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Advanced Composites and Applications

Book of Abstracts

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UNIVERSITY OF LATVIA

83rd International Scientific Conference of the University of Latvia 2025

Advanced Composites and Applications
Tuesday, 11 **February 2025, 10:00-16:00 (EET/UTC +2)**, Online

Programme

Chair: Assoc. Prof. Tatjana Glaskova-Kuzmina		
10:00–10:05	**Tatjana Glaskova-Kuzmina** *University of Latvia, Riga, Latvia*	**Opening of the Conference special session**
10:05–10:20	**Andrejs Krauklis, Floriane Verceux, and Sotirios Grammatikos** *Norwegian University of Science and Technology, Gjøvik, Norway*	**Quantitative structure-property relationships for non-destructive evaluation of aging in polymers**
10:20–10:35	**Stanislav Stankevich, Daiva Zeleniakiene, Jevgenijs Sevcenko, Olga Bulderberga, Katerina Zetkova, Joao Tedim, and Andrey Aniskevich** *University of Latvia, Riga, Latvia* *Kaunas University of Technology, Kaunas, Lithuania* *SYNPO, Pardubice, Czech Republic* *Campus Universitário de Santiago, Aveiro, Portugal*	**Moisture absorption and its modelling of polymer systems incorporated with layered double hydroxide particles**
10:35–10:50	**Monika Chomiak, Mateusz Małysiak, Małgorzata Szymiczek, Michał Szafron, Bartosz Wolny, Oliwia Cudnik, Maciej Smaguła, and Łucja Wantuch** *Silesian University of Technology, Gliwice, Poland*	**Advanced structural analysis of epoxy-carbon composites for lightweight bicycle frames**
10:50-11:05	**Mustafa Dündar, Ergün Ekici, and İlyas Uygur** *Çanakkale Onsekiz Mart University, Çanakkale, Turkey* *Düzce University, Duzce, Turkey*	**Numerical investigation and optimisation of low velocity impact behaviour of thermoplastic based composite materials with different fibre types**
11:05-11:20	**Mostafa Sadeghian, Arvydas Palevicius** *Kaunas University of Technology, Kaunas, Lithuania*	**Application of the differential quadrature numeric technique to study deflection and stability of ultra-small-scale plates**

11:20-11:35	**Leons Stankevics, Olga Bulderberga, Jevgenijs Sevcenko, and Andrey Aniskevich** *University of Latvia, Riga, Latvia*	**Linear and nonlinear viscoelastic models for creep of 3D printed polyethylene terephthalate glycol samples**
11:35-11:50	**Mughees Shahid and Daiva Zeleniakiene** *Kaunas University of Technology, Kaunas, Lithuania*	**Comparative investigations and prediction of elastic properties in various fibre systems of hemp reinforced bio-epoxy plastic composite using numerical and analytical methods**
11:50–12.05	**Virtual coffee break**	
12.05–12:20	**Anish Niranjan Kulkarni, Andrejs Pupurs, and Mārtiņš Irbe** *Riga Technical University, Riga, Latvia*	**Manufacturing of high-performance thermoset composites using electromagnetic induction heating**
12:20–12:35	**Karina Dragašiūtė, Gediminas Monastyreckis, and Daiva Zeleniakiene** *Kaunas University of Technology, Kaunas, Lithuania*	**Localized epoxy curing technology for enhanced aviation composite bonding**
12:35–12:50	**Rudolfs Gravitis, Oskars Platnieks, and Sergejs Gaidukovs** *Riga Technical University, Riga, Latvia*	**Melt blending-induced cross-linking in fiber-reinforced biopolyesters for advanced bio-based composites**
12:50–13:05	**Piotr Zagulski and Rafał Chatys** *Kielce University of Technology, Kielce, Poland*	**Effect of post-curing on the mechanical properties of polymer composites**
13:05-13:20	**Sultan Ullah and Giedrius Janusas** *Kaunas University of Technology, Kaunas, Lithuania*	**Mechanical performance and impact resistance of polymer composites enhanced by glass microspheres and a hybrid matrix**
13:20-13:35	**Martins Nabels-Sneiderds, Oskars Platnieks, Anda Gromova, Liga Orlova, and Sergejs Gaidukovs** *Riga Technical University, Riga, Latvia*	**High-barrier packaging film application: biodegradable poly (butylene succinate) laminate with nanocellulose**
13:35-13:50	**Justas Ciganas, Loreta Kelpsiene, and Urte Cigane** *Siauliai State Higher Education Institution, Siauliai, Lithuania*	**Research and development of innovative composite for roofing applications**
13:50–14:05	**Virtual coffee break**	
14:05-14:20	**Monika Chomiak, Iwona Gródek, Małgorzata Szymiczek, Martyna Gawlas, Martyna Rzepiela, Julia Wawrzynek, Jakub Otyński, and Paulina Ferdyn** *Silesian University of Technology, Gliwice, Poland*	**Accelerated aging and lifetime assessment of organic filler-modified composites**

14:20-14:35	**Elina Vindedze, Tatjana Glaskova-Kuzmina, Partel-Peeter Kruuv, Didzis Dejus, Janis Jatnieks, Maksims Jurinovs, and Sergejs Gaidukovs** *AM Craft, Riga, Latvia* *University of Latvia, Riga, Latvia* *Riga Technical University, Riga, Latvia*	**Characterization and comparative analysis of ISO and ASTM standards for mechanical properties of ULTEM™ 9085**
14:35-14:50	**Nawres J. Al-Ramahi, Roberts Joffe, and Patrik Fernberg** Luleå University of Technology, Luleå, Sweden	**Electro-thermal performance of carbon fiber composites for ice prevention applications**
14:50-15:05	**Muhammad Imran Rameel, Gediminas Monastyreckis, and Daiva Zeleniakienė** *Kaunas University of Technology, Kaunas, Lithuania*	**Integrating MXene coatings into composite materials for enhanced strain sensing**
15:05-15:20	**Mohamad Alsaadi, Declan M. Devine, and Eoin P. Hinchy** *Technological University of the Shannon, Athlone, Ireland* *University of Limerick, Limerick, Ireland*	**A comparison study on the shape memory and viscoelastic behaviour of 4D printed photocurable methacrylate and epoxy-based resins**
15:20-15:35	**Zeenat Akhter and Arvydas Palevicius** *Kaunas University of Technology, Kaunas, Lithuania*	**Piezoelectric polymer PVDF sensors for advanced energy harvesting and sensing applications**
15:35-15:50	**Müslüm Kaplan** *Bartın University, Bartın, Turkey*	**Development and characterization of conductive polymer nanocomposites and their melt-spun filaments for smart textile applications**
15.50–16:00	**Concluding remarks**	

Contents

QUANTITATIVE STRUCTURE-PROPERTY RELATIONSHIPS FOR NON-DESTRUCTIVE EVALUATION OF AGING IN POLYMERS

Andrejs Krauklis, Floriane Verceux, and Sotirios Grammatikos

ASEMlab – Laboratory of Advanced and Sustainable Engineering Materials, Department of Manufacturing and Civil Engineering, NTNU – Norwegian University of Science and Technology, 2815 Gjøvik, Norway, *andrejs.krauklis@ntnu.no*, *floriane.verceux@ntnu.no*, *sotirios.grammatikos@ntnu.no*

Aging processes, due to environmental degradation and recycling, cause significant deterioration in the mechanical properties of polymers, undermining their long-term structural performance. Current industry practices heavily rely on costly and time-consuming destructive testing methods to assess the extent of degradation. To address these challenges, a novel hybrid approach combining Quantitative Structure-Property Relationship (QSPR) modeling with Fourier Transform Infrared (FT-IR) spectroscopy is presented as a rapid and non-destructive evaluation (NDE) methodology for polymers [1].

QSPR methodology was validated using Polylactic Acid (PLA) as a case study, under hygrothermal aging and recycling conditions. FT-IR spectroscopy was employed to monitor molecular-scale changes, particularly the hydrolysis of ester bonds at 1180 cm^{-1}, which serves as a key degradation indicator. By integrating FT-IR data with QSPR models, mechanical properties such as Young's modulus were predicted with high accuracy. Experimental validation has shown that the QSPR-based predictions align well with observed stiffness degradation, capturing trends in aging (15, 30, 45, and 60 days at 40 °C in distilled water) and recycling cycles (up to four iterations).

The presented work provides and advancement to the modular multiscale modeling frameworks [2], aiming to connect molecular degradation mechanisms to predict long-term performance. By linking chemical degradation at the molecular scale to macroscopic mechanical performance, it bridges critical gaps in current aging prediction methodologies. The modular nature of this framework allows the integration of new experimental techniques and modeling tools, enhancing its adaptability and applicability across diverse polymer systems. By providing rapid, cost-effective, and non-destructive tools for real-time polymer health monitoring, it has potential applications across diverse polymer systems and environmental conditions. Future work will focus on extending the methodology to other polymer types and exploring additional degradation mechanisms, such as thermo-oxidation and cross-linking.

Acknowledgements

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MOISTURE ABSORPTION AND ITS MODELLING OF POLYMER SYSTEMS INCORPORATED WITH LAYERED DOUBLE HYDROXIDE PARTICLES

Stanislav Stankevich[1], Daiva Zeleniakiene[2], Jevgenijs Sevcenko[1], Olga Bulderberga[1], Katerina Zetkova[3], Joao Tedim[4], and Andrey Aniskevich[1]

[1] Institute for Mechanics of Materials, University of Latvia, Jelgavas St. 3, Riga, LV-1004, Latvia, Corresponding author: stanislav.stankevich@lu.lv
[2] Department of Mechanical Engineering, Kaunas University of Technology, Studentų St. 56, 51424 Kaunas, Lithuania
[3] SYNPO a.s., S. K. Neumanna 1316, Pardubice 532 07, Czech Republic
[4] DEMaC-Aveiro Institute of Materials, Campus Universitário de Santiago, Aveiro 3810-163, Portugal

The integration of layered double hydroxides (LDHs) into polymer systems offers significant potential for enhancing material properties, particularly for multilayer coatings used in aeronautical and offshore sectors. These materials serve as eco-friendly nanofillers with ion-exchange capabilities, which enable them to interact with and stabilise various chemical species, improving properties such as flame retardancy, thermal stability, and barrier performance [1, 2]. In the context of corrosion protection, this mechanism allows the capture and immobilisation of corrosive anions, thereby enhancing moisture resistance and structural integrity [3]. This study investigates the moisture absorption behaviour of epoxy-based polymer systems modified with Mg-Al/NO_3 LDH nanoparticles (up to 5 wt%). The aim is to characterise moisture sorption parameters, validate the computational model based on Fick's law of diffusion using obtained parameters, and simulate more complex absorption cases for multilayer systems.

Experimental investigations were conducted under diverse environmental conditions, including distilled water, seawater, concentrated salt solutions (up to 26 wt%), and elevated temperatures (up to 50 °C). The results indicated that the diffusion coefficient of water in the epoxy matrix increased significantly with temperature, showing a 3–5-fold rise in hot water compared to room temperature. The presence of salts in water also influenced the diffusion behaviour, increasing the diffusion coefficient by up to 25 % in concentrated salt solutions. Equilibrium moisture content varied with environmental conditions; for example, a higher salinity of 26 wt% reduced water absorption capacity by up to two times. Conversely, elevated temperatures of 50 °C increased equilibrium moisture content by 20–30 %.

These findings were further used to inform the development of a numerical model based on Fick's law of diffusion, employing the finite-difference method for accurate moisture concentration field predictions in single and multilayer systems. The validated models demonstrated excellent agreement with experimental data, capturing the temporal and spatial distribution of absorbed moisture across multilayered structures.

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ADVANCED STRUCTURAL ANALYSIS OF EPOXY-CARBON COMPOSITES FOR LIGHTWEIGHT BICYCLE FRAMES

Monika Chomiak, Mateusz Małysiak, Małgorzata Szymiczek, Michał Szafron, Bartosz Wolny, Oliwia Cudnik, Maciej Smaguła, Łucja Wantuch

Department of Theoretical and Applied Mechanics, Faculty of Mechanical Engineering, Silesian University of Technology, Konarskiego 18A st., 44-100 Gliwice, Poland, monika.chomiak@polsl.pl, mm310088@student.polsl.pl, malgorzata.szymiczek@polsl.pl

In this study, comprehensive mechanical tests and numerical analyses were conducted on laminated composite plates made of carbon fibre and epoxy resin, with the aim of optimizing the design of a bicycle frame. Plates with thicknesses ranging from 2 to 4 mm were manufactured using 7–13 layers of fabric with a grammage of 200–300 g/m^2. Specimens were cut using water jet technology in three in-plane orientations and subjected to tensile and bending tests in accordance with ISO standards. The results demonstrated that the highest tensile strength, exceeding 600 MPa with minimal strain (<1%), was achieved in plates with a higher number of layers. Specimens cut along the diagonal fibers exhibited greater plasticity, although their tensile strength did not exceed 200 MPa.

Additionally, finite element analysis (FEA) performed in Ansys identified critical regions, particularly at the joints, which are susceptible to stress concentrations under operational loads. These findings underscore the necessity of carefully selecting both the composite structure and the manufacturing process for critical areas in the bicycle frame design. The drawing (Fig. 1) presents a part of the designed frame along with the results of the FEM analysis.

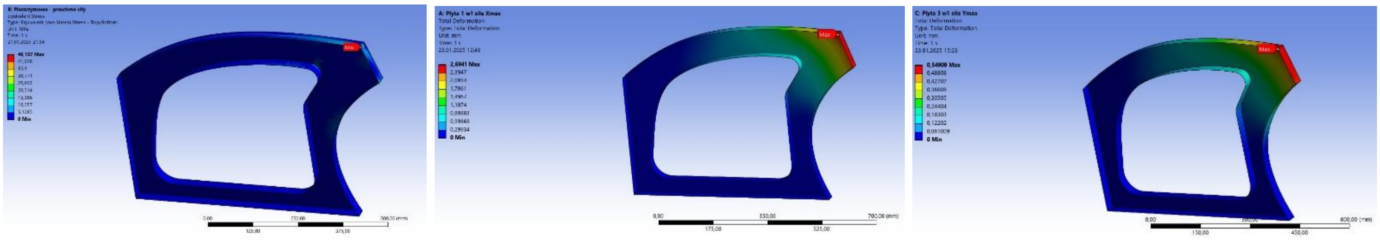

Fig. 1 FEM analysis results – evaluation of tensile strength in the front section of the bicycle frame

Acknowledgements

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NUMERICAL INVESTIGATION AND OPTIMISATION OF LOW VELOCITY IMPACT BEHAVIOUR OF THERMOPLASTIC BASED COMPOSITE MATERIALS WITH DIFFERENT FIBRE TYPES

Mustafa Dündar[1], Ergün Ekici[2], and İlyas Uygur[3]

[1] *Department of Machinery and Metal Technologies, Biga Vocational School, Çanakkale Onsekiz Mart University, Çanakkale, Turkey, m.dundar@comu.edu.tr*
[2] *Faculty of Engineering, Department of Industrial Engineering, Çanakkale Onsekiz Mart University, Çanakkale, Turkey, ergunekici@comu.edu.tr*
[3] *Faculty of Engineering, Department of Mechanical Engineering, Düzce University, Duzce, Turkey, ilyasuygur@duzce.edu.tr*

In the aviation industry, it is of great importance to reduce fuel consumption and carbon emissions by using lighter and environmentally friendly materials. In this direction, polypropylene (PP) based thermoplastic composite materials are attracting more and more attention thanks to their recyclable structure and superior mechanical properties. Glass and carbon fibre-reinforced thermoplastic composites stand out as an alternative solution in aerospace applications by offering a combination of lightness and durability.

In this study, the low-velocity impact behaviour of glass and carbon fibre-reinforced polypropylene-based thermoplastic composites was numerically investigated and optimised. Using LS-DYNA finite element analysis software, impact analyses were performed at different energy levels (2J, 5J, 8J), different impactor diameters (Ø10 mm, Ø15 mm, Ø20 mm) and different composite thicknesses (3 mm, 6 mm, 9 mm). As a result of the numerical analyses, it was observed that the maximum impact load (F_{max}) increased with increasing impact energy, but the absorbed energy varied depending on the striker diameter and material thickness. Increasing the striker diameter increased the rebound effect of the material. In addition, the effects of increasing the thickness of the composite material on the impact strength were evaluated in detail.

The findings provide important data for optimising polypropylene-based thermoplastic composites in terms of impact resistance and their effective use in sustainable aerospace applications.

APPLICATION OF THE DIFFERENTIAL QUADRATURE NUMERIC TECHNIQUE TO STUDY DEFLECTION AND STABILITY OF ULTRA-SMALL-SCALE PLATES

Mostafa Sadeghian and Arvydas Palevicius

Faculty of Mechanical Engineering and Design, Kaunas University of Technology, Studentu 56, 51424 Kaunas, Lithuania, mostafa.sadeghian@ktu.edu

The stability and deflection of nanoplates are numerically investigated in this paper using the differential quadrature method (DQM). In many scientific disciplines, particularly solid mechanics, nonlinear partial differential equations are frequently employed as models to explain intricate physical phenomena. Several examples illustrate the precision and effectiveness of the suggested approach.

When compared to other solutions, numerical solutions derived using this method show a high degree of similarity. Additionally, a number of efficient techniques for figuring out numerical solutions of partial differential equations have been created and refined over the last few decades, and they will be discussed in this paper.

LINEAR AND NONLINEAR VISCOELASTIC MODELS FOR CREEP OF 3D PRINTED POLYETHYLENE TEREPHTHALATE GLYCOL SAMPLES

Leons Stankevics, O. Bulderberga, Jevgenijs Sevcenko, and Andrey Aniskevich

University of Latvia, Institute for Mechanics of Materials, Jelgavas Str. 3, Riga, LV-1004, Latvia
leons.stankevics@lu.lv

Gradual, time-dependent deformation of a material when subjected to constant load over an extended period is called material creep. Creep results from molecule chain deformations, as parts of molecule chains change positions between local energy minimums. If creep deformation is reversible, it is called viscoelastic creep. The material strain during viscoelastic creep can be calculated using different viscoelastic models, with their strengths and weaknesses. The aim of this work was to evaluate different viscoelastic models by precision to experimental data and ease of use with experimental results of 3D printed polyethylene terephthalate glycol samples as a benchmark.

Viscoelastic models are categorised into linear and nonlinear. The material is linearly viscoelastic if strain is proportional to stress at a given time. It is generally described by Boltzmann-Volterra theory:

$$\varepsilon(t) = \frac{\sigma(t)}{E} + \int_0^t K(t-\tau)\sigma(\tau)d\tau\,, \tag{1}$$

where $\varepsilon(t)$ is strain, $\sigma(t)$ is stress at the time t, E is elastic modulus, $K(t-\tau)$ is the viscoelastic kernel.

Different creep behaviour can be obtained by changing the viscoelastic creep kernel within Boltzmann-Volterra theory (1). For this work, the following kernels were evaluated based on adherence to experimental data and ease of use: Duffing, exponential, Prony series, Rzhanitsin, Rabotnov and Abel. Nonlinear models don't have a general form. Findley, Schapery, time-stress superposition, and general cubic models were evaluated among the nonlinear models.

As a result of the evaluation, the Prony series viscoelastic kernel

$$K(t-\tau) = \sum_{i=1}^{N} \frac{A_i}{E\eta_i} e^{-\frac{t-\tau}{\eta_i}} \tag{2}$$

was used to describe creep strain for stress levels less than half of sample strength. The general cubic model

$$\varepsilon(t) = \frac{\sigma(t)}{E} + \int_0^t (c_1\sigma(\tau) + c_3\sigma^3(\tau))\sum_{i=1}^{N} \frac{A_i}{E\eta_i} e^{-\frac{t-\tau}{\eta_i}} d\tau \tag{3}$$

adequately described the creep process for stress up to three-quarters of the strength. In (2) and (3), A_i is relaxation amplitude, η_i is relaxation time, c_1 and c_3 are constants.

COMPARATIVE INVESTIGATIONS AND PREDICTION OF ELASTIC PROPERTIES IN VARIOUS FIBRE SYSTEMS OF HEMP REINFORCED BIO-EPOXY PLASTIC COMPOSITE USING NUMERICAL AND ANALYTICAL METHODS

Mughees Shahid* **and Daiva Zeleniakiene**

Department of Mechanical Engineering, Kaunas University of Technology, Studentu 56, 51424 Kaunas, Lithuania, mughees.shahid@ktu.edu

Natural fibre composites (NFCs) have the potential to enter new markets and demonstrate rising demand, mainly owing to their natural abundance, lightweight nature, high strength-to-weight ratio, and relatively low cost [1]. In addition, predicting the performance and characteristics of materials and components is growing in popularity in several industries [2,3]. This research analyses the elastic properties of hemp natural fibre with a bio-epoxy matrix with the addition of synthetic and natural fibres, considering the influence of fibre volume fractions. The developed representative volume element (RVE) models incorporated varying fibre volume fractions (10%-70%) and different combinations of fibre systems. In a single fibre system, hemp/bio-epoxy plastic composite was investigated. In a hybrid fibre system, flax and S-glass were added as second-phased materials separately with natural fibre hemp to investigate its effect on the elastic characteristics of plastic composite. Furthermore, synthetic S-glass fibre was added with natural hemp and flax fibres in a multi-fibre system. Periodic boundary conditions were utilized to determine the effective elastic properties using the Mori-Tanaka homogenization scheme and finite element analysis. These RVE models evaluated longitudinal, transverse, and shear moduli in addition to Poisson's ratio. The elastic properties were simulated and validated by comparing them with analytical results. The analytical results were obtained using the rule of mixtures, Halpin–Tsai, Nielsen, Chamis, and composite cylinder assemblage. The simulation results suggest that in addition to the fibre volume fraction (VF) increasing from 10% to 70%, the longitudinal modulus, transversal modulus, shear modulus, and Poisson's ratio changed from 9.72 GPa to 55.25 GPa, 1.50 GPa to 7.23 GPa, 0.53 GPa to 2.65 GPa, and from 0.28 to 0.19. The composite cylinder assembly model demonstrated superior results among all analytical methodologies; however, the Nielsen model exhibited the lowest values. The investigation results of the RVE unidirectional model proved strong agreement between analytical and numerical methodologies.

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MANUFACTURING OF HIGH-PERFORMANCE THERMOSET COMPOSITES USING ELECTROMAGNETIC INDUCTION HEATING

Anish Niranjan Kulkarni*, Andrejs Pupurs and Mārtiņš Irbe

Institute of High-Performance Materials and Structures, Riga Technical University, Kipsalas Street 6A-439, Riga, LV-1048, anish-niranjan.kulkarni@rtu.lv

Manufacturing of a carbon/epoxy composite part is a very energy-intensive process. A finished composite part can consume approximately 319 – 428 MJ/kg energy for manufacturing, which includes the energy consumption in production of raw materials such as carbon fibers and epoxy resin, manufacturing of prepregs and curing of prepregs using the conventional method of autoclave curing [10]. To reduce the energy consumption in curing of thermoset composites, volumetric heating methods such as microwave, radio frequency or induction heating have been developed.

The process of induction heating requires formation of closed conductive loops inside the workpiece to be heated. In carbon-fiber reinforced polymeric composites, the fibers can act as current-carrying conductors, and they can generate conductive loops depending upon the reinforcement meso-structure. In the present work, carbon-fiber epoxy composites with $[0,90]_s$ cross-ply layup are manufactured using a moving-coil induction heating setup.

A multi-strand litz wire is used to prepare a circular induction coil. The coil is supplied with high-frequency alternating current, and it is mounted on a CNC router-based rig movable in x- and y-directions. XC130 unidirectional carbon-fiber epoxy prepregs are cut in square-shapes and are placed in desired orientations to form a [0,90]s layup. The assembly is placed in close proximity to the induction coil and the coil is moved in a pre-defined path to achieve required curing temperature inside the workpiece. The temperature is monitored using FLIR A6752sc thermal imaging camera. A moving coil design is meant to avoid generation of cold spots and to achieve uniform temperature inside the workpiece.

The induction-cured composite specimens were tested in quasi-static tensile loading, and their mechanical properties and micro-damage evolution was compared with reference oven-cured specimens. It was observed that micro-damage initiation takes place earlier in induction-cured composites than in oven-cured composites. Properties such as elastic modulus, tensile strength and strain-to-failure in induction-cured composites are on par with oven-cured composites.

Acknowledgements

This work has been supported by Latvian Council of Science, project LZP-2022/1-0572: Development of innovative induction-heating system for manufacturing of high-performance composites with improved mechanical properties [DINCIP].

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LOCALIZED EPOXY CURING TECHNOLOGY FOR ENHANCED AVIATION COMPOSITE BONDING

Karina Dragašiūtė[1], Gediminas Monastyreckis[2], and Daiva Zeleniakienė[2]

[1] *Kaunas University of Technology, Department of Transport Engineering, Studentu str. 56, LT-51424 Kaunas, Lithuania, karina.dragasiute@ktu.edu*
[2] *Kaunas University of Technology, Department of Mechanical Engineering, Studentu str. 56, LT-51424 Kaunas, Lithuania, gediminas.monastyreckis@ktu.lt, daiva.zeleniakiene@ktu.lt*

The bonding process of composite materials in aerospace applications significantly impacts the structural integrity and energy efficiency of manufactured components. Traditional curing methods, such as oven and autoclave curing, are energy-intensive, costly, and unsuitable for handling large composite components, posing scalability challenges [1,2]. These methods often result in inefficient energy use due to the need for prolonged curing cycles and non-homogeneous heat distribution in the bonding areas [3,4]. This study explores an innovative bonding method using carbon nanotube (CNT)-enhanced epoxy adhesives, combined with localized Joule heating as an alternative to traditional curing methods.

In this investigation, CNT-enhanced epoxy adhesives were applied exclusively to the bonding area of single-lap specimens reinforced with glass fibre-reinforced polymers (GFRP). CNT concentrations ranging from 0.25 to 1 wt% were evaluated. A resistive heating method enabled localized curing, with precise monitoring of temperature, electrical resistance, and thermal distribution across the bonding area. Mechanical performance of the bonded specimens was characterized by lap-shear testing in accordance with ISO 4587 standard.

This localized curing approach has shown significant potential for enabling efficient adhesive polymerization while ensuring uniform heat distribution in the bonding area. Results indicate that optimal CNT concentrations (0.5 wt%) achieve a balance between thermal conductivity and mechanical strength, while higher concentrations lead to performance degradation due to agglomeration and void formation. This method offers a scalable, energy-efficient alternative for composite bonding, paving the way for advancements in aerospace manufacturing and other industries requiring high-performance composites.

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MELT BLENDING-INDUCED CROSS-LINKING IN FIBER-REINFORCED BIOPOLYESTERS FOR ADVANCED BIO-BASED COMPOSITES

Rudolfs Gravitis, Oskars Platnieks, and Sergejs Gaidukovs

Riga Technical University, Faculty of Natural Sciences and Technology, Institute of Chemistry and Chemical Technology, P.Valdena iela 3/7, Rīga, rudolfs.gravitis@rtu.lv, oskars.platnieks_1@rtu.lv, sergejs.gaidukovs@rtu.lv

The transition from fossil fuel-derived polymers to bio-based materials is crucial for the future of sustainable materials. Bio-based polymers - poly(butylene succinate-co-butylene adipate) (PBSA) and poly(hydroxy butyrate) (PHB) - were studied as a matrix for reinforced composite materials. Wool fibers were used as reinforcement as it is a valuable natural resource that is being disposed of as waste after the end of use. To address the compatibility of matrix and fibers, cross-linking with two different compatibility agents was used during melt processing. The compatibility agents used were hexamethylenediisocyanate (HMDI) and acrylated epoxidized soybean oil (AESO).

The study developed 15 new composite formulations from recycled wool fibers, bioplastics, and two different modifiers, which promoted the adhesion between the fibers and the matrix. The mechanical, thermal, and thermomechanical properties of the composites were investigated, and the resulting structure was characterized.

The matrix and fibers of the composite without the addition of modifiers show weak interaction at higher filler levels (40 wt%). The addition of modifiers AESO and HMDI in amounts of 10 wt% and 2 wt%, respectively, significantly improves the interaction between the matrix and fibers, which is reflected in a substantial increase in fracture strength compared to the unmodified composite.

Mixing time significantly improves the homogeneity of the samples but reduces the fiber length. The PBSA compositions mixed for 30 minutes exhibited better mechanical properties than those mixed for 5 minutes.

The reinforcement provided by the filler in PBSA compositions improved the storage modulus of the material throughout the viscoelastic region. In modified PBSA composites, the crystallization temperature increased significantly.

Acknowledgements

This project has received funding from the Riga Technical University Master’s grant program B65; ZM-2025/11.

EFFECT OF POST-CURING ON THE MECHANICAL PROPERTIES OF POLYMER COMPOSITES

Piotr Zagulski and Rafał Chatys

Faculty of Mechatronics and Machine Building, Kielce University of Technology, 1000-lecia P.P. 7, 25-314, Kielce, Poland, piotrzagulski1993@gmail.com

This work focuses on analysing the influence of post-curing parameters on the mechanical properties of composite materials, with particular emphasis on their structural stability prior to degradation. Post-curing of polymer composites is a key step in the manufacturing process that affects the final mechanical properties of the material. By controlling the parameters of this process, it is possible to optimise strength, stiffness and structural stability, as well as reducing internal stresses. Appropriate post curing conditions can significantly improve the homogeneity of the polymer network, which affects the homogeneity of the material and its subsequent performance. Incomplete curing can lead to local weaknesses in the structure, which in the long term can lead to a gradual deterioration in the performance of the composite.

MECHANICAL PERFORMANCE AND IMPACT RESISTANCE OF POLYMER COMPOSITES ENHANCED BY GLASS MICROSPHERES AND A HYBRID MATRIX

Sultan Ullah and Giedrius Janusas

Faculty of Mechanical Engineering and Design, Kaunas University of Technology, Studentu 56, 51424 Kaunas, Lithuania, sultan.ullah@ktu.edu

This research presents the development of a hybrid matrix to enhance the impact resistance of polymer matrix composites by blending thermosetting phenolic resin with thermoplastic polyvinyl butyral (PVB). Glass fabric was employed as the primary reinforcement, and glass microspheres were incorporated as micro-reinforcements in varying concentrations. Composites were fabricated using four plies of glass fabric through compression molding, maintaining a fiber volume fraction of 0.6. The hybrid matrix with a PVB-to-phenolic resin ratio of 20:80 exhibited superior energy absorption and mechanical properties under impact loading. The incorporation of glass microspheres further improved mechanical performance, with optimal results achieved at concentrations of 6–8%. Notably, the inclusion of PVB enhanced tensile strength, while a 6% microsphere concentration significantly increased the tensile modulus. These findings underscore the potential of the hybrid matrix and micro-reinforcements to improve the mechanical and impact resistance properties of composite materials, highlighting their applicability in high-impact engineering applications.

HIGH-BARRIER PACKAGING FILM APPLICATION: BIODEGRADABLE POLY (BUTYLENE SUCCINATE) LAMINATE WITH NANOCELLULOSE

Martins Nabels-Sneiderds[1], Oskars Platnieks[1], Anda Gromova[1], Liga Orlova[2], and Sergejs Gaidukovs[1]

[1]Institute of Polymer Materials, Faculty of Materials Science and Applied Chemistry, Riga Technical University, P. Valdena 3/7, LV-1048 Riga, Latvia, martins.nabels-sneiders@rtu.lv, anda.gromova@rtu.lv, oskars.platnieks1@rtu.lv, sergejs.gaidukovs@rtu.lv.
[2]Institute of Materials and Surface Engineering, Faculty of Natural Sciences and Technology, Riga Technical University, P. Valdena Str. 3, 1048, Riga, Latvia liga.orlova@rtu.lv.

Recycling and disposing of non-biodegradable plastic packaging recyclables has proven to be extremely difficult from the perspective of sustainable development. It takes a lot of work and energy, recycling single-use plastic packaging is inefficient. As a result, we need to find alternatives that satisfy our needs while protecting society and the environment as quickly as feasible. Therefore, the fundamental principle should be the selection of ecological and biodegradable materials[1].

Growing concerns about the consequences of packaging made of polymers produced from petroleum on the environment and human health are driving study into alternative packaging materials. Poly(butylene succinate) (PBS) was chosen as the polymer matrix since it is one of the most promising bioderived and biodegradable polymers suitable for film-blowing and laminating applications. A spray coating of 1, 5, 10, and 20 layers of nanofibrillated cellulose (NFC) was sprayed in between layers of blown PBS films.

High layer counts above 10 decreased the adhesion of the laminate layer. For membrane and scaffold uses, more NFC layers might be taken into account. Transparency was significantly reduced by higher NFC layer counts (Fig.1); this could be further studied in certain scenarios requiring nontransparent bio-based and biodegradable materials.

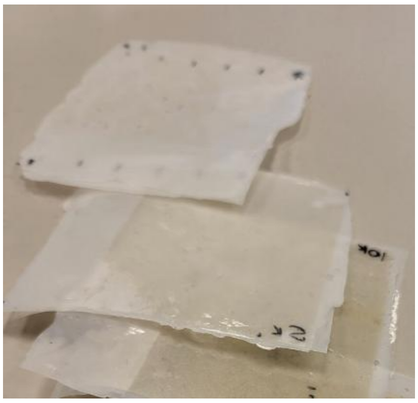

Fig.1 Effect of transparency depending on the number of layers.

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RESEARCH AND DEVELOPMENT OF INNOVATIVE COMPOSITE FOR ROOFING APPLICATIONS

Justas Ciganas, Loreta Kelpsiene[2], and Urte Cigane[3]

[1]*Siauliai State Higher Education Institution, Ausros al. 40, Siauliai, Lithuania, j.ciganas@svako.lt*
[2]*Siauliai State Higher Education Institution, Ausros al. 40, Siauliai, Lithuania, l.kelpsiene@svako.lt*
[3]*Siauliai State Higher Education Institution, Ausros al. 40, Siauliai, Lithuania, u.cigane@svako.lt*

Recent years have witnessed considerable progress in the field of composite structures, with their distinctive blend of strength, reduced weight, and versatility [1]. New technologies in composite manufacturing have made it possible to apply these materials to various applications[2]. The main advantage of composite materials is the reduction in product weight while also enabling lower production costs without compromising quality requirements [3]. This has driven researchers to develop new products utilizing composite. In the context of building materials, the idea of wetting is thoroughly examined, with a special focus on elements that affect wetting behavior, including surface characteristics, chemical composition, pore size and distribution [4,5]. Furthermore, the significance of protecting the construction materials' surfaces is underlined. It is crucial to alter wetting behavior by applying coatings or bulk additions [6]. Another crucial element in the context of hydrophobic coatings is the use of nanoparticles. The structure and compactness of coatings can be altered by nanoparticles, further enhancing their resistance to water penetration [7].

The aim of this study is to modify the surface of composites by additionally using nanocoating for roof applications. The influence of nanocoating on the hydrophobic properties of the composite surface was studied. The influence of surface morphology on the mechanical properties of the composite were investigated. Also, the analysis of the chemical composition of the composite surface were performed. It was found that the proposed nanocoating improves the hydrophobic properties of the composite for roofing.

Acknowledgements

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ACCELERATED AGING AND LIFETIME ASSESSMENT OF ORGANIC FILLER-MODIFIED COMPOSITES

Monika Chomiak, Iwona Gródek, Małgorzata Szymiczek, Martyna Gawlas, Martyna Rzepiela, Julia Wawrzynek, Jakub Otyński, Paulina Ferdyn

Department of Theoretical and Applied Mechanics, Faculty of Mechanical Engineering, Silesian University of Technology, Konarskiego 18A st., 44-100 Gliwice, Poland, monika.chomiak@polsl.pl, iwongro406@student.polsl.pl, malgorzata.szymiczek@polsl.pl

This study presents the design and development of a biocomposite material composed of polypropylene and natural fillers derived from ground pistachio and pecan shells called bio-based filler. The primary objective was to assess the impact of these natural additives on the mechanical and physical properties of the material during the aging process. The production process involved grinding pistachio shells and pecan filler, extruding the composite mixture (polymer matrix with filler content ranging from 5 to 20 wt.%), hot pressing the composite sheets or injection moulding, and subsequently cutting the test samples. The fabricated samples underwent an accelerated aging process (immersion in water at approximately 100°C) to simulate environmental exposure over periods equivalent to 1 ÷ 5 years. Comprehensive characterization techniques were employed to evaluate the physical properties of the composite components and the mechanical performance of the prepared samples, including density, hardness, flexural and tensile strength, as well as impact resistance. Additionally, a Failure Mode and Effects Analysis (FMEA) was conducted to identify potential manufacturing defects, alongside a life cycle assessment (LCA) to evaluate the environmental impact of the developed biocomposite.

The results indicate that only the composite containing 5 wt.% of pistachio shell filler exhibited mechanical strength comparable to pure polypropylene. Higher filler content led to a significant reduction in material performance. Similar trends were observed for the second filler, where an optimal balance between mechanical strength and biodegradability was noted at lower concentrations. Notably, with increased aging and filler content, the biocomposite demonstrated an accelerated natural degradation rate compared to the unmodified polymer, confirming its potential for enhanced biodegradability.

These findings contribute to the advancement of sustainable polymeric composites, aligning with contemporary research on eco-friendly materials for advanced engineering applications.

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CHARACTERIZATION AND COMPARATIVE ANALYSIS OF ISO AND ASTM STANDARDS FOR MECHANICAL PROPERTIES OF ULTEM™ 9085

Elina Vindedze[1], Tatjana Glaskova-Kuzmina[1,2], Partel-Peeter Kruuv[1], Didzis Dejus[1], Janis Jatnieks[1], Maksims Jurinovs[3], and Sergejs Gaidukovs[3]

[1] *AM Craft, Braslas 22D, LV-1035 Riga, Latvia, elina@am-craft.com*
[2] *University of Latvia, Institute for Mechanics of Materials, Jelgavas 3, LV-1004 Riga, Latvia, tatjana.glaskova-kuzmina@lu.lv*
[3] *Riga Technical University, Institute of Chemistry and Chemical Technology, P. Valdena 3, LV-1048 Riga, Latvia*

This study investigates the mechanical properties of ULTEM™ 9085, a high-performance thermoplastic widely used in aerospace and automotive applications due to its exceptional strength-to-weight ratio, flame retardancy, and thermal stability. The research focuses on a comparative analysis of ISO and ASTM standards for three critical mechanical tests: tensile, compression, and three-point bending, performed at three different test speeds (2.5, 5, and 10 mm/min) for specimens printed in three orthogonal directions (X, Y and Z). The specimens were manufactured using fused deposition modelling (FDM) technology in the same building job to ensure consistent material and process parameters. The results provide insights into how variations in testing standards and speeds influence mechanical property evaluation, offering valuable guidance for material selection and certification in safety-critical applications.

The comparative analysis of tensile tests between ISO 572-2 and ASTM D638 standards revealed distinct trends across the X, Y, and Z directions. Tensile strength in the X and Y directions was higher under the ISO standard across all test speeds, while in the Z direction, results varied. At 2.5 mm/min, ASTM showed superior tensile strength, but ISO outperformed at higher speeds (5 and 10 mm/min). The elastic modulus was similar for ISO and ASTM in the X and Y directions, while speed effects in the Z direction led to higher values under ISO at 2.5 and 10 mm/min. Compression testing highlighted greater sensitivity to speed variations in ISO 604 results for the X and Y directions, while ASTM D695 remained more uniform. ISO consistently showed higher compression strength in X and Y, whereas ASTM achieved superior results in Z. Compression modulus values were higher under ISO in all directions and speeds, indicating stronger stiffness characterization. The three-point bending tests presented mixed results. Flexural strength was higher for ISO 178 in the X direction, whereas ASTM D790 yielded higher values in the Y direction. Flexural strength varied depending on the test speed for the Z direction, showing no clear dominance of either standard. However, flexural modulus measurements consistently favoured the ISO standard across all three directions.

These findings illustrate the nuances between testing standards, material anisotropy, and strain rate, offering valuable insights into the mechanical performance of ULTEM™ 9085 under different testing conditions.

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ELECTRO-THERMAL PERFORMANCE OF CARBON FIBER COMPOSITES FOR ICE PREVENTION APPLICATIONS

Nawres J. Al-Ramahi, Roberts Joffe, and Patrik Fernberg

Division of Materials Science, Luleå University of Technology, SE-971 87 Luleå, Sweden, *nawres.al-ramahi@ltu.se*, *roberts.joffe@ltu.se*, *patrik.fernberg@ltu.se*

This study investigates the electrical and thermal performance of carbon fiber composites for de-icing and anti-icing applications e.g. in wind turbine blades and aircraft wings. The laminates with lay-ups ($[0_2]_T$, $[90_2]_T$, $[0/90]_T$, $[\pm45]_T$, $[0/45/-45/90]_T$) were considered. These composites were tested and numerical simulations were carried out to evaluate the influence of fiber orientations and laminate layer thickness on the electrical resistance of composites resulting in different capabilities to generate heat. A finite element model using coupled-field solid elements was developed to simulate thermal-electric interactions and assess the distribution of temperature in laminates. Results indicated that unidirectional laminates with 0° fiber orientation exhibited the lowest electrical resistance with the highest heat generation capacity, making them the most efficient configuration for de-icing and anti-icing applications. The $[90_2]_T$ laminate showed significantly higher in-plane resistance than the rest of the materials (roughly 2000 times greater than that of the $[0_2]_T$ laminate). This is according to the theoretical assumption that fibers in $[90_2]_T$ layers are insulated by a polymer matrix which blocks current flow through the laminate. However, the resistance is not infinite, since misalignments and waviness of reinforcement create contact points between fibers, allowing some current to pass. This inter-fiber interaction also explains out-of-plane electrical conductance in composites. The results of numerical simulations are closely aligned with experimental data, thus validating the model's accuracy. The findings provide insights into optimizing the design of carbon fiber composites for multifunctional applications, considering both electrical performance and structural requirements.

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INTEGRATING MXENE COATINGS INTO COMPOSITE MATERIALS FOR ENHANCED STRAIN SENSING

Muhammad Imran Rameel, Gediminas Monastyreckis, and Daiva Zeleniakienė

Kaunas University of Technology, Department of Materials Engineering, Studentu str. 56, LT-51424 Kaunas, Lithuania, muhammad.rameel@ktu.edu, gediminas.monastyreckis@ktu.lt, daiva.zeleniakiene@ktu.lt

The integration of MXene coatings into composite materials has garnered significant attention due to their outstanding mechanical and electrical properties. Titania-based MXenes exhibit promising characteristics for strain-sensing applications in fiber-reinforced polymer (FRP) composites[1,2][1,2]. However, their stability is compromised due to oxidation in ambient environments [3][3].

In this study, we developed molybdenum-based MXene coatings capable of detecting low strain values typically encountered in such composites. These coatings demonstrate greater stability and higher resistance to oxidation, making them highly suitable for real-time strain sensing in FRP composites. We synthesized molybdenum-based MAX phases, Mo_2TiAlC_2 and Mo_2TiC_2 MXenes, using a molten salt method as an alternative to conventional HF etching – an environmentally friendly approach for MXene preparation. The synthesized MXenes were spray-coated onto glass fiber-reinforced composites. The coatings were evaluated based on their electrical resistance behavior. Additionally, the purity of the MAX phase and MXenes was analyzed using X-ray diffraction (XRD), while morphology and elemental composition were examined via scanning electron microscopy (SEM) and energy-dispersive X-ray spectroscopy (EDX). Furthermore, the coatings' adhesion properties and sensitivity to surface roughness were investigated.

This work presents novel insights into more stable MXene-based strain-sensing coatings. Molybdenum-based MXenes exhibit significantly higher chemical stability and oxidation resistance compared to titania-based MXenes, particularly in ambient air. This improved stability enhances the washability of sensor coatings and reduces degradation, especially in harsh environments. These advanced MXene-based coatings are scalable, lightweight, and offer superior long-term performance for strain-sensing applications in composite materials.

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A COMPARISON STUDY ON THE SHAPE MEMORY AND VISCOELASTIC BEHAVIOUR OF 4D PRINTED PHOTOCURABLE METHACRYLATE AND EPOXY-BASED RESINS

Mohamad Alsaadi[1,2], Declan M. Devine[2], and Eoin P. Hinchy[3]

[1] PRISM Research Institute, Technological University of the Shannon, Athlone, Ireland, *mohamad.alsaadi@tus.ie*
[2] PRISM Research Institute, Technological University of the Shannon, Athlone, Ireland, *declan.devine@tus.ie*
[3] School of Engineering, University of Limerick, Limerick, Ireland, eoin.hinchy@ul.ie

4D printing is the additive manufacturing of objects that can transform their shape in a controlled and predictable way when subjected to external stimuli. Thermo-responsive shape memory polymers (SMPs) are highly suitable materials for 4D printing smart devices due to their actuation function and the capability of recovering their original shape from the deformed one upon heating. This study presents the results of employing methacrylate- and epoxy-based photocurable resins in 3D printing using a digital light processing (DLP) printer making them excellent candidates as smart materials for a wide range of complex-shaped shape-morphing soft robotics as actuators and thermal sensors or aerospace as self-deploying structures. This work provides significant knowledge required to understand the shape programming and its shape-changing region of SMPs for the better utilization of 3DPd structures. A comparison of viscoelastic and shape memory performance was investigated. The viscoelastic behaviour in terms of storage modulus, loss modulus, tan delta (Also called loss factor and damping factor) and glass transition temperature (T_g) were evaluated. The shape memory behaviour in terms of shape fixity and shape recovery results were determined using dynamic mechanical thermal analysis (DMTA). DMTA is used to reveal the molecular mobility performance through three different regions i.e., glass region, glass transition region, and rubbery region. The shape-changing region (Within the glass transition region) between the T_g value from the loss modulus and the T_g value from the tan delta was also studied. The temperature-memory behaviour was investigated for flat and circular 3DPd structures to achieve sequential deployment. It was found that the shape-changing (Morphing) region for the methacrylate-based objects was (47 °C to 83 °C). In comparison, it was (128 °C to 166 °C) for epoxy-based objects. The shape fixity ratios and the shape recovery ratios from the DMTA were greater than 97% and 90%, respectively for both materials.

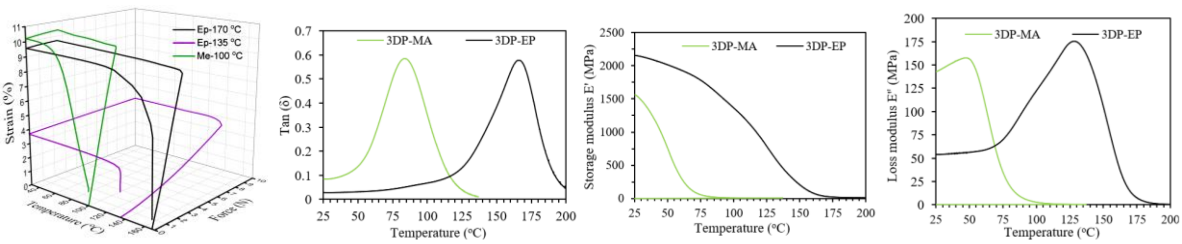

Figure shows the Thermomechanical SMP cycle of 3DPd samples using the 4-steps-DMTA test; and viscoelastic behaviour.

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PIEZOELECTRIC POLYMER PVDF SENSORS FOR ADVANCED ENERGY HARVESTING AND SENSING APPLICATIONS

Zeenat Akhter and Arvydas Palevicius

Faculty of Mechanical Engineering and Design, Kaunas University of Technology, Studentu 56, 51424 Kaunas, Lithuania, zeenat.akhter@ktu.edu

Polyvinylidene fluoride (PVDF), a well-known piezoelectric polymer, has emerged as a promising material for advanced energy harvesting and sensing applications due to its flexibility, durability, and exceptional piezoelectric properties. This study investigates the use of PVDF sensors for converting ambient mechanical energy into electrical power, addressing key challenges in scalable and sustainable energy harvesting systems. A specially designed energy harvesting circuit was developed, incorporating a rectifier, energy storage capacitors, and an LED load to demonstrate practical energy utilization. Previous research highlights the capability of PVDF-based systems in biomechanical energy capture and self-powered sensing [1]. Furthermore, hybrid composites of PVDF with advanced materials, such as reduced graphene oxide, have been shown to enhance energy conversion efficiency [2]. This work establishes PVDF as a versatile piezoelectric polymer, paving the way for innovative solutions in energy harvesting and sensing technologies for diverse applications [3].

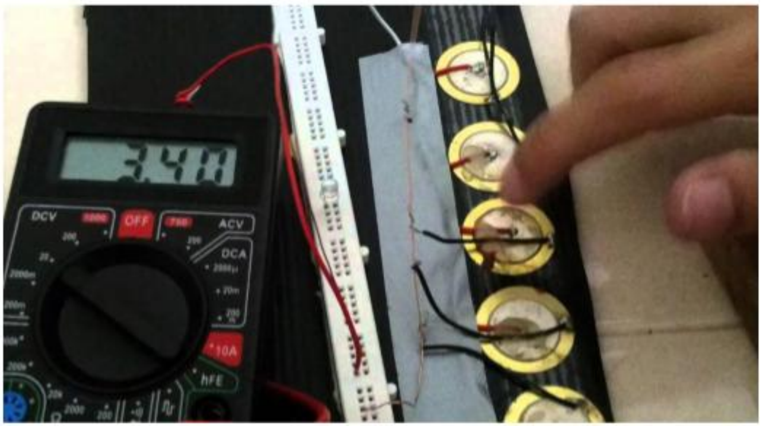

Fig. 1. Experimental setup showcasing voltage output from sensors under mechanical stress.

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DEVELOPMENT AND CHARACTERIZATION OF CONDUCTIVE POLYMER NANOCOMPOSITES AND THEIR MELT-SPUN FILAMENTS FOR SMART TEXTILE APPLICATIONS

Müslüm Kaplan

Department of Textile Engineering, Bartın University, 74110 Bartın, Turkey, mkaplan@bartin.edu.tr

This study systematically investigates conductive polymer nanocomposites and their transformation into functional filaments for smart textile applications. The research focuses on polyamide 6 (PA6) based nanocomposites incorporating various conductive nanofillers, examining the relationships between nanofiller content, processing parameters, and final properties. Nanocomposites were prepared through melt mixing and characterized for their morphological, electrical, and rheological properties using light microscopy, SEM, and electrical conductivity measurements.

The key findings demonstrate optimal electrical conductivity with nanofiller loadings below 5 wt% (using various carbon-based nanomaterials such as CNTs, CB, and graphene) while maintaining processability. The successful melt spinning of conductive filaments was completed within a processing window of 100-1000 Pa.s melt viscosity, with winding speeds between 25-1000 m/min, enabling consistent fiber formation. Results show that mechanical properties of the filaments are influenced by nanofiller type and content, with tensile strength typically decreasing at higher loadings while maintaining sufficient elongation at break for textile processing (Fig. 1). These findings establish clear processing parameters and composition guidelines for producing conductive polymer filaments with balanced properties suitable for smart textile applications.

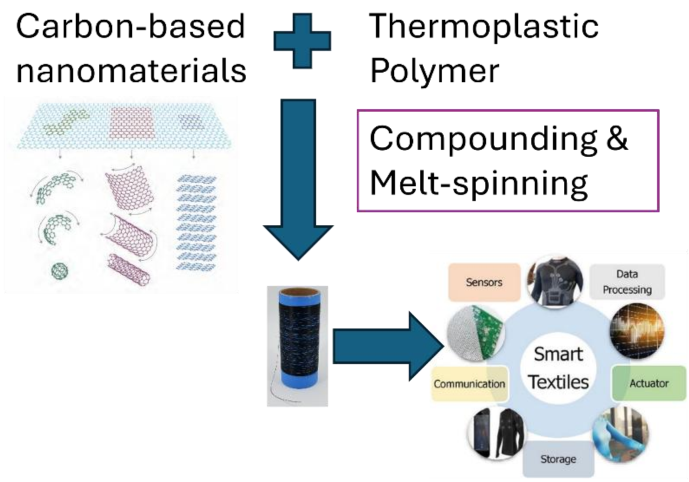

Fig.1. Schematic illustration of the research approach: fabrication of smart textiles by incorporating carbon-based nanomaterials into thermoplastic polymers via melt-processing.