for bone repair and regeneration. To better mimic the composition and behaviour of bone tissue, the electrospinning technique is used to obtain nanofibrous membranes with a high surface-to-volume ratio. Furthermore, the addition of gold nanoparticles gives higher antibacterial properties to the bio-based membranes. The keratin-based scaffolds are characterized in terms of mechanical properties, biocompatibility and antibacterial activity. Biocompatibility is evaluated by performing cell viability tests on human osteoblast-like SaOs-2 cells. The presence of gold nanoparticles in keratin-based scaffolds promotes cell growth on the surface of the scaffolds and also reduces the early process of bacterial adhesion (after 3h) of Gram-positive *Staphylococcus aureus* and Gram-negative *Escherichia coli* bacteria. Hence, the nanofibrous keratin-based membranes can play a crucial role in tissue engineering, representing a promising alternative to the conventional use of bone grafts for bone regeneration. Further studies will be performed to better evaluate their potential and their antibacterial properties.

Keywords: tissue engineering, wool keratin, electrospinning

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Digitalization in compression stockings development for people with special needs

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Compression therapy with a textile elastic product, that creates pressure on the stump is a method to prevent swelling, correct stump formation, repair the scars, and reduce phantom pain for an amputee. The quality of such a product depends on its compliance with the shape and size of a particular patient's limb and the distribution of pressure created by the product along the limb. 4D scanning is prominent in assessing the girths and lengths of the body parts and studying the interaction between the compression clothes and the body. The new concept for the development of compression stockings is presented in this work. The limb scan mesh cloud created in MOVE4D system was used for size measurements and analytical dependencies of the leg's circumference and average radius on the leg's sites were established. The study results for 4 volunteers and two compression class stockings allow us to evaluate the conformity of products: The obtained results show, that the used stockings fit better for the second volunteer. The elastic properties of knitted fabrics at different levels were also studied to investigate a factor providing graduate pressure. All the results were used to create a stocking model that fits the limb well.

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Keywords: compression stocking, 4D scan, limb shape and size, extensibility, analytical model, prototyping

*Speaker

Machine Embroidery for Biomedical Applications

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Embroidery has evolved from a decorative craft to a major area of interest in technical textiles and is already showing considerable potential in a variety of applications, including the creation of complex mesh structures for lightweight construction or active heating and sensor integration for smart textiles. Beyond technical applications, these free-standing embroidered structures promise advances in fields such as biomedical applications and tissue engineering.

The advantages of embroidery-based mesh fabrication over competing textile technologies include the ability to create smooth or soft edges, precise control over pore size, and the targeted integration of reinforced areas that mimic the biomechanical properties of biological tissues. In addition, embroidery technology enables the creation of 3D curved structures that can be adapted to the geometries over which the curved mesh is to be draped. In addition, embroidered meshes can be made from a variety of materials, including biodegradable and non-biodegradable filaments and combinations thereof.

This presentation will provide an overview of how mechanical and geometric properties can be tailored compared to conventional meshes widely used in the medical field. In addition, an insight will be given into how pore sizes can be specifically tuned and analyzed to create optimal conditions for biomedical applications. A special focus will be on the production of 3D textiles by embroidery techniques, highlighting their advantages in surgical contexts.

Keywords: machine embroidery, medical textiles

*Speaker

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Plasma-Treated Bacterial Nanocellulose-Lignin Composites for Neuralgia Implants

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This research envisages the use of bacterial nanocellulose (BNC) as a biomaterial for implants to mitigate neuralgias, focusing on the material's inherent limitations. BNC is widely valued for its excellent mechanical properties, ease of modification, and non-anthropogenic degradability. However, its absent electrical conductivity, insufficient antimicrobial activity, and weak interaction with neural tissues restrict its application as a neural implant. To overcome these challenges, lignin/glycerine was incorporated into BNC, and a dielectric barrier discharge (DBD) plasma surface treatment was applied to enhance biocompatibility and improve integration with neural tissues. Plasma treatment is known to modify surface characteristics, namely hydrophilicity and protein adsorption, facilitating cell adhesion and reducing immune response.

The incorporation of lignin and glycerine prior and after DBD-plasma treatment aims to optimise BNC as a neural implant. Different dosages of DBD-plasma treatment (5, 10, and 15 kW/min/m^2) were applied, improving the cytocompatibility of L929 fibroblasts and BNC suitability for biomedical applications. Higher DBD-plasma dosages promoted surface etching, which increased the formation of a denser micro-hole structure and higher surface roughness, as confirmed through atomic force microscopy. Subsequently, the lowest DBD-plasma dosage (5 kW/min/m^2) was selected for further functionalisation of wet and dry samples, DBD treated and untreated, using glycerine (3 wt%) and/or lignin (3 wt%). Morphological characteristics (scanning electron microscopy), hydrophilicity (contact angle), and antimicrobial activity were evaluated. The DBD-plasma treatment on never-dried BNC exhibits greater lignin uptake. The DBD-post-treatment of the functionalised samples led to an increase in the hydrophilicity. The combination of lignin and glycerine considerably improved antimicrobial activity against *Pseudomonas aeruginosa*. Therefore, DBD-plasma-assisted functionalisation of BNC with lignin/glycerine improved implant cellular growth and enhanced the material's antimicrobial properties, making it a promising candidate for neuralgia treatment applications.

Keywords: bacterial nanocellulose, kraft lignin, DBD-plasma, L929 fibroblast cells, neuralgia, im-

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plant

Green Wound Dressing Development

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Nowadays, the use of nanofibers in the wound dressing application is quite usual. In current development we aimed to produce a wound dressing combined properties of wound healing and the eco-conception regarding the process development.
In this regard, a special selection of wound dressing components has been done in order to be as green as possible. Therefore, based on the literature review, the greenest one as polymer, was Polycaprolactone. To obtain good properties in terms of hydrophilicity, this initial polymer was combined with gelatin obtained from fish bones.
Different materials were evaluated to be used as active components, from Manuka honey to Curcuma. Finally, based on the literature review, we selected an active component directly produced in nature, the Allicin. Allicin is the active component that presents, as it has been confirmed in the literature, a good behavior in terms of anti-bacterial and antioxidant activities. Allicin is directly produced from garlic.
To obtain a regular structure of nanofibers, Taguchi DOE has been used to define the good electro-spinning conditions.
In addition to producing nano-sized fibers, we explored various fiber shapes and compositions. This included creating single nano-fibres made from polycaprolactone, bi-component fibers combining polycaprolactone and gelatin, and core-sheath nano-fibers with active components selectively positioned either within the mono nano-fibres, in the core, or in the sheath.
The evaluation keys for the Taguchi DOE was, the diameter and its CV%, the number of beads and its CV% and the production efficiency in terms of beads and fibers percentage.
Regarding the anti-bacterial activity, aureus staphylococcus and e-coli bacteria has been tested and the results presented are significantly encouraging.

Keywords: wound dressing, electro spinning, nanofilament, natural active product, allicin, PCL, gelatin

*Speaker

Load-Bearing Bone Substitution Material Utilizing Textile Building Principles of Glass Sponge Euplectella Aspergillum

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Living organisms and their tissues have a hierarchical structure from the nano to the macro level. This intricate interplay across hierarchical levels enables for property profiles that are perfectly adapted to the specific habitats and behaviors, all while minimizing material usage. Bone tissue, for example, consists of hierarchical structures of collagen fiber-reinforced hydroxyapatite (HAp), created by osteoblasts. This structure provides a combination of, high strength, adequate ductility, and regenerative capacity. To effectively substitute bone, functional biomaterials must reflect this key property profile including biomimetic pore sizes, mechanical properties and biocompatibility. to date, technical solutions have required a compromise between biological and mechanical properties, as established methods and materials are not capable of mapping both at the same time. The high proportion of cellular components in bone makes it challenging to abstract and imitate its structure through engineering. yet this is essential for developing an ideal bone substitution material. We intend to close this gap by researching a biomimetic approach based on the glass sponge Euplectella aspergillum. This deep-sea dweller is also hierarchically structured and has design principles that generate bone-like properties, such as high compressive strength, stiffness and ductility. At the same time, it consists nearly fully of inorganic materials. Eup. Asp. utilizes a combination of building principles including fiber-reinforced composites, 3D weaving structures, and concentric glassfibers with organic lamellae to enable crack deflection. Here, we present results on impact of these principles on mechanical properties of the macroscopic structure via modelling and computational methods as well as utilization of fiber additive manufacturing (FAM) approaches.

Keywords: glass fiber, glass sponge, Euplectella Aspergillum, bone substitute, Hierarchical Structure

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Fiber-based Soft Robotic Cardiac Biomedical Device for Treatment of Heart Failure

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FIBROHEART aims to explore a novel therapeutic strategy for managing heart failure by developing a 5D biomimetically engineered fiber-based system with intrinsic heart-like properties. This innovative approach minimizes interference with the cardiovascular system while striving to preserve the structural integrity of the heart to the maximum extent possible. Unlike conventional techniques, FIBROHEART functions by emulating physiological processes without necessitating direct contact with blood. Its key innovation lies in the incorporation of liquid crystal elastomer (LCE) fibers into an active biomimetic 3D fiber structure. The FIBROHEART system, incorporating integrated polymer sensor and actuator networks, will be placed around the native heart, serving both as a supportive scaffold and as a cardiac pump. This approach is anticipated to confer several benefits, including a minimal invasive surgical procedure, diminished risk of complications, and improved long-term quality of life for patients. The research focusses on numerical simulation to mimic the heart's physiology and develop a design of the fiber-based system. It also explores stimuli-responsive LCE materials and advanced spinning technology for their production. Innovative methods and concepts will be developed to manufacture patient-specific 3D fiber-based structures using biomimetic, programmable LCE fibers. Additionally, a fiber-based direct cardiac compression device will be designed to synchronize with the heart rhythm, providing continuous support to cardiac function throughout the entire cardiac cycle. The research will explore advanced minimal invasive surgical techniques, contributing to the advancement of soft robotic biomedical engineering for heart failure treatment. FIBROHEART offers a promising alternative to current ventricular assist devices and total artificial heart implants. This presentation will outline the core concepts of FIBROHEART and showcase first results regarding generation of LCE fibers and evaluation of their biocompatibility.

Keywords: tissue engineering, textile heart, artificial muscle, liquid crystal elastomer, soft robotic

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Tailoring Bioactive Glass Fiber Composition for Targeted Cell Behavior: A Promising Approach in Regenerative Medicine

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Silicate bioactive glasses are extensively utilized in biomedical applications, including bone regeneration, dental restoration, tissue engineering, and drug delivery, owing to their capacity to bond with natural bone, release therapeutic ions, and stimulate cell proliferation. Obtaining continuous fibers from these materials is difficult due to the thermal properties of the melt. The study describes three exemplarily glass compositions suitable for the production of endless fibers and presents results on cell response for mouse calvarial pre-osteoblasts (MC3T3-E1) and mouse myoblast cells (C2C12). Four bioactive glass compositions (S53P4, 13-93, 1-06, and 18-06) were prepared as cuboid specimens. Key thermal parameters were evaluated, including the melt processing interval where glass melt has ideal viscosity (10^3 to 10^4 Pa·s) for fiber extrusion. Good fiber formation capability was observed in all glasses except S53P4. Fibers (10-20 μm diameter) were produced, collected, and cut into 90 cm bundles. For cytotoxicity evaluation, MC3T3-E1 cells were seeded and incubated. For differentiation analysis, C2C12 mouse myoblasts were cultured. Samples were prepared for SEM imaging and stained with Calcein AM for visualization. Cell viability was maintained across all fiber surfaces for the seeded cells. Within 24 hours of exposure, MC3T3-E1 cells demonstrated notable elongation along the glass fibers extending up to 180 μm. The cultivation of C2C12 myoblasts induced considerable glass corrosion, most prominently in glass 1-06, resulting in the apparent formation of hydroxyapatite on the fiber surface. These bioglass fibers promoted significant myoblast elongation. Conversely, C2C12 cells cultured on the slowly degrading glass 18-06 exhibited a significant decrease in surface area and assumed a spherical shape, suggesting an unfavorable cellular response to this particular substrate. The experimental results clearly demonstrate that the composition of bioactive glass plays a critical role in influencing the behavior of different cell types. Variations in cellular responses, such as changes in elongation and reductions in surface area, observed across various glass compositions underscore the need to tailor glass formulations to achieve specific biological outcomes. These findings are especially encouraging for the development of fiber-based biomaterials incorporating bioactive glasses. The adaptability of these materials in supporting diverse

*Speaker

cell types and eliciting targeted cellular responses positions them as promising candidates for a wide range of biomedical applications, including both hard and soft tissue regeneration.

Keywords: Bioactive glass fibers, Regenerative medicine, In vitro testing

17- Apparel science and production technology

Ultrasonic-Assisted Interfiber Autohesion in Meltblown Nonwoven Structures

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Autohesion is a unique class of adhesion that enables the bonding of two identical surfaces by establishing intimate contact at interfaces. Creating intimacy between two identical surfaces poses a challenging task, often constrained by the presence of surface roughness and chemical heterogeneity. To surmount this challenge, we document a variety of autohesive traits in polypropylene-based meltblown nonwovens, accomplished through a facile, scalable, energy-efficient, and cost-effective ultrasonic bonding process. The mean work of autohesion for a single polypropylene bond, serving as a figure of merit, has been computed by extending the classical Johnson -Kendall- Roberts (JKR) theory by factoring in peel strength along with key fiber and structural parameters of nonwoven materials. Achieving a high figure of merit in ultrasonically bonded nonwovens hinges on the synergistic interplay of key process parameters, including static force, power, and welding speed, with the fiber and structural properties acting in concert. In this regard, peel-off force analysis has also been conducted on a series of twenty-seven ultrasonically bonded meltblown nonwovens prepared using a 33 full factorial design by systematically varying process parameters (static force, power, and welding speed) across three levels and extension rate. X-ray microcomputed tomography (microCT) analysis has been performed on select ultrasonically bonded nonwoven samples to discern their bulk characteristics. A broad spectrum of mean work of autohesion for a single polypropylene bond, ranging from 1.88 to 9.93 J/m^2, has been ascertained by modulating key process parameters. This study offers profound insights into optimizing autohesion in nonwovens, thereby advancing their potential applications in technical and industrial textiles, including filtration systems, automotive components, and medical disposables.

Keywords: autohesion, ultrasonic bonding, nonwoven, peel off, work of autohesion

*Speaker

Optimizing Apparel Production with Web-Based Line Balancing

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Digital transformation empowers apparel manufacturing by enhancing efficiency and streamlining operations, providing a competitive advantage. This study introduces a web-based digital line balancing program utilizing the parallel assignment method to optimize production processes and improve line efficiency. The system integrates Enterprise Resource Planning and Manufacturing Execution Systems, combining order details (styles, quantities, delivery dates) from ERP with sewing operations, Standard Minute Values, and task dependencies from MES via API connections for comprehensive system alignment.

The proposed system employs a parallel station-based, position-weighted optimization approach for dynamic workload balancing. Tasks are distributed based on takt time, leading to improved cycle times and increased production speed. The integration of SMV values enables accurate task duration predictions, supporting effective resource allocation and production planning. Dynamic SMV values, calculated from historical performance data obtained from process monitoring devices, facilitate real-time line balancing adapted to shop floor conditions.

Task assignments and machine placements are optimized following lean manufacturing's continuous flow principle. This approach supports the system's decision-making process, aligning workshop activities with production objectives. The web-based platform combines digital balancing with KPI-driven reactive adjustments, addressing both predictive planning and real-time operational challenges.

Preliminary results demonstrate significant improvements in production efficiency, bottleneck reduction, and order fulfillment accuracy. This innovative integration of ERP, MES, and digital line balancing represents a transformative application of Industry 4.0 principles, offering a scalable and efficient framework for ready-made garment production.

Keywords: apparel manufacturing, Industry 4.0, digitalization, real-time process monitoring, digital lean line balancing, production efficiency.

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Impact of Lean Operations on the Nigerian Garment Manufacturing Performance

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Lean manufacturing techniques have played a significant role in the garment manufacturing industries and enhance the competitiveness of their products in the local and global markets. The continued daily striving of the ready-to-wear garments produced in Nigeria to compete with their international counterparts calls for academic attention. Therefore, the purpose of this paper is to determine the impact of lean manufacturing techniques on the performance of selected small- and medium-scale garment industries in Nigeria. The study employed qualitative and quantitative data collection for this study. The process time and floor layout are studied and mapped using Value Stream Mapping. The qualitative data were collected through direct observation and personal interview. On the other hand, the quantitative data, such as cycle time, production lead time, available time, and break time, were collected through time study and the companies' records. The performance indicators of the two industries were measured before and after the implementation of lean manufacturing techniques. Findings indicate that the effective application of LM tools leads to significant improvements in key performance indicators (KPIs). Specifically, in the Episode and Evergreen garment industries, the production lead time, work in process (WIP), non-value-added time, and defects were reduced by *68% and 48%, 66% and 75%, 2% and 6%, and 20% and 29%,* respectively. On the other hand, the assembly line efficiency and quantity of garments produced per day improved by 40% and 48% and 48% and 50%, respectively. It is noteworthy to state that the implementation of LM tools has improved the Episode and Evergreen garment industries performance in terms of quality, production lead time (PLT), cost, and prompt delivery of products.

Keywords: lean operation, Nigerian garment industry, value stream mapping, operations performance, ready-to-wear garment.

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Effect of sewing parameters on the performance of seams in flat strong tightly woven straps

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This paper examines the impact of sewing parameters on the performance of webbing strap seams, focusing on enhancing seam strength, efficiency, and durability. Webbing straps—strong, tightly woven fabrics—are widely used in applications ranging from sports and automotive safety to military and transportation equipment. Sewing patterns, such as straight lines, Z-lines, box, and X-box patterns, are selected based on specific performance requirements, with thread type, stitch length, and tension playing crucial roles. The study systematically investigates how these parameters affect seam performance using a high-strength polyester webbing (25mm wide, 1mm thick) and two types of durable polyester threads (70 and 135 Tex). Seams were created with a Dürkopp Adler M-Type Delta D867 lockstitch machine and were tested for tensile properties, following ISO 13935 standards, using a Zwick Universal testing machine. Key performance metrics, including maximum force, elongation at maximum force, force at break, and elongation at break, were analyzed to assess the relationship between sewing parameters and seam behavior. The findings reveal that specific parameters - particularly the sewing pattern and thread thickness - significantly influence seam strength and efficiency. For instance, straight-line sewing patterns with thicker threads demonstrated enhanced tensile strength. Additionally, variations in sewing diagram and thread density were found to directly impact the seam's load-bearing capacity and deformation resistance. These results underline the importance of selecting optimal sewing configurations to meet application-specific demands. Statistical modeling of these relationships further allows for fine-tuning seam performance by identifying the most impactful sewing parameters and their ideal settings. Future studies will build on these insights by incorporating a broader range of webbing characteristics and manufacturing conditions, aiming to further enhance the reliability and durability of webbing straps across diverse technical applications.

Keywords: webbing straps, seam strength, sewing parameters, tensile performance, sewing patterns, thread density, lockstitch sewing, technical textile, durability optimization, design of experiments (DOE).

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Impacts of sewn seams on the air permeability of spacer fabrics with conventional and spacer stitching technology

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Spacer fabrics (SF) are distinguished by their unique three-dimensional architecture, which consists of two outer layers interconnected by spacer yarns. This structure imparts exceptional properties such as enhanced pressure elasticity, superior water vapor permeability, and excellent air permeability, making SFs highly versatile for a wide range of applications. However, the sewing process used in fabricating spacer fabrics presents significant challenges in preserving their three-dimensional structure and functionality. Sewing inherently introduces compressions along stitch lines, leading to localized deformation that compromises the fabric's thickness, mechanical integrity, and permeability properties. This study investigates the impact of sewn seams on the air permeability of spacer fabrics. Stitched samples were prepared using two methods: conventional sewing (Dürkopp Adler M-Type) and a spacer stitching technology developed at ITM, TU Dresden. Unlike conventional methods, the spacer stitching technology minimizes compression during stitching, enabling uncompressed seam formation in 3D textile assemblies, including spacer fabrics. Air permeability testing was conducted using the FX 3300 Air Permeability Tester (Textest AG, Switzerland). Two airflow conditions were evaluated: perpendicular to the fabric layer (through stitch holes) and tangential to the fabric layer (perpendicular to stitches). Results revealed that stitching methods influence the air permeability of spacer fabrics. While system leakages during testing were identified and addressed through corrective measures, the uncompressed seam formation provided valuable insights into optimizing air permeability performance. Ongoing investigations aim to refine testing procedures and offer a more comprehensive comparative analysis of sewing impacts on spacer fabrics air permeability.

Keywords: air permeability, sewing, spacer stitching

*Speaker

18- CAD/CAE, modelling and simulation in textile and apparel

Numerical simulation of the geometrical and mechanical properties of automotive seat belt webbing

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Seat belt webbing is an important part of the automotive seat belt system, which is well-known as the most successful protective device for vehicle occupants, reducing the fatality rate by approximately 45%. Therefore, understanding the structure and mechanical behaviours of seat belt webbing is essential. This work, using Algorithm-Aided Design and the Finite Element-based Method, is aimed at studying the geometrical and mechanical properties of automotive seat belt webbing.
First, the study modelled the structures of woven seat belt webbing at the yarn level with input parameters such as yarn material properties (e.g., density, Young's modulus, Poisson's ratio, yield stress, tangent modulus, etc.), weaving pattern, and weave density. Polyester yarn and nylon yarn were selected as representative yarn materials for seat belt webbing, as they are the most commonly used in the market. The seat belt patterns were produced using plain, twill and satin weaves. Then, these woven seat belt webbing models were simulated to determine the mechanical behaviour under tensile and shear loading. In parallel, the experiments were also performed to evaluate the reliability of the simulation process. The seat belt webbings were produced by weaving machines, and their structure and mechanical properties were analysed using a digital microscope and a tensile machine.
The results demonstrate a strong correlation between the simulation data and experimental data, confirming the effectiveness of this method for modelling the mechanical behaviours of seat belt webbing. The factors contributing to the high breaking strength of seat belt webbing include the use of polyester yarn, the 2/2 twill weave pattern, and a high weave density. This research offers a valuable methodology for the development of innovative yarn materials and textile structures, such as auxetic materials, to enhance the functionality of seat belt webbing in future research.

Keywords: modelling and simulation in textile, finite element based method, algorithm aided design, automotive seat belt webbing.

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Numerical and Experimental Study on Mechanical Behaviour of Multifilament Woven Structures

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Multifilament woven structures, made of warp and weft yarns with multiple textile strands, exhibit complex mechanical behaviour due to their anisotropic nature. To accurately simulate the mechanical behaviour of these woven fabrics, all fibres in the samples need to be modelled, with a special focus on contact friction interactions. Traditional methods often struggle to capture fibre interactions, making advanced computational modelling like multiscale modelling and finite element-based methods (FEM) essential for analyzing mechanical properties.

This study investigates the mechanical behaviour of multifilament woven structures through a combination of numerical simulations and experimental analyses. The overall mechanical performance of the material is assessed by integrating both microscopic and macroscopic modelling. At the microscale, individual fibres are modelled to capture their unique properties. The simulation then progresses to the macroscale, where the entire fabric structure is modelled. At this scale, a unit cell of plain-woven fabric is created to evaluate how the yarn arrangement within the fabric influences the material's global mechanical behaviour. The numerical analysis was conducted using the finite element-based model. Fibre and yarn geometries were measured with microscopy, and experimental tests were performed to complement and validate the numerical models.

The simulation results closely align with experimental data, providing insights into the influence of microstructural features such as the properties, arrangement of individual fibres and weave geometry on the overall performance of woven structures. The findings highlight the importance of integrating computational and experimental methods to optimize the design and reliability of woven structures for demanding applications in industries like aerospace, automotive, and protection. This research contributes to the development of predictive models that can simulate the real-world behaviour of complex woven structures.

Keywords: numerical and experimental study, nultifilament woven structures, nechanical behaviour, nultiscale modelling, finite element-based method.

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Finite Element Modeling of Warp-Knitted Fabrics for Biomedical and Composite Applications

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Warp knitted fabrics are used in a variety of ways, including knitted garments, home textiles, medical textiles, technical fabrics, and non-crimp fabrics, enhancing their durability, functionality, and aesthetic appeal. However, when developing a finite element method (FEM) model for these types of fabrics, accurately creating the geometry of the warp knitted structure can be challenging. Careful approximation of the stitch geometry is essential, as it significantly influences the final simulation results. This paper presents an approach to develop the geometry of the warp-knitted fabric structure to better reflect reality.

To validate this approach, two FEM models are developed in LS-DYNA: one for a warp-knitted fabric for a medical application and another for a unidirectional non-crimp fabric, both of which incorporate a pillar stitch type. The warp-knitted fabric is utilized as an attachment tube for the fixation of muscle tissue during hip replacement surgery. A tensile test is conducted on one half of the warp-knitted fabric, and the results are compared with the simulation outcomes for validation. Additionally, the attachment tube is fitted over a prosthetic and visually compared with real-time experiment.

The non-crimp fabric is used as a reinforcement for a composite material. A hemisphere drape test is performed on the non-crimp fabric both in real life and through simulation. Finally, a visual comparison is made to assess how the pillar stitches in the fabric behave during the draping process.

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Keywords: FEM model, non crimp fabrics, pillar stich, warp knitted fabric

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Local deformation of spacer monofilaments in 3D mesh fabric under compression

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Three-dimensional spacer fabric has been integrated into automotive seat ventilation systems due to its excellent cushioning and ventilating properties. This one-piece sandwich structure has standing post-buckled spacer monofilaments of varied curvature and torsion throughout the length. When subjected to compression, spacer monofilaments experience compressive strain on one side and tensile strain on the other side. Unlike the fixed neutral axis passing through the centroid of a beam in pure bending, the neutral axis of a spacer monofilament does not pass through the centroid, showing a nonuniform response to applied loads and twisting behavior along its length. This paper analyzes the mechanical behavior of spacer monofilaments of a typical 3D mesh fabric by examining the position and rotation of neutral axis along their length through a finite element (FE) simulation based on micro X-ray computed tomography reconstruction. It is found that the neutral axis deviates from the centroid of monofilaments. The compressive area occupies a larger portion than the tensile area, making compressive regions more susceptible to failure. The numerical simulations also show that more vertical spacer monofilaments exhibit sharper fluctuations in neutral axis deviation along their length. The neutral axis of vertical spacer monofilaments can rotate up to three times that of the inclined ones. Hence, more vertical monofilaments have greater curvature change and less torsion variation than more inclined ones. This indicates that spacer monofilaments absorb energy through not only bending but also twisting deformation. The largest twisting occurs nearly 2 mm from the endpoints, where Von Mises Stress (VMS) is lowest, while the highest VMS is found in the intermediate part of the spacer monofilament. The internal stresses from twisting are below the material's yield strength. It is considered that twisting of monofilaments enhances fabric compression resilience to avoid damaging monofilaments.

Keywords: finite element model, spacer fabric, monofilament, neutral axis, centroid

*Speaker

Evaluation of Pressure Values of Real and Virtual Compression Garments with Adhesive Stripes

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Virtual prototyping with 3D technology provides valuable insights into comfort and fit through strain, stress, and pressure distribution maps, making it a valuable tool in garment design and development. The aim of this research is to compare pressure values of compression sleeves with adhesive stripes using virtual fit technology and real garment pressure testing.
Knitted fabric and adhesive polyurethane film were used to design virtual and real compression sleeves with "Y" and "X" shaped film elements, purposely placed according to Kinesio taping techniques. Polyurethane film covered 40% of the product area. The garment pattern design and 3D visualization were accomplished using Modaris (CAD Lectra) software. The pressure values of virtual garments were determined by applying tensile testing results and reducing pattern of the garment in transverse direction to reach 20 mmHg compression that ensured the 1st compression class when primed on a cylinder of 100 mm diameter. Virtual sleeves were fitted on virtual cylinders of various diameters to determine the differences in the pressure values as the size of the body changes. The pressure values were calculated by the Laplace law, using a radius of cylinder and the strain of the material in transverse direction at the garment local points. Compression sleeves were fitted on 100 mm diameter cylinder imitating a curvature of a human limb. FlexiForce sensors were used for direct measurements and determination of the pressure exerted by real garments.
The evaluation and comparison of virtual and real pressure results allows to study the possibilities of prediction and optimization of compression values of functional products using 3D virtual fitting technologies. Application of virtual fit technology in compression garments development process can ensure the particular pressure value in the certain zone of the functional garment and evaluate the change in compression properties as the body dimensions' change.

Keywords: virtual fit technology, 3D CAD, Modaris 3D, pressure sensor, compression garments, adhesive technologies

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Filament Wound Composite Analysis: Comparison Using the NASA Multiscale Analysis Tool (NASMAT) and Finite Element Analysis

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Fiber reinforced composite materials, owing to their tailorable thermomechanical and functional properties, allow one to produce a structure that is stronger, stiffer, and lighter than its metal counterpart while performing the same function, yielding a more efficient structure. This not only allows for the improvement of current technologies like aircraft structures, but also enables new technologies like gaseous hydrogen storage for mobility applications, which are otherwise impractical when manufactured using traditional metals due to weight and space restrictions or material embrittlement. However, the use of composites imposes greater design and manufacturing challenges on an engineer, since they are is heterogenous, having a distinct structure across multiple length scale, behave generally anisotropically at the structural level and require complex manufacturing and processing methods. Capturing this complex behavior requires detailed numerical simulations, including the modeling of microstructural features like undulations, voids, and fiber alignment. In this paper, multiple repeating unit cells (RUCs), representing filament wound composites, are developed (via a script provided in the Appendix) and analyzed. The refinement of these RUCs is varied, and the analyses are performed using both the Abaqus finite element software and the NASA Multiscale Analysis Tool (NASMAT). A study is undertaken to compare the predicted effective elastic properties of the wound RUC to a laminate representation of the wound RUC, which neglects the undulations. Additionally, two different sets of periodic boundary conditions (PBCs) have been examined. One approximates the real boundary conditions using a standard approach and the other represents the PBCs exactly through the use of an offset. Lastly, a comparison of the local elastic stress fields is made among the models and approaches. Since wound structures are often approximated as laminated structures, it is important to understand the degree to which this assumption is valid, namely by first comparing the elastic constants and local elastic fields. This will provide, on the one hand, information concerning the bulk mechanical behavior and, on the other hand, insights concerning local load distributions and likely damage initiation sites.

Keywords: filament Winding, undulation, NASMAT, FEM

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Modeling and Simulating Smocks of Apparel in a Dynamic Environment

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Smock has been widely employed on the waist of apparel design for its distinctive aesthetics. However, when worn in motion, it will undergo deformation triggered by pressure, which can compromise the aesthetics. This study aims to explore the relationship between deformation and pressure of smock in dynamic environment. To reach this objective, the study first constructed a 3D cross-section model for smock on the waistline of a human avatar in a standing position. Then, by applying pressure conditions representative of typical movement as level walking, the finite element model (FEM) of the cross-sectional outlines was conducted to obtain the displacements occurring on the smock. By analyzing the resulting displacements, the functional relationship among displacement, pressure and angle for the waist of smock was determined. There are two contributions out of this work: (1) proposing a functional relationship among displacement, pressure and angle for the waist of smock based on FEM, which provides a new method to identify the interaction of pressure and displacement for smock in dynamic environment. (2) This functional relationship can also guide the aesthetic design of the smock by controlling the textile pressure regarding the displacement.

Keywords: dynamic simulation, 3D Modeling, deformation, smock, finite element model

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The digital restoration and dynamic display system of the apparel in heritage painting based on evidence-based theory a case study of the admonitions of the instructress to the court ladies

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The Admonitions of the Instructress to the Court Ladies is a representative heritage painting from the Eastern Jin Dynasty in China, which depicts the female apparel in the Eastern Jin Dynasty, reflecting the tradition and life style of ancient times. However, due to factors such as long age, improper preservation and human-induced damage, the original work has lost, and only Tang Dynasty copies remain, while also suffering from varying degrees of damage. The aim of this study is to restore the apparel in this heritage painting by applying evidence-based theory and inherit these apparel by demonstrating the cultural and social context reflecting from these apparel. To reach this objective, this study applied literature research, site exploration and measurement and behavioral observation to collect the textual and visual evidences regarding the apparel from the Eastern Jin Dynasty in China, forming a comprehensive evidence-based framework. Then, by thoroughly analyzing the information in the framework and historical and cultural context of this artwork, the attributes of the apparel in the painting were refined and determined, and digital restoration models of these apparel were established through 3D clothing modeling. On this basis, a dynamic display system was further developed by employing animation technology and virtual reality (VR) to present the cultural and social background of the apparel. There are two main contributions from this work: (1) the implementation of evidence-based theory ensures the reliability and historical accuracy of the restoration process, providing important references for related restoration regarding heritage textiles; (2) the development of the dynamic display system allows a broader audience to understand and appreciate the ancient apparel, promoting the preservation and inheritance of the heritage textile.

Keywords: apparel, digital restoration, evidence, based theory, 3D modeling, dynamic display system, the admonitions of the instructress to the court ladies

*Speaker

Computational analysis of plain weft knitted fabrics for the study of air permeability and thermal conductivity

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In this work, the combined influence of both the properties including Air Permeability and Thermal Conductivity of knitted structures is analyzed. For this purpose, different plain weft knitted structures were developed by using multiple fibers (i.e. polyester, polypropylene, and acrylic) and of different yarn specifications (i.e. staple, mono & multifilament). The developed computational models were validated with the actual values of the fabrics extracted from image analysis and then used for the parametric analysis to evaluate the effect of structural parameters including stitch density and thickness over the air permeability and thermal conductivity of the fabrics.

Keywords: computational modelling, weft knitting, polyester, polypropylene, acrylic, air permeability, thermal conductivity.

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Assessment of the quality of clothing fit to the user‘s body in the virtual environment

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The paper attempts to assess the quality of clothing fit to the body in a virtual environment. This was done by discussing the use and operation of a 3D scanner and an open source CAD system. The default values of fabric drape coefficients used in virtual fitting programs do not allow for depicting the real image of clothing on the body.
The paper compares the drape of woman blouse represented as a scanned clothing (real) and its virtual simulations. The simulation of fabric drape of blouse with the same fabrics and clothing patterns in Bender was done by two methods. The concept of fabric formability (its default value and this from literature) as a physical and measurable representation of fabric drape, was used in the virtual space and its measurement method was proposed. The experiment shows what a challenge it is to assess the quality of clothing fit to the body in virtual space on the example of a given analysis to receive a right reproduction of clothing textile material in virtual environment.
Moreover the paper prove the importance of the need and proper way of definition of fabric model in clothing simulation enabling to reproduce the real fabric drape on the user's body.

Keywords: clothing fit, fabric drape coefficient, open source CAD system

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Modeling and Simulation of the Deformation Process in Woven Textiles Composed of Recycled Carbon Fibers

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An essential step in the production of textile semi-finished products for carbon fiber-reinforced composite components is the draping of the textile geometry into a three-dimensional surface body. During the draping of particularly complex geometries, errors can occur in the textile topology due to the limited axial deformability of the carbon fiber yarns. These defects limit the mechanical composite properties.

The incorporation of recycled carbon fibers (RCF) into friction-spun hybrid yarns allows for the alignment of fibers within the yarn, facilitating the creation of load-bearing thermoset composite structures. However, the mechanical properties of these yarns are not uniform; they exhibit stochastic behavior due to the characteristics of staple fiber yarns, including variations in RCF length and processing conditions. Furthermore, the movement of individual fibers within each yarn contributes to increased textile deformation. Taking these aspects into account, it is possible to develop new, intricate structures with enhanced properties.

It is essential to investigate how the variability of staple fibers affects the deformability of textiles. Additionally, a meso-scale model of the textile is developed based on its construction properties. While integrating the variability of yarn properties into the material model, Monte Carlo simulations of textile deformation are performed to identify critical areas within the draped textile. The results are compared with experimental data, demonstrating the applicability of the stochastic simulation approach.

Keywords: fem textile deformation draping simulation recycled carbon fibers stochastic

*Speaker

Auxetic structures for insole design according to feet pressure maps

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Auxetics is the general term used for auxetic materials, structures, or fabrics that exhibit a negative Poisson Ratio compared to conventional structures. Their specific properties as energy absorption, high shear stiffness, variable permeability, light-weight, etc, makes them attractive for a wide range of applications. These applications in the textile industry can be such as comfortable clothing or footwear products. Insoles, as part of footwear products, play a vital role in foot comfort and these properties can fit perfectly to design insoles based on auxetic structures. In this work an approach to model insole with re-entrant structures is conducted. Under compression loading these structures exhibit the negative Poisson's ratio (NPR). The compression loading is customized based on foot pressure maps generated from healthy participants. The additive manufacturing techniques offer the possibility to manufacture these insoles with the required mechanical properties according to the pressure area of the foot. The 3D printing process is based on Fused Deposition Modeling technology using PLA and TPU elastomeric material. To assure the stability of these structures, the 3D printed insoles Re-entrant (RE) structures have undergone compression tests. The results promise a great future for further development.

Keywords: auxetic structures, insoles, feet pressure maps, customization, 3D printing

*Speaker

Overview of Algorithms for Constructing Knittable 3D Graphs from CAD Models and Non-Developable Complex Geometries with Derived 2D Knitting Charts

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Flat knitting offers significant potential for demand-driven production and is particularly well-suited for various smart textile applications as well as the tailored fabrication of close-to-skin textiles with a high degree of technological integration. Despite these promising prospects, significant gaps remain in digital engineering and simulation using 3D CAD development environments. Processes and algorithms to bridge these gaps have been the focus of intensive international re-search for over a decade. The standardization of new digital processes is still under development, with no definitive timeline for completion.

Knittable polygon meshes are typically characterized by quad dominance, with uniform edge ratios representing rows of stitches (courses) and columns of stit-ches (wales). Increases and decreases in the mesh occur at topological singularities, which are generally represented by triangular polygons. Internationally, well-established methods for generating quad-dominant meshes—including vector field-based, graph-based, and hybrid approaches, as well as divers remeshing pi-pelines — are widely used for constructing knittable meshes.

The present paper provides a brief overview of the most important established methods and presents new research findings in the field of graph-based polygon mesh generation. Special focus is placed on the calculation and construction of fundamental computational geometries in the wale direction, referred to here as contours, which are essential for the graph-based targeted design of 3D knitted textiles. This work aims to contribute to the development of standardized digital processes by proposing novel methods for the construction of knittable 3D mes-hes and highlighting their application potential across various domains of textile production.

Keywords: 3D Knitting, Textile CAD, Knitting Charts, Mass Customization

*Speaker

Enhancing 3D Mesh Parameterization Model for Sewing Pattern Generation

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Computer graphics play a significant role in the virtual product development process, particularly with accurate and realistic visual feedback of designed garments draped on 3D human body mesh. The popular 3D design software enables users to iterate their garments interactively, both on a 3D mesh and in 2D sewing patterns. For body-tight clothing, the 3D design approach, based on the patch decomposition and following pattern parametrization, is predominantly preferred. Numerous methods have been proposed to compute optimal pattern designs through mesh flattening. However, the resulting contours deviate significantly from practical designs. The problem is that they don't rely on material properties and manufacturing requirements. This research is focused on automatic, skintight sewing pattern generation via 3D body mesh parameterization. We propose the general constraints for the sewing pattern shapes and analyze the limitations of the existing parameterization algorithms, which are standard in the computer graphics community. Our work discusses the tradeoffs between patterns that accurately match the body contours and common production patterns. The goal of our work is to provide guidelines on how to adapt the parameterization algorithms to make them more suitable for the sewing pattern generation of woven and knitting fabrics.

Keywords: pattern design, 3D mesh parameterization, manufacturing requirements, mesh flattening

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Is it possible to transform these carrier arrangements into one another?

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The realisation of stents for coronary or abdominal artery, as well as ship's ropes and buttonhole strands, is only possible through a modification of the laying paths during the braiding process. The advent of modern maypole braiding machines, equipped with continuously rotating horngears and controllable switches, has enabled the production of highly intricate braids comprising an arbitrary number of laying path alterations along the final product. It is essential to plan the individual switch operations with great care in order to avoid collisions. In this paper, we present a novel approach to mathematically verify whether two carrier arrangements can be converted into one another. To illustrate, consider a theoretical braiding machine with a single horngear. It is evident that the braiding pattern of two adjacent carriers cannot be converted into a pattern with a free slot between them. This incompatibility is not limited to a few combinations of carrier arrangements; it extends to numerous non-obvious combinations of carrier arrangements. Our novel algorithm runs on standard hardware, empowering users and scientists to design highly complex braids without the pitfall of attempting to create braids with incompatible carrier arrangements.

Keywords: carrier arrangement, path syntheses, maypole braiding, braiding program, graph theory, markov chain

*Speaker

Numerical simulations for prediction of the mechanical behaviour of medical compression stockings

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Medical compression stockings (MCS) are the most common treatment for lymphatic and venous diseases. Their unique structure is a combination of the weft knit (elastic and giving the shape of the product) and the inlay yarn (rigid and responsible for the compression). The areas with a greater presence of inlay yarn will be therefore stiffer and will exert greater compression. Nowadays numerical methods are the most promising for predicting the compression effect, combining digital twins of the limb and fabric.
This work focuses on developing a new MCS behaviour model and proposing a different approach for finite element simulations (digital twins). The new model, named hybrid, represents both components of the fabric structure at a local level, in a so-called unit cell. The unit cell, besides combining the behaviour of the weft knit (elastic) and inlay yarn (rigid), integrates the structural parameters that differ between compression zones (course and wale density, dimensions). All these parameters, mechanical and structural, are identified from experimental tests.
The numerical simulation is developed according to the hybrid model: the identified parameters of the unit cell are transferred to the finite elements. To validate the model, and the integration of the structural parameters, the sensitivity to inlay yarn density is studied. The simulations consist of placing the tubular MCS, with different densities but same dimensions, over a rigid cylinder with bigger diameter. The results confirm that the model is able to predict a greater compression in the regions with higher inlay yarn density.
Ongoing experimental tests recreate the same placement of the MCS over a rigid cylinder, and determine the compression with a pressure sensor inserted between the two. A good result correlation between experimental and simulations, will allow to validate the hybrid model for predicting the behaviour of MCS with simple geometries.

Keywords: medical compression stockings, knitted fabric, mechanical model, finite element simulation, pressure sensor

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Challenges and opportunities for modeling athletes' scan-knit compression apparel

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This study focuses on the challenges and opportunities for pressure modeling of scan-knit compression apparel. It aims to achieve custom-fit compression garments that provide the necessary compression across the body through scan technology and fabric mechanics. Athletes' precise body positions and anthropometric measurements were determined using a size-Stream scanner, a non-contact 3D body scanning technology. Using a Picopress pneumatic pressure measurement equipment, which measures compression at different points down the leg from ankle to thigh, the compression was evaluated and compared with the modeled results. Laplace-based and other modeling methods were investigated, and it was found that stress/strain-based modeling was suitable for the knitted structures instead of the modulus or tension (T) based principles. Modeling based on the modulus or tension principle will lead to findings that do not reflect the fabric response because of the hysteresis effect that textile-knitted structures follow in their mechanical behavior. The modeling of circular knitted garments is another significant obstacle addressed in this study, as each body size garment in every course often has a unique mechanical response, which must be considered when developing such models. Using scanner-direct measurements opens the possibility of creating bespoke apparel with the necessary compression at each garment part.

Keywords: compression garment, fabric modulus, textile modeling, circular knitting

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19- Robotics and Automation in the textile and clothing production

Adaptive tracking and tracing assistance system for order management in highly flexible, made-to-measure textile production of technical textiles

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Manufacturers are increasingly switching their production to the manufacture of innovative technical textiles. In the process, production-related IT must change just as much as the manufacturing processes itself. An adaptive tracking and tracing assistance system for made-to-measure companies was developed using innovative flexibilization technologies from the Industrial Internet of Things, mobile computing, wireless communication and model-based low-code programming, which includes the following functions. For example, the user can log in to the tablet-based assistance system using wireless technology and to the sewing workstation using an optical marker scan. Furthermore, training assistance is available for the onboarding of new employees by means of step-by-step guidance. The materials to be sewn can be detected automatically using innovative, low-cost camera and mirror technology. Plug-and-produce sensor technology and smartphone-supported, marker-based declaration functions (for the set-up, cleaning and repair processes) are also used for sensor-based process monitoring. The extent to which the workstation is occupied is also permanently detected. Hybrid technology consisting of a localization system and wearable scanning glove is used to support production-related picking processes. The overall system is highly customizable thanks to its model-based architecture and helps garment manufacturers to meet the extensive requirements for batch tracking in the production of technical textiles.

Keywords: industrial internet of things, mobile computing, wireless communication, model, based low, code programming

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Microfactory for the automated assembly of textile products

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Given that the majority of textile production is currently concentrated in the Global South, there is a limited number of facilities in Europe and North America that could potentially be utilised in the event of a crisis. The socio-economic and political developments that occurred at the beginning of this decade demonstrated the fragility of global supply chains, specifically regarding medical and apparel textiles. In response, efforts have been made to diversify textile production locations.
As the costs of labour and energy and the regulatory burden are significantly higher in Europe than in countries currently engaged in production, economic efficiency during diversification can only be achieved through the streamlining and automation of processes that are currently completed manually. Due to the low degree of standardisation in textile assembly, manufacturers are largely autonomous in their efforts towards automation, and solutions cannot be readily transferred into different production environments.
This paper presents a micro factory for the assembly of basic medical and apparel products for crisis supply. While the smallest feasible version of this factory is presented, the concept can be scaled according to demand, while overall material flow and processes remain unchanged.

Keywords: automation, textile assembly, microfactory

*Speaker

Manufacturing technologies for textile based soft robotics

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Over the last decade, wearable soft robotic devices have emerged as highly promising solutions for rehabilitation and motion assistance, largely due to their adaptable and flexible structures. These devices are seen as a safer alternative to rigid metal exoskeletons, which can pose risks in human-robot interactions. Soft robotics, using materials such as elastomers and textiles, offer significant advantages due to their low cost, lightweight nature, and flexibility, which make them ideal for creating wearable systems. However, despite their strong potential, current soft robotic devices still face several limitations. They are often bulky, unreliable, non-scalable, and lack essential mobility and portability. These drawbacks make them impractical for use outside of controlled clinical environments, where they could be most beneficial, such as in continuous home rehabilitation and support during daily activities. The TEXWEAROTS was developed with the aim of overcoming these challenges by creating untethered, knitted soft robotic devices. The primary focus of TEXWEAROTS is to address the major issues related to reliability, mobility, sustainability, and the integration of wearable soft robotic systems. This innovative research work aims to produce a knitted robotic glove that is free from bulky components, making it lighter and more comfortable for the user. In addition, the glove integrates key functionalities such as seamless actuation, sensing, and self-powering capabilities. These advancements significantly improve the practicality of wearable soft robots by making them more reliable and capable of performing effectively over extended periods. By achieving these goals, TEXWEAROTS seeks to revolutionize the use of soft robotics for rehabilitation and motion assistance, making them more accessible and efficient for real-world applications, particularly in home-based therapy and assistance for daily living activities.

Keywords: textile based, soft robotics, manufacturing

*Speaker

20- Textile economy, textile supply chain management

Sustainability Intelligence (SI): Transforming Denim Supply Chain Management – A Comprehensive Case Study of Turkey's Denim Industry

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This paper, as part of broader research, explores how Sustainability Intelligence (SI) is driving the transformation of denim supply chain design through two case studies of internationally renowned Turkish companies: a denim mill and a denim exporter. Sustainability Intelligence (SI) is a framework developed to integrate environmental, social, and economic sustainability into complex industrial systems. The denim industry, like many others, is under pressure to address these sustainability dimensions while maintaining financial viability. However, practical approaches to systematically achieving these goals remain challenging for many businesses.

This research presents an in-depth analysis of sustainable practices implemented by the two Turkish companies, focusing on their innovations in production techniques, responsible resource management, and commitment to social responsibility. The study critically examines how these companies adopt multiple dimensions of fashion sustainability, including environmental, social, and economic aspects, while addressing the financial challenges associated with scaling sustainable solutions.

The methodology for this paper draws on semi-structured interviews and thematic analysis, applied specifically to the two case studies of the Turkish companies. However, the Sustainability Intelligence (SI) framework was developed through a broader research methodology that employed grounded theory. This broader methodology included semi-structured interviews, focus group discussions, and multiple case studies, analyzed through the constant comparative method. While the specific findings in this paper are derived from the case studies, the SI framework they are based on was informed by this comprehensive research approach, ensuring a robust and systemic understanding of sustainability in the denim supply chain.

The paper highlights the role of SI Navigation (SIN) and SI Synthesis (SIS) in guiding the sustainable transformation of denim supply chain design. By applying these key tools from the Sustainability Intelligence (SI) framework, the paper demonstrates how denim companies can align their operations with sustainability goals, providing actionable strategies for achieving long-term systemic change within the industry.

Keywords: denim Industry, fashion system transformation, supply chain management, sustainability intelligence.

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Integrating Leagile Methodology to Foster Industrial Innovation and Entrepreneurship in Morocco's Fast-Fashion Textile Sector

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This study explores the role of entrepreneurship in both education and industry, focusing on how fostering an entrepreneurial mindset can drive innovation within organizations. While entrepreneurship is often associated with new venture creation, it also plays a crucial role within established companies through intrapreneurship. In the fast fashion industry, innovation is essential for maintaining competitiveness, and intrapreneurial initiatives enable companies to adapt and grow.

Building on this perspective, this study examines how intrapreneurship fosters innovation within a fast fashion enterprise. In an industry characterized by rapid changes and competitive pressures, internal entrepreneurial initiatives play a crucial role in driving innovation and optimizing processes.

This project focuses on the study of the implementation of a product development process in a Fast-Fashion context with the specificities of the Textile-Clothing industry of Morocco. An in-depth study has been carried out to optimize the process of creating collections. By translating fashion trends into affordable garments, Fast-Fashion requires just-in-time production and a highly responsive logistics organization. To meet these challenges, an innovative 'Leagile' model, combining the principles of Lean and Agility, has been developed and implemented in a Moroccan company. This hybrid mechanism improves the fluidity, performance and adaptability of processes while aligning with market requirements. After presenting the constraints and weakness of the Classic Process in terms of responsiveness, we will present an optimized process that integrates all the aspects and requirements of a Leagile value chain.

By combining entrepreneurship and operational innovation, this project demonstrates how the development of individual skills and the optimisation of industrial processes can jointly strengthen the Moroccan textile and clothing sector and contribute to its economic dynamism.

Keywords: fast fashion, textile innovation, leagile methodology, process optimization, entrepreneurship

*Speaker

21- 3D and 4D Body Scanning

Evaluating Dynamic Body Deformation in Breast-Bra Interactions via 4D Scanning Techniques

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The human body continuously deforms during movement, and when wearing tightly fitted clothing, these dynamic deformations interact with the garment. In the case of bras, breast tissue undergoes significant deformation during motion. One of the key functions of a bra is to reduce this movement to minimize discomfort and pain. Using 4D scanning technology, these dynamic body deformations can be captured. However, the large volume of data generated poses challenges for efficient analysis, and currently, only a few methods exist to process and utilize this data effectively.
This research investigates breast-bra interaction both experimentally and digitally using 4D scan data. Through motion analysis, comparable movement phases of a test subject are identified. A cross-sectional analysis is then applied to examine breast deformation behavior across different bra types and in a braless condition. The insights gained from this method can contribute to the future development of improved bra designs. Additionally, this study presents approaches for integrating 4D scan data into digital modeling processes for garment development.

Keywords: high speed body scanning, bra-brest interaction, modelling, clothing

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Enhancing Anthropometry and Ergonomics Concepts in the Design of Personal Protective Equipment: 3D Body Scanning of Portuguese Firefighters

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The fit of Personal Protective Equipment (PPE) is fundamental to ensuring the well-being, safety, and performance of firefighters during their activities. Many current PPEs do not take into account the diversity of body types and gender among firefighters, leading to difficulties related to fit and effectiveness, which significantly impact their work. This study aims to describe the initial stages of ongoing research that seeks to address these issues by emphasizing the concepts of anthropometry and ergonomics in the design process, particularly through the 3D body scanning of firefighters from different fire brigades across Portugal.

The 3D body scanning process enables a fast and accurate anthropometric study, providing crucial information for the development of various PPEs, especially Personal Protective Clothing (PPC), that is personalized and inclusive, respecting the diverse physical characteristics of firefighters.

The study highlights the importance of a user-centered method that considers anatomical diversity and ergonomic requirements from the earliest stages of the design process. Simultaneously, the research shows how gathering initial data on firefighters' personal satisfaction with this equipment allows a discussion on the benefits that this method can bring to their performance, comfort, and safety while on duty, as well as the potential for increased PPE efficiency through better fit in hazardous situations.

By analyzing the ergonomic challenges faced by the diverse workforce of male and female firefighters, this study proposes an innovative design methodology that leverages available technologies to promote more effective and inclusive fashion design in the realm of PPE.

Keywords: ergonomics, 3D body scanning, personal protective equipment, firefighters, inclusive design.

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Adaptive leg morphotype used in the improvement of compression therapy

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Compression therapy is one of the oldest treatment methods for Chronic venous insufficiency and lymphoedema and it is primarily delivered through Medical Compression stockings. In compression therapy, it is essential to correctly adapt the interface pressure to the patient's body geometry to achieve the desired therapeutic effect, but this task remains a challenge for both medical professionals and industrial parties because both leg morphology and leg size should be considered for optimal fit. However, current designs focus only on the ankle, calf, and upper tight measurements, neglecting the overall shape of the leg. Personalised products that take into consideration the individual's anthropometric measurements, show the best results in terms of effectiveness. As in an industrial environment, it is rather challenging to implement the concept of mass customization of compression stockings, it is indispensable to improve the sizing system and product design in a way that the market could offer a larger variety of off-the-shelf products that are adapted to a larger population. It would also be an improvement to provide medical professionals a tool, that could help them choose the optimal product size for certain leg shapes. To answer these challenges, we have developed adaptive leg morphotypes, that represent a specific leg shape and can adapt to the size of its representing population. By changing the height and circumferential parameters of the adaptive leg morphotype, it is capable of changing its length and volume. By doing so, the parametric leg will also allow the direct design of 3D medical compression products, whose dimensions vary once the size of the leg has been changed. The parametric model could help in the optimization of the manufacturing process and product design with the potential to enhance comfort, donning ease, pressure configuration, and size accuracy, largely contributing to the effectiveness of compression therapy.

Keywords: adaptive leg morphotype, sizing system, medical compression stocking, 3D parametric model

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An integrated Software solution for the confection of 3D-scan to knit made-to-measure prosthetic liners

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In recent years, the maturing of the 3D-scan technology has opened up new possibilities for manufacturing made-to-measure garments in a mass-customization-like approach. The technology provides a way to effortlessly and reproducibly obtain the geometry of the human body. This information may then be processed into garment patterns to construct a garment, that optimally fits the body of the scanned person. However, to realize such a workflow, more challenges in processing the 3D-scan-data remain: Garment fit is determined not only by the pattern and its assembly, but also by material behavior of body and fabric. This needs to be taken into consideration when the pattern is generated as well. Further, in medical wear, there may be the need to further contextualize the scan with information. To be used in practice, all of these functions need to be easily achievable for the professionals which deal with the customers (and/or patients). This work presents the efforts of creating an integrated software solution for the creation of knitted made-to-measure prosthetic liners. It facilitates all steps necessary for pattern creation, starting with the scanned mesh.

Keywords: 3D scan, scan-to-knit, prostetic liners, medical wear

*Speaker

Analysis of motorcycle protective pants: A comparison of 3D and 4D scans to evaluate the fit

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The clothing industry is currently undergoing a digital transformation. The conventional product development of physical sample parts is now being replaced by fit analysis in the digital space. This process is not yet so well established in the product development of protective clothing. Positioning protectors while seated on the motorcycle is particularly important for motorcyclists' protective clothing. The aim of this work is to analyze the mounting process on the motorcycle and the change in position of the protectors during this dynamic movement.
In the fashion industry, a rigid avatar or possibly a 3D scan is mainly used for fit analysis in digital space. This technology already enables designers and manufacturers to precisely evaluate the fit and appearance of garments. However, by capturing static poses, only limited insight can be gained into the garment's behavior during dynamic movements. This is particularly relevant for protective clothing, such as motorcycle protective pants, where dynamic movement plays a crucial role.
This research approach investigates the improvement of garment analysis of motorcycle protective pants using 4D scanners. Standard fittings in the fashion industry are usually performed on static poses. This does not allow mapping the translation between the rider's standing pose and the seated pose on the motorcycle. The protectors are incorporated into "pockets" in the protective clothing, which results in the protectors' movement. The positioning of the protectors is decisive for the comfort of the motorcycle clothing in the riding pose.
In this study, the meshes of the protective clothing captured by 4D scans in motion are compared with the meshes created by 3D scans in various static poses. The aim is to identify and evaluate the differences in material deformation between the two methods. By analyzing the meshes of both simulations, a deeper understanding of the fit of the motorcycle protective pants should be gained.

Keywords: digitalization, 3D scan, 4D scan, clothing product development

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4D body scanning: A study of changes in foot geometry during extension movement

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A wide range of people wear compression socks. The elderly, pregnant women, people with venous problems, or people who spend a lot of time sitting during the day. Compression socks act to improve or prevent health problems. For this reason, the correct fit is essential for the functionality of the compression sock. The foot's geometry is in continuous changes due to walking or various activities. These dynamic changes are often not accounted in the design of compression socks, which can lead to pain, discomfort, and loss of function. Capturing 3D shape of the human body is available through 3D scanning technology, but including the dynamic shape can be realized with 4D scanning systems. The MOVE4D high speed 3D (4D) scanning system allows the geometry of the human body to be captured in motion at high frequency. This allows us to capture and analyze these changes for better fit and comfort of various wearable products. In this work, an investigation of the changes in foot geometry of several people during the same movement is depicted. Various changes in circumference and overall geometry during the stretching motion of different people's feet are scanned by the high speed body scanner. The 3D models of the legs generated are analyzed by using a specially developed Python-based software library. The results visualize the areas of geometry change and provide novel information for designing optimized compression socks. Combining 4D technology with automatic data analysis generates good results to improve and optimize clothing products.

Keywords: high speed scanning, foot dimensions, compression socks, Matlab script.

*Speaker

Body Movement during a Turntable-3D-Scan and its Influence on the Scan Accuracy in the Context of Clothing Development

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The generation of a 3D-Scan on a turntable 3D-Scanner requires a full rotation of the turntable, which typically takes between 20 and 30 seconds. In this time, a living subject makes small movements, which affect the accuracy of the resulting 3D scan. Small deviations between the geometry of the scanned subject and its model can be tolerated, but bigger deviations make the scan unusable. Efforts to stabilize the subject during the scan on the other hand may affect the posture of the subject, which is unwanted in many use cases, especially in the medical sector. Therefore, it would be beneficial to better understand how accuracy is affected by movement during the scan and how different measures to decrease movement impact posture and accuracy. Four different measures have been tested by capturing the 3D-scanning process using a 4D-scanning system and comparing movement over time and the circumferences of the generated models. The results are presented in this paper.

Keywords: 3d body scanning, 4d body scanning, accuracy, performance

*Speaker

22- Leather and shoes industry

Digital technologies are the basis of a progressive approach to improve production of orthopedic shoes

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Orthopedic footwear is one of the most important shoe products related to additional rehabilitation aids and made individually for each patient, taking into account his medical diagnosis, anthropometric parameters, doctor recommendations and personal consumer requirements.
Orthopedic shoes can perform their main function with the help of following elements:
- Special shape and parameters of the shoe last designed according to the patient's foot and medical recommendations,
- Built-in orthoses that fix the position of the foot,
- The special design of the shoe upper, which allows to use the shoe in various pathologies or traumatic conditions,
- Insert corrective, offloading, or pain-relieving insoles,
- Specially shaped shoe soles.

The variety of types and designs of orthopedic shoes complicates the methodology of its development and the production process.
However, the development of digital technologies opens up new prospects for the development of this sector of production, increasing the accuracy of design processes, reducing dependence on labor-intensive manual operations that require extensive practical experience. The 3D foot scanning method allows us to obtain and collect information about patients' feet without the need to use huge areas for storage of plaster casts. Also, the obtained digital information is of great value for analyzing the processes of progress or regression in the clinical condition of the feet of consumers. The growing availability of additive technologies makes it possible to reduce dependence on a few large factories, introducing convenient small local productions in various regions with own making the shoe lasts, insoles, soles and orthoses.
Today's Ukrainian realities require radical actions to implement advanced technologies to improve the production process of orthopedic shoes for numerous cases of wounds, injuries, and partial amputations of the lower limbs. Borrowing the experience of developed Western European countries, we need to adapt advanced technologies to the conditions of the Ukrainian production of orthopedic footwear.

Keywords: orthopedic footwear, digital technology, shoe production, additive technology, shoe last, foot

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Shape stability of leather for footwear uppers depending on the tanning method and moulding conditions

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In order to model the process of forming a shoe upper on a last, the influence on the form stability of leathers for shoe uppers of various conditions of their tan-ning, as well as the conditions of the process of formation and fixation of the spa-tial form, was investigated. The ability to form and retain the shape of footwear is laid down during the for-mation of the structure of leather at the stage production it. Since the most re-sponsible process for forming the dermis structure is the tanning process, the form-fastness of leathers using different tanning methods - chrome, vegetable, synthetic, and aldehyde - was analysed. It has been established that chrome-tanned leathers demonstrate the highest rate of shape stability (92 %). In contrast, the leathers of other methods show lower, although relatively high, shape stability (at the level of 82-89 %). High form stability of leathers for footwear uppers of different tanning methods is achieved under conditions of moisture-heat treat-ment: with moistening before the technological moulding operation by at least 5 % and a thermal fixation temperature of no more than 80 °C.

Keywords: shape stability, tanning, leather

*Speaker

Investigating the beamhouse processes in ostrich leather technology

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The results of this work present the studies of the beamhouse processes in the processing technology of ostrich skins. In order to reduce the negative impact of wastewater on the environment and speed up the soaking process, the enzyme preparation Letan SE2 and the surfactant CH-22C, which meet the requirements of the European regulations REACH and ECHA, were used. When using these initial preparations in the soaking process, there is an intensive removal of mucopolysaccharides and non-collagen proteins from the interfiber space, the moisture content in the leather tissue of the ostrich skin increases, and the moisture is evenly distributed by density and area. In studies of the liming process, a liming method was proposed using hydrogen peroxide and sodium hydroxide, without the use of lime and sodium sulfide. The appearance of the "WET BLUE" leather samples was examined organoleptically, and the shrinkage temperature and pH values were also determined. Research on the possibility of carrying out beamhouse processes using environmentally friendly chemicals, which allows reducing the level of harmful, polluting effects of chemicals on the environment, which is very important for preserving the environment.

Keywords: ostrich, skins, process, soaking, liming, beamhouse processes, tanning, dyeing, fatting, finish, wet, blue, krast, leather

*Speaker

Tanning of nutria skins (Myocastor coypus) using interpolycomplex-based methods and investigation of their physical-chemical and mechanical properties

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The technology of the tanning process in fur production and the chemical substances used during the tanning process have been studied. A new interpolycomplex tanning agent has been synthesized, taking into account the properties of the chemical substances used in the tanning process. General information about the nutria (Myocastor coypus) animal is provided. During the research, a tanning technology using local tanning agents, instead of imported chemicals, has been developed. The interaction of various tanning agents with nutria leather collagen was studied, and IR spectroscopic analysis results were provided. Based on these results, interpolycomplex treatments were applied to nutria skins in different ratios. For comparison of experimental results, two standard nutria raw leather samples of the same II grade were selected. These skins were processed using both traditional tanning methods and interpolycomplex-based tanning technology, and the results were compared. The effect of the tanning process using the traditional method and the interpolycomplex-based method on nutria skins was studied, revealing that the experimental samples exhibited higher hydrothermal destruction temperature, strength limit, and elongation at break compared to the control sample. The amounts of mineral substances, fats, and moisture in the tanned nutria fur samples were determined, and their compliance with state standards was confirmed. Based on the experimental results, it was concluded that the chemical materials with interpolycomplex tanning agents react actively with collagen, forming strong bonds in the treated furs.

Keywords: nutria, interpolycomplex tanning agent, tanning, dermis, collagen, fur, epidermis, leather, fur, hydrothermal destruction, fat, chromium, maximum elongation, strength, mineral substances.

*Speaker

Production of elastic polymer adhesives and study of their physicochemical and mechanical properties

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This study investigates the synthesis of elastic polymer adhesives and examines their physical, chemical, and mechanical properties. Elastic polymer adhesives with significant properties, including high adhesiveness and resistance to friction and heat pressing in both dry and wet conditions, as well as resistance to organic solvents used for cleaning secondary leather tissue products, have been obtained and explained. These adhesives were prepared using incompletely vulcanized rubber. The experimental elastic polymer adhesives were compared with coatings prepared using existing technology. Both the experimental and control elastic polymer adhesives were prepared according to the current technology, and control samples of secondary leather tissues with general physical and chemical properties were utilized. During the research, elastic polymer adhesives based on raw rubber (incompletely vulcanized rubber) were applied to the surface of chrome-tanned split leather of large cattle. A-92 gasoline was used as an aggressive medium. It was proven that changes in the physical and chemical properties of the secondary leather tissue surface during the dyeing process are related to the nature of the dye, its structure, and its interaction mechanism with collagen. The reduction of the electrokinetic potential of the surface of secondary leather tissues dyed with anionic dyes was explained as being associated with the interaction of the dyes with collagen functional groups and the deposition of oppositely charged dye molecules on the surface of the secondary leather tissues.

Keywords: Elastic, polymer, adhesive, finishing, collagen, secondary leather tissue, structure, raw rubber, plasticizer, carbon black, aerosil, pigment, "galosha" gasoline, tensile strength at relative elongation, residual elongation, cold resistance, and hardness.

*Speaker

Tanning of large horned cattle hides using furfural and its physical-chemical properties

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This research develops a tanning technology for large cattle hides using locally sourced tanning agents, replacing imported chemical substances. The study investigates the use of furfural as a tanning agent for large cattle hides and examines the physical-chemical and mechanical properties of cattle leather. Various tanning agents' interactions with large cattle hide collagen were analyzed using IR spectroscopy, and based on these results, tanning treatments were applied to the hides using furfural as the tanning agent. To compare experimental results, two identical large cattle raw leather samples were selected. These hides were processed using both the traditional tanning method and furfural-based tanning technology, and the outcomes of both methods were compared. The effect of the tanning process on large cattle hides using the traditional method and furfural-based tanning was studied, revealing that the leather tanned with furfural exhibited higher hydrothermal stability, strength, and elongation at break. Additionally, the amounts of fat, mineral substances, and moisture in the samples were determined and found to comply with state standards. Based on the obtained results, it was concluded that strong bonds were formed in the leather matrix of the experimental samples.

Keywords: furfural, tanning agent, leather, washing, softening, shriveling, pickling, tanning, destruction, complex, physical, mechanical, chemical properties, mineral substances, fat content, moisture content.

*Speaker

Study of the properties of modified wet-blue leather semi-product using laser radiation

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In this research, along with chemical treatments for producing Wet-Blue leather semi-products, a physical method - laser modification - was applied. Laser treatment facilitates the formation of reactive radicals due to the breaking of various bonds within the collagen structure. These reactive radicals significantly accelerate the chemical reactions with chromium-tanning complexes during subsequent processing stages. Collagen was selected as the model system to study leather modification, and native collagen, chromium-treated collagen, and laser-modified collagen were investigated using IR spectroscopy in the 4000–500 cm^{-1} wave range. It was found that treatment with chromium oxide and laser radiation induces certain structural changes in collagen, observable as changes in the absorption intensity of functional groups within the collagen molecule. By analyzing the absorption spectra of native and modified collagen, the interactions between collagen and the modifiers were studied. Furthermore, it was confirmed that pre-treatment of the dermis tissue with laser radiation before the tanning process improves the physical-mechanical properties of sheep Wet-Blue leather semi-products. Specifically, the tensile strength limit was improved by 33.3%, and elongation at 10 MPa stress increased by 14.7% compared to sheep Wet-Blue leather semi-products produced using traditional technology.

Keywords: collagen, dermis, laser irradiation, chromium, tanning, Wet, Blue, IR spectroscopy, radicals, hydrothermal destruction, tensile strength limit, elongation under stress.

*Speaker

Effect of acid protease on the properties of ostrich leather

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Developing a competitive and environmentally friendly leather technology is becoming an urgent task. The article presents the results obtained in the study of a combined pickling- bating process in order to improve the technology for processing ostrich skins. At present, enzymes are widely used in leather production. Research has been conducted to study the effect of enzymatic pickling on the properties of the collagen protein of the ostrich skin dermis and the effect of enzymatic treatment on subsequent processing processes and on the properties of Wet blue chrome tanned leather. The use of proteolytic enzyme preparations active in an acidic environment in the pickling process affected the properties of the dermis. The proposed method of enzymatic pickling allowed to enhance the binding of chromium tanning agents and to increase the shrinkage temperature of Wet blue tanned leather. Enzymatic pickling had a positive effect on the dyeing and greasing processes and on the physical and mechanical properties of the resulting leather. The physical and chemical properties, elemental composition and morphological structure of ostrich clothing leather samples were determined. The proposed processing method serves to expand the range of exotic leathers. The use of an enzyme preparation in the proposed processing method allowed to shorten the technological cycle and reduce the consumption of water and chemicals in technological processes.

Keywords: ostrich skin, exotic leather, ostrich clothing leather, processing technology, process, bating, pickling, tanning, physical and chemical properties, morphological structure, elemental analysis.

*Speaker

Study of moisture exchange properties of natural modified leathers for shoe uppers

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Of great importance in winter footwear are the moisture exchange properties of the shoe upper, i.e. their ability to transfer moisture released by the foot. The greatest attention should be paid to the fact that wet materials have higher thermal conductivity coefficients. Based on organosilicon compounds water repellents forming a thin invisible water repellent film not disturbing the air permeability of materials are highly effective. The film is durable, resistant to chemicals, high and low temperatures and has a high mechanical strength.To create a more affordable and effective water repellent composite based on new compounds, it is needed to study moisture exchange of waterproofed upper leather. This work is a study of the properties of composites on the basis of acrylic polymers and polyvinilethynildihydroxichlorsilane as water repellent finishing materials. The main subjects of research are as follows: methacrylic emulsion, hydrolyzed polyacrylamide, polyvinilethynildihydroxichlorsilane, penetrator and widely used polyethylhydrosiloxane. A composition of water repellents in various initial ratios was prepared on their basis. Water repellents were prepared by consecutive stirring of the above materials at a temperature of 20-22°C within 3-4 hours. Analysis of the results showed that the most suitable materials for the autumn and spring, winter footwear and especially safety shoes used under aqueous conditions may be leathers treated with waterproofing composition based on polyvinilethynildihydroxichlorsilane.

Keywords: polyvinylethynyldihydroxychlorosilane, polyethylhydrosiloxane, methacrylic emulsion, hydrolyzed polyacrylamide

*Speaker

Human Pressure Perception of Foot - Protocol and Sensitivity Map

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The recent design process of footwear products, particularly those requiring a higher level of fit, such as sports footwear, considers not only the physical properties of materials but also large datasets of human foot shapes and contact pressure. This type of deductive design is an essential concept for improving product quality in mass production. However, the variety of datasets integrated into the deductive design process remains limited and insufficient. In particular, incorporating the perspective of human pressure perception on the foot is crucial for enhancing footwear comfort. It is expected that utilizing datasets for the design process of human pressure perception on foot is available to improve comfort of footwear products. The purpose of this study was to create a sensitivity map of human pressure perception of a foot. To achieve this, a test method was developed, involving the construction of a test apparatus and the establishment of a test protocol. Additionally, a sensitivity map was created corresponding to two sites, the foot dorsum and the posterior foot, respectively, by conducting a human pressure perception test on the foot using four cooperative panels and analyzing their data. The findings revealed that the bottom part of both the medial and lateral sides of the posterior foot site exhibited a lower pressure threshold for pressure perception, indicating high sensitivity. On the other hand, the calcaneus and Achilles tendon in the posterior foot site exhibited a higher pressure threshold for pressure perception, indicating low sensitivity. Additionally, the bottom part of both the medial and lateral sides of the foot dorsum site also exhibited high sensitivity. However, the area above the high-sensitivity region on the medial side of the foot dorsum site exhibited low sensitivity. The overall sensitivity distribution was discussed from the perspective of anatomical structure.

Keywords: human pressure, perception, foot, sensitivity

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23- Modern Textile Education and Training

Educational project "Nachhal(l)tigkeit" - Teaching sustainability in an elective course for an environmentally friendly textile and clothing industry

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The textile and clothing industry is undergoing a transformation towards a sustainable circular economy. With growing ecological and social challenges, the demand for professionals with a systemic understanding of sustainability and solution-driven skills is urgent. This is intensified by a shortage of skilled workers and traditional, discipline-specific training approaches at many universities, which struggle to keep pace with sustainability requirements, technological innovations, and regulatory changes. To address this challenge, an agile teaching project is introduced in the Master's programs at the Faculty of Textile and Clothing Technology at Niederrhein University of Applied Sciences. This initiative aims to complement conventional teaching methods by offering a bilingual, practice-oriented elective course specifically tailored to the sustainable textile and clothing industry. The course equips students with a comprehensive understanding of sustainability, integrated with technical, scientific, and practical expertise. Key topics include the circular economy, bioeconomy, and sustainability management within the textile sector. A central feature of the course is its focus on hands-on projects, carried out in collaboration with industry partners. Guided by professors and researchers, students work on real-world challenges faced by businesses and societal stakeholders, developing practical, innovative solutions. Another important aspect is fostering connections between international students and German small and medium-sized enterprises to help alleviate the skilled labor shortage in the industry. The bilingual approach not only broadens access for international students but also enables them to serve as knowledge multipliers, applying what they have learned within companies across the global textile supply chain. Through this elective, future textile engineers are prepared to navigate the ecological and social challenges of the industry and actively contribute to more sustainable textile production and use. The concept is designed to be transferable to other subjects, with materials available as Open Educational Resources.

Keywords: teaching sustainability, circular economy, project based teaching

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From Open Source to Custom Fit: Digitizing and Personalizing Fashion Patterns with 3D Prototyping

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This study analyzes the integration of 3D digital prototype tools into the fashion design process using a practical case study of digitizing and customizing an open-source file pattern from a well-known fashion house. The pattern was modified to fit a specific body form using CLO3D software and then virtually sewn onto a parametric avatar to replicate fabric drape, fit, and garment manufacturing. This virtual garment was then compared to a physical version of the same clothing to see how well the digital prototype matched the physical garment. The research emphasizes both the benefits and drawbacks of using 3D virtual prototyping in fashion design. While digital tools provide substantial benefits in terms of customisation, efficiency, and avoidance of physical waste, several differences between virtual and real fits have been identified. These differences highlight the vital need of accurate body measurements and fabric behavior models for achieving precision in the virtual world. Furthermore, the study emphasizes the possible obstacles provided by the user's limited experience in obtaining precise body measures, which may have influenced the overall comparison of virtual and actual results. Despite these challenges, this study shows that 3D digital prototyping has tremendous potential in fashion education. Fashion school courses can be improved by giving students access to innovative 3D technology, which allows them to "digitally play" with historic and renowned haute couture patterns. This hands-on experience with high-fashion elements not only broadens their grasp of garment structure, but also improves their design skills by allowing them to experiment with personalization and fit in a virtual setting. Through these innovative technologies, students can get vital insights into the complexities of fashion design, expanding their skill sets and better preparing them for the industry's changing demands.

Keywords: 3d virtual prototype, personalisation, fashion education, custom-fit

*Speaker

Promoting EU Strategy for Sustainable and Circular Textiles through Interdisciplinary Education

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The textile industry, vital to daily life and the European economy, faces significant sustainability challenges. The "EU Strategy for Sustainable Textiles (EUSusTex)" project, a three-year initiative supported by the European Commission under the Jean Monnet Module Activity, addresses sustainability challenges in the textile industry. This paper presents the objectives, methodologies, and initial outcomes of EUSusTex, highlighting its role in advancing the EU's sustainability agenda through education and industry collaboration.
EUSusTex aligns with key sustainability frameworks, including the EU Green Deal, Circular Economy Action Plan, European Industrial Strategy, and UN Sustainable Development Goals. The project aims to facilitate the transition to a circular economy in the textile sector by examining the climate and environmental impacts of textile materials, processes, and waste while educating stakeholders on sustainable practices.
Central to EUSusTex is an innovative course open to students from various faculties at Bartin University, ensuring diverse perspectives on sustainable textiles. The curriculum integrates theoretical knowledge with practical applications, focusing on circular economy principles and sustainable sourcing. Skills gained are designed to be applicable in students' future careers across various sectors.
The project employs a multi-faceted approach, combining educational initiatives with national and international dissemination activities. Workshops, seminars, and awareness campaigns spread knowledge about sustainable textiles and circular economy principles beyond academia.
Initial results show increased awareness and interest in sustainable textile practices across disciplines. The course's interdisciplinary nature has fostered innovative thinking and cross-sector collaboration while identifying key areas for improvement in current textile production and consumption patterns.
This paper discusses EUSusTex's potential long-term impacts on the EU textile industry and broader sustainability goals. It outlines future research directions, policy recommendations, and strategies for scaling up European educational initiatives, promising significant contributions to sustainable textiles and circular economy education.
Acknowledgements. This study is supported by the European Education and Culture Executive Agency (EACEA) through the EU Erasmus+ Program Jean Monnet Module Activities (Project Number: 101085813).

Keywords: sustainable textiles, circular economy, green deal, EU strategy, interdisciplinary education, Eco-design, textile recycling

*Speaker

Integrating Education for Sustainable Development in Fashion Design: A Design-Based Research Approach

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In line with the United Nations' 2030 Agenda, this doctoral research investigates how Education for Sustainable Development (ESD) can be integrated as a guiding principle in fashion design programs in Germany and Iran. Using the Design-Based Research (DBR) methodology, the study follows six phases: (1) systematic literature review, (2) curriculum analysis, (3) expert interviews and participant observation, (4) development of a fashion design course, (5) course implementation in a different cultural context, and (6) compilation of recommendations. In the first phase, the extent of ESD integration in fashion design programs was assessed, supplemented by expert interviews in both countries, and observations at the Hochschule Hannover University of Applied Sciences and Arts (HSH). Course development involves analysis, development, implementation, evaluation and reflection following the DBR approach. After the first iteration at the HSH in the summer semester of 2024, this paper focuses on the second iteration at a vocational school in Hanover and investigates how a course based on the ESD approach and using the USELESS Product Lifecycle as a didactic tool can improve students' understanding and skills of sustainable fashion design. The course adopts a holistic approach to sustainable design, focusing on the environmental, social, and economic pillars of sustainability, the Ecodesign for Sustainable Products Regulation, and the circular economy. Pedagogical methods such as interactive lectures, document- and image-based discussions, think-pair-share, concept mapping, and hands-on workshops were used. Assessment was conducted through e-portfolios documenting reflections, while feedback was collected through session-specific questions and a group interview. Responses were analyzed using qualitative content analysis with MAXQDA. The findings provide recommendations for integrating sustainability into fashion design programs and will guide future iterations in Germany and Iran.

Keywords: Design-Based Research (DBR), Education for Sustainable Development (ESD), fashion design, vocational school, higher education

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Service Learning on Sustainability in Textile and Fashion Education – Preliminary Results of the European Project ”TexUnite”

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The strong demand for the transformation of the textile and fashion industry towards sustainability requires a continuous implementation of the guiding principle of Education for Sustainable Development (ESD) in textile and fashion education and industry. Universities are important (educational) institutions where the environmental, social and economic dimensions of society are considered in an integrated way. The aim is to develop solutions for current and future challenges and to train decision makers for different fields of action and to develop emancipatory reflection, creativity, and problem solving and action skills for sustainability-oriented competences. The European project ”TexUnite” promotes the key competencies required to achieve sustainability goals by introducing Service Learning (SL) in textile and fashion education through project-based seminars. University teachers from six partner universities in five countries are enabled to carry out SL projects through their active participation in the online training module Sustainable Textile Lab (SusTexLab). The project thus promotes environmental and social engagement in higher education and reflects this engagement as a central part of academic learning, where all actions are aligned with European approaches to sustainability. Students are involved in community service projects with partners such as sustainable companies, NGOs and schools to address social and environmental issues in the context of fashion and textiles, gaining social, political and environmental experience through their involvement. As part of their university studies, the projects are linked to their subject related learning. The project-oriented seminars are planned together with the stakeholders and the students' experiences are reflected and linked to the competences of the modules. Intercultural communication and cooperation between the student teams of the participating partner universities will take place through virtual exchange. The results of the project will be made available as Open Educational Resources (OER) in the OER repository ZOERR and in the European Open Access database EPALE.

Keywords: education for sustainable development, higher education, service learning, open educational resources

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Industry 4.0 Skills in Textile Small and Medium Enterprises - Evaluation about the current state, gaps and needs for education

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The TEX 4.0 project aims to provide VET learners, including the current textile workforce and NEETs with training and upskilling on Textile 4.0-related technologies in order to keep up with the rapid technological advances of the sector and to increase their employability opportunities. The project objectives are: to identify the needs of VET trainers and learners in the field of Industry 4.0 technologies training; to develop a curriculum on Industry 4.0 skills in the Textile sector for VET Trainers; to equip VET trainers, learners, and textile stakeholders with the necessary knowledge and tools through an innovative training package on Industry 4.0-related skills; to provide an e-learning format with attractive and dynamic functions where all material will be integrated; to implement engaging training activities using participatory approaches in order to test the results and upskill the target groups; to disseminate the project results through partners and the project's networks and enhance their impact across the EU.
The purpose of this work is to point out existing knowledge, gaps, and educational needs related to Industry 4.0 and its underlying technologies for the textile sector, identified through a wide survey with the participation of VET trainers, VET learners, and textile stakeholders (owners, managers, Chamber of Commerce representatives). The survey outcomes included in the report will lay the ground for the creation of the TEX4.0 Curriculum, which is expected to cover a spectrum of Textile 4.0 technologies and practices to better understand Textile 4.0 and its underlying technologies, what are the gaps and needs, and how the technologies can be exploited within the textile sector.
The research was conducted in 6 European countries (Belgium, France, Germany, Italy,

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Greece, and Romania), with questionnaires designed for VET trainers and VET learners as well as focus group discussions with textile stakeholders (owners, managers, Chamber of Commerce representatives). The included questions in the interviews and questionnaires were tailor-made for each of the target groups. During its implementation period, which lasted from February to March of 2024, 120 responses from the VET trainers and 128 responses from VET learners to the research questionnaires were collected from the aforementioned European countries, while overall 33 textile stakeholders participated in the national focus group discussions.

Keywords: Vocational training, TEX4.0, skills, gap analysis

Fostering decision-making competence in secondary schools: An empirical study on adaptive learning in consumer education for fashion and textiles

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The development of an adaptive learning environment for consumer education in the field of fashion and textiles was guided by empirical research and implemented in regular ninth grade classes at secondary schools in Baden-Württemberg, Germany. The effectiveness of this learning environment was evaluated through empirical analysis. Central to the research was the investigation of Aptitude-Treatment-Interaction (ATI) effects, focusing on how various teaching methods impacted student learning while addressing individual learning needs. Decision-making competence, defined as the ability to navigate complex situations lacking clear solutions, was a core objective of the intervention. Within the context of fashion and textiles, decision-making situations often involve balancing multiple quality dimensions, including sustainability considerations. Research indicates that students benefit from structured support in their decision-making processes, though the degree of structuring must be carefully calibrated. Over-structuring can hinder independent decision-making, while insufficient structuring risks leaving students without adequate guidance. This study also accounted for the expertise reversal effect, highlighting that structuring must align with learners' existing competencies to avoid adverse effects on their skills. Recognizing that students exhibit varying levels of decision-making competence, the adaptive learning setting was designed to enhance their ability to incorporate quality dimensions into purchasing decisions and articulate their reasoning. The research aims to validate that differentiated structuring of learning materials fosters ATI effects, offering empirical insights for creating adaptive educational strategies. By doing so, this study contributes to the development of pedagogical approaches that promote decision-making competence in consumer education, particularly in the field of fashion and textiles.

Keywords: consumer education, decision making competence, adaptive learning, aptitude treatment interaction, empirical study

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3D Concepts for Fashion Education in Ukraine (3D4U)

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3D Concepts for Fashion Education in Ukraine (3D4U) (www.3d4u.org) is a three-year project 101128856 co-funded by the European Union under the Capacity Building in Higher Education (CBHE) program ERASMUS-EDU-2023-CBHE-STRAND-2. The project aims to bridge the gap in advanced technological skills within Ukraine's fashion education system by integrating cutting-edge 3D concepts into academic curricula and industry practices until it formally concludes in Oct 2026. With global fashion rapidly adopting 3D tools—such as digital design, virtual prototyping, additive manufacturing, virtual showrooms, digital avatars, body scanning, and collaborative platforms—these technologies are reshaping design, development, and production processes. They enable faster prototyping, reduced physical sampling, improved early-stage quality, and a lower environmental footprint. Leading fashion institutions worldwide are already leveraging these tools, and 3D4U brings this innovation to Ukraine. The project consortium includes eight partners, four from the EU and four from Ukraine, representing higher education institutions, associations, and organizations with strong expertise in education, research, and EU project management. 3D4U focuses on building digital capacity in Ukrainian higher education institutions (HEIs) by establishing three specialized 3D hubs, fully equipped for 3D modelling and prototyping. The project's key outcomes include:
- Creation and equipping of three 3D hubs at Ukrainian HEIs
- Training of faculty members by EU experts
- Development or modernization of at least five academic courses in 3D fashion technologies
- A standardized training program for fashion industry professionals
- Six industry-driven pilot projects within HEI departments
- Education of 100 undergraduate and postgraduate students through semester-long courses
- Introduction of 50 working professionals from other Ukrainian HEIs to 3D concepts via specialized seminars

Project results are shared via Facebook, YouTube, and Instagram, while a Moodle-based collaboration and learning platform is under development. Through these efforts, 3D4U aims to foster innovation, enhance educational quality, and support the digital transformation of Ukraine's fashion sector.

Keywords: 3D design, 3D modelling and prototyping, 3D printing, fashion education, industry collaboration

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Textil Trainer 2.0 – Building Skills for Tomorrow's Textile Workforce

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The Textil Trainer 2.0 project addresses the pressing need for skilled workers and accessible vocational training in Saxony's textile industry. Building on the established and widely used platform www.textil-trainer.de, the initiative focuses on expanding and individualizing digital learning for industry newcomers, career changers, and SMEs. A central goal of the current project phase is the development of new course content, particularly in response to direct feedback from industry partners. The platform's content will more comprehensively reflect the textile value chain and offers enhanced usability through a newly introduced overview course on the textile chain. To further improve accessibility, selected courses are being professionally translated into English, enabling multilingual workforces to benefit from the content. The platform continues to offer features such as simplified language, glossary support, and interactive learning elements for various user groups — from production staff and administrative employees to trainees and students. In close cooperation with regional companies and vocational schools, the project develops customizable learning paths and provides tools for company-specific training solutions. This ensures a tailored, flexible approach to upskilling that meets the demands of the textile sector. Textil Trainer 2.0 thus strengthens the long-term digital infrastructure for vocational education in Saxony's textile industry and supports a transition toward sustainable and inclusive knowledge transfer.

Keywords: Digital Learning, Vocational Training, Textile Education, Sustainability, Customized Courses

*Speaker

Training and applications of virtual prototyping of clothing in the industry

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5 Technological Centre for Textile and Clothing of Portugal (CITEVE) – Vila Nova de Famalicão , Portugal
6 Technical University Iasi, Faculty Industrial Design and Business Management – Iasi, Romania

Virtual prototyping enables a digital design process of clothing with numerous advantages, such as: drapeability and fit simulation of a garment on a human avatar, faster design and ready-to-market production, as well as a better communication between design and production department within a textile-clothing enterprise. There is a high need of professionals in virtual prototyping of clothing on European level and this is why preparation and training of higher education students in this domain is important. The pattern drawing and fitting on a human 3D model is made via specialized proprietary software. Such software is however expensive and available as desktop applications (Lectra Modaris, Optitex, CLO etc.). This paper presents an online, free access simulation platform for virtual prototyping of clothing as well as the correlated Moodle e-learning platform with the underlining educational materials, meant for training of higher education students and young professionals from the industry. Six research and educational providers from Europe have gathered expertise to provide these training instruments, within the frame of the Erasmus+ project DigitalFashion (www.digitalfashionproject.eu). The simulation platform uses four databases (fabrics, garment patterns, styles and human avatars) to provide the image of drape and fit depending on the selected data (https://digitalfashion.ensait.fr/login). The Moodle e-learning platform tackles the educational materials developed in relation to the four databases of the simulation platform. The e-learning course presents in a user-friendly way the educational materials on fashion database, fabrics database, garment database – use cases, 2D / 3D design and garment e-shopping. The fashion module presents the fashion requirements and the basic design elements of a garment, the fabric module presents the fabric properties and the digitalization of a real fabric into a virtual one, while the garment module tackles design cases and the 2D and 3D design modalities. The e-shopping module presents the final purpose of the simulation platform, namely the virtual try-on. The Moodle e-learning course is free accessible with authentication at https://www.advan2tex.eu/portal/. The Moodle V4.3

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e-learning course was implemented in the six languages of the project (English, Dutch, French, Portuguese, Romanian and Slovenian) and includes Book resources, Quiz activities, and File resources. The simulation platform and the Moodle e-learning platform are correlated, since the Moodle e-learning course relates to the presentation of the databases needed to program the simulation platform.

Keywords: Moodle, training, students, professionals, 3D clothing design

Special Session SFB TRR 280 Design Strategies for Material-Minimized Carbon-Reinforced Concrete Structures

Interphase Structuring in Carbon-Reinforced Concrete

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Due to its unique properties, carbon reinforced concrete (CRC) represents a sustainable and future-oriented alternative to conventional steel reinforced concrete and enables material-efficient and slender structures.
In order to ensure efficient utilization of the high-performance filaments, the fiber bundles must be impregnated to create full force transfer between the individual filaments. This impregnation is often polymer-based, for example using epoxy resins.
A disadvantage of this measure is that the insufficient interaction between the polymer impregnation and the concrete matrix leads to brittle, premature failure. Such failures typically manifest in spalling and delamination of the concrete cover. A micro structured interphase between the impregnated textile reinforcement and the concrete matrix is required.
A look at nature shows that plants embed stiff fibers in less stiff parenchymatous tissue with the help of graded cell regions, thus avoiding the formation of a sharply defined interface. Instead, crack propagation is influenced by factors such as cell wall thickness and cell density.
Transferring this biological principle to CRC, the impregnating material in the interphase between concrete and reinforcement should be gradually reduced, offering the possibility of increasing fracture toughness through a gradual material transition and improved mechanical interlocking.
The development of such layers employs both resin and polymer dispersions, which are processed into porous structures characterized by open access to the surrounding, allowing penetration by the concrete matrix. In this study, different strategies were used for creating an open-cell porous polymer layer. The morphology of these layers are analyzed by SEM and μCT including parameters such as porosity, cell size, cell wall thickness and the proportion of open cells. The surface roughness and the penetration of matrix materials into the open cells are also assessed.
Initial tests have shown that porous polymer structures can be applied to yarns.

Keywords: carbon reinforced concrete, interphase design, Bio, inspiration, porous polymer

*Speaker

Special Session GRK 2430 Interactive Fiber Rubber Composites

The power of twist in polymer fibers for twisted coiled actuators

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Recent advancements in fiber-based actuators have spotlighted twisted, coiled polymer actuators (TCPAs) as a promising technology, offering a combination of high energy density, cost-effectiveness, and environmental sustainability. A comprehensive review of current literature underscores the potential of TCPAs while also revealing significant hurdles in scaling production and maintaining stability for widespread textile integration. Our research directly addresses these challenges through an innovative manufacturing paradigm rooted in false-twisting techniques.
The approach enables rapid, continuous production of intensely twisted polymer monofilaments, simultaneously allowing for the seamless incorporation of functional elements for thermal actuation and sensory capabilities. The study delves into the impact of this additional helical tier, alongside critical parameters such as twist intensity, thermal processing conditions, and chirality, on the actuator's contractile behavior.
Exploiting the inherent structural integrity of plied yarns, we demonstrate the feasibility of processing these advanced TCPAs using conventional textile equipment. This may facilitate the creation of complex, multi-yarn contractile systems through circular braiding techniques, effectively producing artificial muscles at a scale previously unattainable.
The findings reveal that monofilament coils can achieve remarkable contraction rates of up to 60%, with a direct correlation between twist density and actuator efficiency in single-filament configurations. Interestingly, this relationship becomes more nuanced in plied-yarn structures, where the interplay between polymer chain orientation and yarn-level twisting leads to enhanced contractile performance through synergistic effects. This work not only advances the theoretical understanding of TCPA behavior but also presents a practical pathway for their integration into large-scale textile applications. By bridging the gap between laboratory concepts and industrial feasibility, the next generation of smart textiles and wearable technologies could be powered by TCPAs.

Keywords: fiber, shaped actuators, active textiles, twisted coiled polymer actuators, thermos, active fibers

*Speaker

Development and evaluation of anisotropic glass fibre rubber composites with stiffened section and integrated SMAs

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This paper investigates the deformation behaviour of Shape Memory Alloy (SMA) wire integrated glass fibre rubber composites with stiffened section aimed to study the influence of fibre orientation. The study involves manufacturing and testing of the SMA wire integrated composites to analyse and assess the deformation behaviour when it is activated. Advanced textile technologies, including Tailored Fibre Placement (TFP) and knitting were employed to manufacture the semi-finished fabrics. The angled fibres were obtained by sequentially moving a set of needle pins attached to the needle bed frame of the flat-knitting machine. The stiff section was created by the variation in the density of fibres and the samples were varied based on the length of the stiff section. Silicone was considered as the matrix material and the composite was cured at room temperature for 48 hours following the vacuum assisted resin infusion process. As the SMA wire is activated, the deformations were observed and captured using the Microsoft Azure Kinect cameras. Three cameras were positioned in three different perspectives to capture the three-dimensional deformation behaviour in the composites. The synchronised videos from three cameras were then post-processed to obtain colour and depth images, which were used to generate the point clouds for precise 3D spatial analysis. These point clouds enabled the identification and tracking of specific deformation points within the composite. This study offered valuable insights to the deformational patterns generated by the samples, offering a basis for optimizing and tailoring the bending-twisting behaviour of SMA wire integrated fibre rubber composites.

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Keywords: 3D spatial analysis, interactive fiber rubber composites, shape memory alloy

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Innovative Testing of Rubber and Textile Fibers: Insights into Durability and Mechanical Transitions

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Semi-crystalline polymers, including rubbers and textile fibers, are commonly used in applications where durability and performance under stress are essential. These materials are frequently exposed to continuous mechanical, chemical, thermal, and environmental stresses, especially in high-performance and industrial contexts. Unlike clothing textiles that can experience relaxation when not in use, rubber and textile materials in demanding applications often endure constant stress, making long-term reliability critical to prevent material failure.

Standardized testing methods offer valuable insights into the baseline capabilities of rubber and textile materials. However, understanding the long-term durability and fatigue of these materials requires evaluating their behavior in conditions that closely mimic real-world environments. The mechanical behavior of fibers and rubber components is typically visco-elastoplastic, evolving based on the stresses encountered over time. For instance, freshly manufactured materials may display different mechanical properties than those subjected to extensive use.

To explore the mechanical behavior of rubber and textile materials in relation to parameters such as polymerization degree and crystallinity, we developed a quasi-static, modulated mechanical testing approach. This method applies a low-amplitude strain modulation on standardized quasi-static stress, allowing us to probe visco-elastoplastic properties and identify material transitions. The approach is adaptable to various testing conditions, whether at elevated temperatures or in controlled atmospheres and aqueous environments, making it suitable for both rubber and textile applications.

This study introduces tests on rubber and textile fibers using a specialized experimental setup. Our system integrates a monitoring device with a standard dynamometer to track the material's central region during quasi-static movement. The setup includes two cameras: a visible-light camera for observing local elongation through image correlation with laser illumination and a thermographic camera for atmospheric tests to validate the identification of mechanical transitions based on strain modulation.

This research advances our understanding of the mechanical behavior of rubber and textile materials through innovative testing techniques and detailed analysis. The insights gained have significant implications for enhancing the durability and functionality of these materials in applications requiring continuous mechanical strength under prolonged stress.

Keywords: polymers, textile, uniaxial tensile test, modulation, DIC

*Speaker

Investigating the role of microstructure evolution on the properties of magneto-active elastomers

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Magneto-active elastomers (MAEs) are advanced composite materials consisting of a soft elastomeric matrix embedded with magnetic micro-inclusions. These materials exhibit complex multiscale response that presents significant challenges for modeling and analysis. In the absence of an external magnetic field, the mechanical behavior of MAEs can be approximated as that of a rubber matrix reinforced with rigid filler particles. However, under an applied magnetic field, the magneto-mechanical coupling arises from magnetic interactions among the embedded particles. These interactions induce macroscopic deformations of the elastomer and lead to microstructural rearrangements, such as the formation of particle columns aligned with the field. To characterize the mechanical behavior, a transversely isotropic Neo-Hookean model is employed, capturing the anisotropic elastic response of the material. The magnetic behavior is modeled using a dipolar mean-field approach, which accounts for interactions between magnetized particles under an external field. Furthermore, an additional term is introduced governing the microstructural evolution during deformation. Several forms of this term are systematically evaluated to identify the most effective framework for capturing microstructural dynamics. The proposed model enhances our understanding of the interplay between microstructural evolution and the magnetically induced deformation and stiffness of MAEs, thereby providing critical insights into their behavior and guiding the development of predictive tools for these multifunctional materials.

Keywords: material modeling, Magneto, active elastomers, multiscale modeling

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Development of high-modulus glass fibres for the light-weight constructions

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The development of high-modulus glass fibres (HM-GF) based on magnesium-aluminium-silicate glass compositions offers significant potential for lightweight construction, particularly in applications requiring high mechanical performance and thermal stability at a competitive cost. This study explores the influence of specific oxides, such as Y_2O_3, ZnO, and CeO_2, on the mechanical properties and spinnability of 36 novel glass compositions. Fibres with diameters as small as 13 µm were produced and characterized for their elastic modulus and tensile strength. The optimal composition, T9, demonstrated an elastic modulus exceeding 100 GPa, a 31.2% increase in tensile strength, and a 17.6% improvement in specific modulus compared to conventional E-glass fibres. However, challenges such as crystallization and reduced spinnability were observed, particularly in compositions with high Y_2O_3 content. Mechanical testing of fibre-reinforced composites revealed that HM-GF-based composites outperformed conventional materials, with V10-GF composites achieving a 51.8% higher flexural strength and a 48.4% higher modulus. These results underscore the potential of MAS-based HM-GF as advanced reinforcements for structural applications. Future work will focus on compositional refinements, interface optimization, and scaling up production to facilitate the adoption of these next-generation glass fibres in high-performance composites. This research lays the groundwork for sustainable, high-performance materials with enhanced mechanical properties

Keywords: high modulus, glass fibers, light weight

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Constitutive Modeling of Magnetorheological Elastomers (MREs)

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Magnetorheological elastomers (MREs) are composite materials consisting of a rubber matrix filled with magnetizable particles. The mechanical properties of these materials can be altered by inducing external magnetic fields. The coupling behavior of MREs makes them suitable to be used as actuators. This has led to increasing interest in experimental, theoretical, and numerical studies of magnetoelastic materials over the last decades. Several modeling strategies have been proposed to describe the magnetoelastic response of MREs at finite deformation. Generally, these approaches can be categorized either as macroscopic phenomenological models or homogenization-based frameworks. In phenomenological models, free energy functions describe the overall response, where the behavior of particles and the matrix is described without the need of modeling the matrix and particles as separate continuums. On the other hand, homogenization approaches can be applied to MREs, in which the matrix and particles are discretized separately. This work provides an overview of theoretical and numerical frameworks used to model magnetorheological elastomers (MREs), which comprise isotropic incompressible matrix and spherical iron filler particles. The outlook is to derive a reliable phenomenological model, which can be employed to numerically simulate the respective magnetostriction Response efficiently.

Keywords: magnetorheological elastomers, phenomenological models, homogenization approaches, finite deformation, numerical simulation

*Speaker

Sustainable and recyclable matrix and functional elastomers for I-FRC with hybrid and time-variable crosslinking structures

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Conventional Elastomers are primarily used in the automotive industry as tyres & various seals, dampers and insulations for construction etc. Due to their specific strengths, elastomers have established themselves as versatile materials, functioning alongside other materials in both high-performance and everyday applications. Within the scope of RTG 2430, we are working on modified elastomers exhibiting thermoreversible crosslinking & cohesive bonding, to facilitate reprocessability and to contribute to a circular economy and appeal to major production processes. The emergence of bio-based polymers, with a focus on recyclability and sustainability, has opened new opportunities for the development of reprocessable elastomeric materials. In this work, we leverage well-founded polymer science principles like melt vitrimerization and ionic modification with bio-based and synthetic polymers to develop a thermally reprocessable elastomeric material. Furthermore, we investigate the ageing characteristics of these materials through thermomechanical characterization to understand their long-term performance. Finally, we explore compounding formulations to integrate the material for assembly processes with fibre reinforcement as well as develop test methods to assess recyclability, reusability and degradation. This research will also contribute to the objectives of related subprojects within RTG 2430, supporting broader advancements in sustainable elastomeric materials.

Keywords: elastomer, thermoreversibility, sustainability, polymer fibre reinforcement, crosslinking, reprocessability, polymers

*Speaker

Influence of Fiber Material on Actuation Performance in Fiber-Reinforced DEAs

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Polymer-based composite systems are frequently linked to fiber-reinforced plastics due to their notable strengths, including a superior strength-to-weight ratio, corrosion resistance, and durability when compared to metals. Another class of polymers that can be functionalized through fiber reinforcement are fiber-rubber composites, which are often considered for use in soft robotics. When combined with electro-active polymers, such as dielectric elastomer actuators (DEAs), they can be utilized as actuators. DEAs are often used in biomimetic applications due to their rapid actuation speed and ductility and can be manufactured in a variety of configurations. A common configuration is the strip actuator, which is straightforward to fabricate with freely adjustable dimensions. In combination with a passive fiber reinforcement layer, strip actuators can be forced to exhibit mechanically anisotropic behavior. These FRDEAs (fiber-reinforced DEAs) provide electro-active forces that are independent of their aspect ratio and their deformation is limited to one degree of freedom, simplifying control of the DEAs. While it has been demonstrated that FRDEAs can be reinforced with a composite of silicone and carbon fibers, their behavior using different reinforcing fibers has yet to be fully investigated. This study examines the impact of the selected fiber reinforcement material on the mechanical and electro-mechanical behavior of FRDEAs, with a particular focus on fibers commonly utilized in fiber-reinforced plastics, such as glass and basalt. The variation of the fiber material impacts the fiber-matrix adhesion, thus influencing the degree of mechanical anisotropy. This is studied globally through strain tests and locally via digital image correlation. Additionally, the resulting electro-mechanical properties of the actuators and their long-term stability are investigated.

Keywords: dielectric elastomer actuators, electro-active polymers, soft robotics, fiber-rubber composites, soft actuators

*Speaker

Damage evolution in fiber-reinforced dielectric elastomer actuators: combined in-situ thermographic and stress measurement techniques

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The degradation of fiber-rubber-composite (FRC) base materials, the inevitable imperfections introduced during the composite manufacturing process, as well as respective damage developments over the life cycle of FR-DEAs (fiber-reinforced dielectric elastomer actuators) have mainly been understood in terms of isolated mechanisms to date. Their interactions, their prediction and preventive measures need to be investigated further in order to get predictable and robust actuators. Therefore, new methods are to be developed to enable a deeper understanding of the damage mechanisms of FRCs and the prediction of their evolution up to failure. Preliminary inspection can reveal production defects in DEAs: Thermographic methods have proven to be a suitable method for these complex composite structures, as they can visualize the characteristic production defects with relatively inexpensive hardware. Likewise, in-situ DIC (digital image correlation) has proven to be a helpful method for measuring the development of damage also in the base material. Passive thermoelastic stress analysis (TSA) or active heat flow thermography relies exclusively on thermographic data. In contrast, the combined measurement methods developed are intended to make thermal effects such as strain crystallisation, friction- and unwinding processes distinguishable from stress fields in the sample. Production-related damage, its development during use and material-related degradation up to failure are to be characterised and classified in-situ over the entire life cycle. For some materials, it has been shown that combined stress field and thermographic measurement methods can have fundamental advantages. These promising approaches are to be made usable for the class of FR-DEAs through the development of test setups combining in-situ impulse thermography and passive thermography with simultaneous DIC, as well as corresponding methods that provide consistent results.

Keywords: dielectric elastomer actuators, thermography, digital image correlation, fiber rubber composites, soft robotics

*Speaker

Carbon Fiber-Constrained Multilayer Dielectric Elastomer Actuator Fabricated via the Sheet-to-Sheet Method

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Dielectric elastomer actuators (DEAs) exhibit high energy and power density while also being extremely deformable. These properties make them promising for applications in bionic robotics and artificial muscles. However, DEAs require a high electric field strength (20–100 V/µm) to operate. To reduce the voltage demand, the thickness of a single DEA layer is typically on the micrometer scale. As a result, stacking dozens or even hundreds of DE layers are required to achieve sufficient displacement in the thickness direction. Utilizing displacement in the planar direction can significantly reduce the required number of DE layers. However, the in-plane strain of DEAs is biaxial, which means that if uniaxial actuation is desired, the strains that occur perpendicular to the working direction are of no use. Eliminating these strains reduces the actuator's degrees of freedom, resulting in improved actuator performance. In this work, a carbon fiber prepreg was developed using a unidirectional non-crimp fabric with a soft silicone as the matrix material. The use of a soft matrix material instead of the conventional stiff resins results in a composite with a high degree of mechanical anisotropy. Multilayer DEAs were fabricated using the sheet-to-sheet method and reinforced with the carbon fiber composite layer. The resulting DEAs were characterized and exhibited significantly higher strains and forces than their unconstrained counterpart during uniaxial motion.

*Speaker

Theoretical calculations of thermo-mechanical properties for new I-FRCs

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The design and optimization of Interactive Fiber-Rubber Composites (I-FRCs) necessitate a fundamental understanding of their thermo-mechanical behavior across multiple scales. This study establishes quantitative structure-property relationships for polymer-based elastomeric matrices using an integrated computational framework that includes molecular dynamics (MD) simulations in LAMMPS and ab initio computations in VASP. The primary emphasis is first on polyethylene (PE) as a model system for assessing heat transport, mechanical durability, and mass transfer properties, with the methodology being extended to other high-performance polymer composites. LAMMPS will be used to run MD simulations using the Green-Kubo (EMD) approach to compute thermal conductivity by studying phonon transport and interfacial thermal resistance within fiber-reinforced composite systems. Ab initio calculations exploiting the Boltzmann Transport Equation (BTE) will be carried out in VASP to determine electronic density of states (DOS), charge distribution as well as cohesive energy and phonon dispersion relations to better understand the intrinsic thermo-mechanical properties of candidate elastomer matrices. Mechanical stability and failure modes will be evaluated via deformation tests to determine the stress-strain response and energy dissipation mechanisms. The unique feature of this research is going to be the incorporation of AI-driven screen algorithms to improve material selection and accelerate predictive modelling. This study systematically examines molecular weight, crystallinity, crosslinking density, and chain dynamics to connect atomistic-scale simulations with continuum-level modeling and create comprehensive material datasets for advanced meso- and macro-scale applications. Initial studies imply that phonon transport efficiency and chain orientation effects improve heat conductivity and anisotropic mechanical characteristics of crystalline polyethylene. Expanding the approach to incorporate different elastomeric polymers will allow for a deeper study of next-generation I-FRCs thermal and mechanical performance.

Keywords: interactive fiber-rubber composites (I-FRCs), molecular dynamics (MD) simulations, ab initio, Green-Kubo method, Boltzmann transport equation (BTE), phonon transport, AI-driven material screening, electronic density of states (DOS)

*Speaker

Investigation of magneto-active soft materials and their complex deformation using 3D printing technology

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Soft actuators with multiple degrees of freedom have long attracted extensive research and attention for achieving diverse shape transformations. Among them, magnetic actuators with programmable structural design and controllable deformation enabled by 3D printing technology are particularly prominent in the field of soft robotics. In this study, a concept for the realisation of 3D printable magnetic excitable actuators is presented. This involves the fabrication of suitable printing filaments by compounding thermoplastic rubber materials with magnetic particles, followed by the production of magneto-active soft materials (MASMs) using Fused Deposition Modelling (FDM) techniques. To achieve MASMs with controlled deformation capabilities, key parameters such as magnetic field strength, field direction, and magnetisation temperature need to be investigated. The study of compounding technology establishes a solid foundation for the subsequent fabrication of 3D MASM components and their successful magnetisation. Future research will primarily focus on the pre-magnetisation of 3D MASM components and their characterisation. Additionally, a finite element model for analysing the magnetically driven deformation and motion behaviour of 3D MASMs is essential. This concept highlights the potential of 3D-printed elastic magnetic actuators in the fields of soft robotics and bionics.

Keywords: 3D-Printing, magnetic field, soft materials

*Speaker

Intelligent Control of Spatial Deformations in Soft Prototypes Driven by SMA Wires: A Roadmap

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In this presentation, I outline a roadmap that leverages prototypes from cohorts I and II—potentially enhanced with additional sensors and modifications — as well as any newly available prototypes to gather comprehensive system data. These data will serve two primary purposes. First, it will be used to develop and validate a model of the system. Second, it will form the basis for designing a control algorithm using reinforcement learning (RL). To fully explore RL, both model-based and model-free RL approaches will be implemented and compared. Moreover, both offline and online RL methods will be investigated. Offline RL will involve training on pre-collected data, though it may sometimes prove less efficient in unforeseen situations. In contrast, online RL enables the agent to learn in real-time, but interacting with a live System carries risks if the agent takes suboptimal or dangerous actions. Evaluating These complementary approaches will allow for a thorough assessment of performance, adaptability, and safety. In parallel, a hybrid modeling approach will be developed that combines data-driven models with classical models. This integration is expected to yield a more accurate representation of system dynamics and, as a result, enable more precise control. One control strategy within this hybrid framework will be Model Predictive Control (MPC), which excels at managing system constraints. The performance of these advanced methods will be benchmarked against traditional control techniques such as robust control. The motivation for employing these intelligent methods stems from the increasing nonlinearity and complexity due to spatial deformations of the new prototypes which have multiple inputs and outputs—conditions under which conventional control methods often become inefficient. By exploring various RL paradigms and hybrid modeling strategies, this work aims to harness the strengths of both data-driven and classical approaches. While these advanced approaches offer significant advantages, they also come with challenges, such as convergence issues in RL and the complexities involved in integrating classical and data-driven models.

Keywords: reinforcement learning, shape memory alloys, hybrid modelling, model predictive control

*Speaker

Techniques for Inducing Pure Twisting Deformation in Shape Memory Alloy Integrated Textile Rubber Composites: An Experimental and Numerical Approach

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Shape Memory Alloy (SMA) integrated textile rubber composites are used in soft robotics to develop multi-joint structures capable of performing complex spatial motions with a higher degree of freedom. The complex deformations in these structures can be categorized into bending, twisting, and bend-twist coupling. Several studies have been carried out regarding the analysis of bending deformation of composite structures using pre-stretched SMA actuators. The objective of this research is to explore techniques for achieving twisting deformation in composite structures through the temperature-dependent activation of SMA actuators. Three different SMA states are chosen to develop three techniques for inducing twisting deformation. The first technique involves the use of standard SMA, which is twisted into a helical structure before being integrated into the composite. The second approach uses linearly pre-stretched SMA, where the SMA wire is wound around two layers of textile to form a double Z-shaped network near the fixed support of the structure. Finally, a commercially available SMA torsion wire is placed within the composite specimen, specifically designed to generate torque in the actuators. Under thermal activation, the transformation stress generated due to the phase change induces twisting in the structure. Additionally, the effectiveness of these techniques is compared based on actuation torque generation, twist angle symmetry and ease of SMA integration into the composite.

Keywords: shape memory alloy, phase transformation, pre-stretch, fiber-rubber composites, soft robotics

*Speaker

Textiles as smart materials in soft and switchable robotics

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This work investigates the application of textile structures as functional components in soft robotic systems, utilizing fiber anisotropy to achieve controlled mechanical properties and integrated sensing capabilities. The research focuses on three primary areas: solid-state joint design, shape memory alloy (SMA) actuator enhancement, and distributed sensor integration. Fiber orientation and textile architecture are employed to create solid-state joints with directionally-dependent stiffness properties. The anisotropic nature of aligned fiber reinforcements enables selective compliance and stiffness modulation without conventional mechanical joints. Experimental characterization demonstrates controllable bending and torsional responses based on fiber arrangement patterns. For SMA actuator systems, textile integration provides thermal management and mechanical constraint functions. The fiber matrix constrains actuation directionality, resulting in measured improvements in response time and displacement accuracy compared to unconstrained SMA elements. Braiding techniques are utilized to incorporate temperature and strain sensing elements directly into fiber-reinforced elastomer composites. Conductive fibers and temperature sensitive wires are integrated during the braiding process, creating distributed sensor networks within the material structure. The embedded sensors provide continuous monitoring of thermal conditions and mechanical deformation states throughout the robotic system. Mechanical testing and thermal characterization validate the performance of these textile-based approaches across various loading conditions and temperature ranges. The results indicate that textile integration offers a viable method for combining structural, actuating, and sensing functions within soft robotic materials, with potential applications in adaptive systems requiring distributed feedback control.
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Keywords: soft robotics, fiber-elastomer composites, integrated sensing, shape memory actuators

*Speaker

Author Index