KAUNAS UNIVERSITY OF TECHNOLOGY

INSTITUTE OF PHYSICAL ELECTRONICS OF
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THE DEVELOPMENT OF AIR-JET TEXTURED SEWING THREADS AND ANALYSIS OF THEIR PROPERTIES

Summary of the Doctoral Dissertation
Technological Sciences, Materials Engineering (08 T)

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KTU FIZIKINĖS ELEKTRONIKOS INSTITUTAS

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General characteristics of the study

Scientific novelty of the study. Augmentative assortment of yarns, increasing requirements for their quality and improvement of their production technologies - all those factors require the knowledge of the requirements of the garment industry to this product and, with respect to those requirements, the ability to offer new variants of the sewing thread assortment adjusted to particular purposes.

As well as properties of all the yarns, properties of sewing threads are greatly influenced by type of fibers used and the finishing applied. During air-texturing process, the composition and the properties of final threads are significantly influenced by various parameters of the process, i.e. air pressure, and overfeed of core yarns and wrapping yarns, presence or absence of thermo-setting, and temperature of the latter.

Usually polyester is used for manufacturing of sewing threads. In this work, polyester and polytetrafluoroethylene yarns are used as components of air-textured yarns being created, because it is widely known that polytetrafluoroethylene yarns have low friction coefficient, are resistant to high temperatures and chemical substances. But sewing threads can not be produced from polytetrafluoroethylene only, because it is not strong. For this reason, it was expedient to produce air-textured yarn composed of polyester and polytetrafluoroethylene components, thus employing the advantages of the polytetrafluoroethylene filament.

An important task is an optimization of the properties of air-textured threads that contain polytetrafluoroethylene yarn, i.e. the optimization of air-textured sewing threads characteristics through its evaluation, forecasting of indicator values, and selection of proper technological parameters. Using mathematical experiment-planning model, associations between complex properties of air-textured sewing threads and their technological parameters of production are analyzed.

Such components of air-textured sewing threads allow broadening of the assortment of air-textured sewing threads suitable for garment sewing.

Results of the study allows to obtain data on mechanical and other indicators (as well as the regularities, tendencies, and character of their changes) of air-textured polyester/polytetrafluoroethylene (PES/PTFE) as well as polyester/polyester (PES/PES) yarn that is better known practically. Those findings on changes of the indicators of air-textured sewing thread are of big importance for both scientific and practical sectors, i.e. Lithuanian textile enterprises (since, in order to increase profitably, enterprises have to use newest technologies more effectively).

The aim of the study is to develop air-textured threads for sewing working clothes with high speed sewing machines; also to study and forecast mechanical and other indicators of sewing threads being produced through the creation of mathematical models that define the association between yarn indicators and technological parameters of production.

Objectives of the study: 1) to select the mathematical experiment plan (and its quality assessment indicators) for the technological parameters of the production of air-textured sewing threads; 2) to produce air-textured sewing threads using components of different staple structures and properties, when applying the mathematical experiment planning method; 3) to study mechanical properties (breaking force and breaking tenacity, elongation at break, work of break, friction coefficient, and seam breaking force) of the produced testing air-textured sewing threads; 4) to investigate the influence of thermosetting to the produced air-textured polyester sewing threads; 5) to create mathematical models that interrelate different indicators of air-textured sewing threads and technological parameters of their production; to study the informative value of those models; 6) to forecast mechanical indicators of air-textured sewing threads, and to present mathematical models graphically; 7) to investigate the dependence of developed and manufactured air-textured sewing threads on their technological parameters.

Approbation of the study. 7 publications are published on the topic of the dissertation; 4 of these publications are in reviewed journals.

The content of dissertation

In the first part introduction and discussion on the scientific novelty of the study is presented. After the survey, the aim of the study is formulated.

In the second part the survey of literature is presented.

In the third part the plan of the experiment and the stages of the studies on mathematical models are presented.

With respect to the object of this study and the peculiarities of the production technology of air-textured yarns, only the main factors that influence the indicators of the studied yarns are examined: when producing PES/PES yarns, following two parameters of the process that essentially influence the quality of the final product are changed:

- Overfeed of the wrapping yarn;
- Pressure of air fed to the texturing nozzle.

When producing PES/PTFE yarn, three parameters of the process are changed:

- Overfeed of the wrapping yarn;
- Overfeed of the core yarn;
- Pressure of air fed to the texturing nozzle.

In both cases of yarn production, two multifilament yarns are fed as a core, and one – as a wrapping yarn. Thus three multifilament yarns in total. Core yarn is hydrated in all cases. All these factors are independent, inter-compatible, and important. All factors are either considered to be constant, or presumed to have little effect on the studied process. A rotational second- and third-line plan is selected as the production and experiment plan. The regression coefficients of mathematical model are calculated with the help of matrix method, using the computer program EKSPLA created at the Department of Textile Technology, Kaunas University of Technology. Mathematical regression coefficients are evaluated from the viewpoint of the uniformity of their dispersions and according to the informativeness criterion F_i. In addition to that, the coefficients of the equations are evaluated.

Methods of the study of the properties of air- textured sewing thread. Studies of yarn stretching characteristics are performed using tensile testing machine ZWICK/ Z 005. Tests are performed according to the standard for yarn stretching ISO 2062, 05/1995 set by the International Standardization Organization.

Determination of abrasion resistance is performed using a reconstructed Hungarian-made fatigue tester applied to wearing through abrasion. Principal scheme of this machine is presented in Fig. 1. Yarn 1 is fixed in clamps 2. The former, after passing through the guide rollers 3, is threaded into a needle 4 that is immovably fixed in a holder. Next, the yarn passes through guide rollers 3 and 6; weight 7 is attached to its end. Next, the needle with the holder 5 moves in constant amplitude horizontally in an excursion.

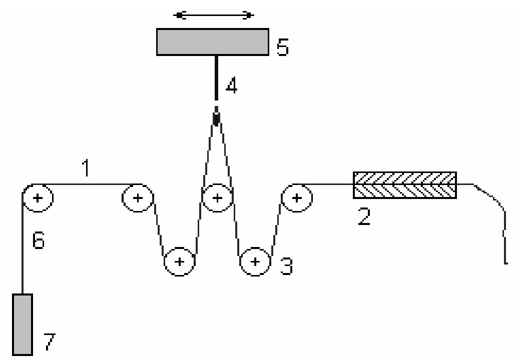

Fig. 1. Principal scheme of the wearing machine

During this test we evaluate whether the yarn is able to withstand all the cycles. The sample that withstands the highest number of cycles under the same conditions is considered to be the most acceptable.

Friction coefficient of the yarn is tested on a stand is produced by a Swiss company “C. Rotschild” on the basis of the “F – Meter” apparatus (see Fig. 2). Tested yarn 2 is fed from the package 1 and slips at a certain speed, passes the draft unit 3-4. At this unit, the internal force of the yarn is equalized. This internal force of the branch of the yarn that passes on and off the friction cylinder 6 is measured using gauges 5 and 7. Test is performed when the yarn is evenly passing all the aforementioned components; in addition to that, a special handle is used to regulate the speed of the yarn movement. The yarn in the machine moves when being pulled by a constrainedly rotating disc 8. The signals of both gauges are amplified. Their values are marked off on exponential appliances or may as well be recorded using a recorder. The friction coefficient μ is calculated according to L. Euler's formula.

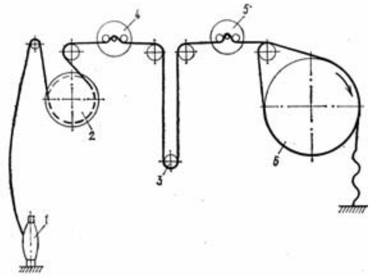

Fig. 2 Principal scheme of the apparatus for the testing of friction coefficient of the yarn.

The strength of the seams of working clothes was determined according to the ISO 13935-1:1999 standard. Tests are performed using the tensile testing machine ZWICK /Z 005.

In the fourth part results are presented and discussed of the testing of the half-cycle characteristic of the stretching of air-textured yarn, the results of the multi-cycle abrasion-reeling testing, the results of the testing of the friction of air-textured yarn, and the results of the testing of the strength of the sewing thread seams.

As we know, one of the most important requirements for sewing thread is high strength. Stretching tests were performed with the following types of sewing thread produced at the Department of Textile: PES with thermo-setting, PES without thermo-setting, and PES+PTFE. The following parameters were chosen as the main ones that mostly determine the quality of the yarn and its behavior during sewing: the breaking force and the breaking stress, breaking tenacity, work of break, etc.

Yarn with thermo-setting used during its production has 7-14% greater breaking forces, 6-17% greater breaking tenacities, and 4-20% lower breaking stress. This can be explained by the morphological differences between the air-textured yarn with and without thermo-setting, developing after thermo-setting.

The yarn was worn by imitating conditions present in a sewing machine. Testing was performed with 1.5, 2, and 2.5 N loads, for 20, 50, and 100 cycles. Stretching tests were performed after wearing testing. Not all types of yarn passed the wearing testing – some of them broke before reaching 50 or 100 cycles. All types of yarn passed the 20-cycle testing with 1.5 N load, while none passed the 100-cycle testing with 2.5 N load.

These findings showed that wearing for 20 cycles with 1.5 N load in most cases resulted in an increase in the breaking force. This can be explained by the fact that the elementary filaments in the worn yarn untwined and straightened, but did not experience physical influence sufficient for decreasing their breaking force. The straightening of the filaments resulted in the increase of the breaking force.

During sewing, the thread rubs against the back rests or the needle eye. The same part of the thread passes the needle eye for several dozens of times. For this reason it is important to determine the friction characteristics of the yarn.

The highest friction coefficient is exhibited by yarn that contains only PES and produced with the use of thermo-setting (except for No. 3), while PES/PTFE yarn has the lowest coefficient. Yarn containing the PTFE component has a characteristic sleekness and smoothness, since this component is significantly more slippery than the PES component. Thus, the introduction of the PTFE component into the PES yarn composition results in lower friction coefficient of the yarn.

When sewing at high speeds, the yarn experiences mechanical and thermal effect. The strength of the yarn decreases due to the changes in the mechanical properties of its components under the influence of dynamic loads, as well as due to the changes in the structure of the yarn. The strength and the structure of the sewing thread change because of the friction against the needle eye and the woven fabric. The sewing of any product requires the selection of suitable sewing thread so that sufficiently strong seams are made at the junction sites.

The sewing thread experiences the abrasion effect, which results in partial strength loss. The greatest strength in the woven fabric is exhibited by the seam made with PES yarn without thermo-setting. The friction of the PES/PTFE yarn is lower, and therefore the strength of seams made with this yarn is lower. The strength of the seam in the woven fabric is significantly affected by the magnitude of the friction forces between the yarns in the seam loops.

During the test, the character of the destruction of these seams was observed. The patch-seam UD1 is composed of only two layers of the woven fabric connected by one quilting seam. When stretching the patch-seams UD1, the sewing thread is broken, thus unstitching the whole seam, but the woven fabric remains intact. The generalization of the seam strength testing showed that the strength of the seams sewn with all the studied yarn was sufficient, since the seams came unstitched.

The fifth part presents the results of the testing of mechanical and other indicators of air-textured sewing thread, the statistical characteristics of these indicators, and the indicator prognostication results. The prognostication of the indicators was performed through the creation and the explanation of the dependence on two production parameters of the air-textured PES/PTFE sewing thread when the third parameter is constant. Three-dimensional surfaces were created to define the aforementioned characteristics.

The air-textured sewing thread was produced when changing three technological production parameters – air pressure during texturing in the head X_1, core component feeding speed X_2, and wrapped component-feeding speed X_3. The prognostication of the indicators was performed through the creation and the explanation of the dependence on two production parameters of fancy twisted yarn when the third parameter is constant. In order to achieve this, three-dimensional surfaces were created to define the aforementioned dependences. Charts were produced using MICROSOFT "Excel" software package.

In the equations expressing the dependence between the mechanical indicators and technological production parameters of air-textured sewing thread, nearly all regression coefficients were statistically significant, except for the PES/PTFE yarn with two non-significant regression coefficients expressing work dependence, and the PES/PES yarn without thermo-setting with two non-significant regression coefficients expressing the dependence of the breaking internal force and breaking force. In the PES/PES yarn with thermo-setting, two regression coefficients expressing the dependence of the breaking force were non-significant. All the coefficients of the dependence of the breaking power of the PES/PTFE yarn were significant. Significant regression coefficients expressing the dependence of the specific breaking power were found in the PES/PES yarn without thermo-setting, as well as significant regression coefficients expressing the work dependence – in the PES/PES yarn with thermo-setting.

The most notable variation in the number of significant and non-significant regression coefficients was observed in equations that expressed the dependence of the work of break of the PES/PTFE yarn and the technological production parameters of the air-textured yarn - as many as two coefficients were totally non-significant; the same variation (two non-significant coefficients) was observed in the equations that reflected the dependence of the breaking force of the PES/PES yarn with and without thermo-setting, and the technological production parameters of the air-textured yarn.

All informative models are for the PES/PTFE air-textured sewing thread. Only one non-informative model was found for air-textured PES/PES yarn with thermo-setting, and one - for air-textured PES/PES yarn without thermo-setting. The non-informative mathematical models were not used in the further stage of the study – the prognostication of the properties of air-textured sewing thread.

Using the presented graphical dependences of the breaking force of the air-textured PES/PTFE sewing thread, it is complicated to unambiguously define the changes in this indication, since the change in the breaking force in the studied air-textured yarn was very different. For instance, the maintenance of a constant speed of the wrapped component feeding (X_3) = 30% coupled with the increase in the pressure change in the texturing head resulted in the elevation of the breaking force of the PES/PTFE sewing thread. When the pressure change in the texturing head was equal to zero, the speed of the core component feeding was constant, but the speed of the wrapped component feeding was changed in the whole interval, the breaking force started to increase. In addition to that, the change of the optimization parameter of the PES/PTFE yarn with respect to the X_3 axis was much more intensive than with respect to the X_1 axis. The maintenance of the constant speed of the core component feeding (X_2) = 15% at the same time increasing the changes in the pressure in the texturing head resulted in an increase followed by a decrease in the breaking force of the PES/PTFE sewing thread. Like different character and the tendencies of the breaking force of different air-textured PES/PTFE yarn, different minimal and maximal values for different variants were set in the presence of different values of the studied factors.

Fig. 3-5 presents the dependences of the breaking force and the technological production parameters for the PES/PTFE sewing thread.

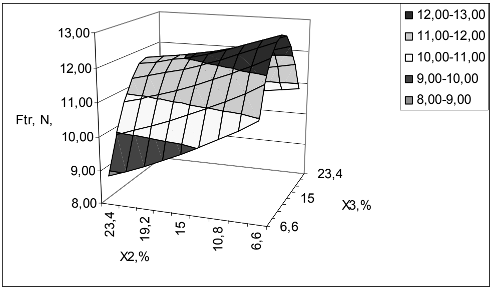

Fig. 3 The dependence of the breaking force of the air-textured PES/PTFE sewing thread on the feeding speed of the core and the wrapped components

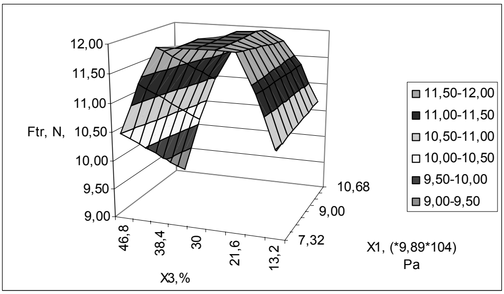

Fig. 4 The dependence of the breaking force of the air-textured PES/PTFE sewing thread on the feeding speed of the wrapped component and the pressure in the texturing head

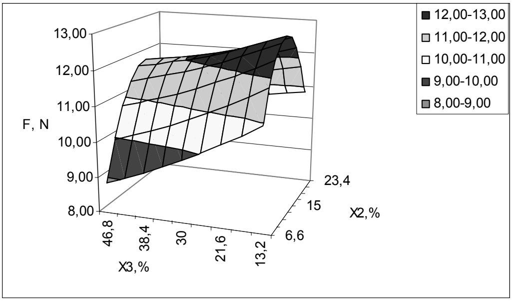

Fig. 5 The dependence of the breaking force of air-textured PES/PTFE sewing thread on the feeding speed of the core component and the pressure in the texturing head

It can be stated that the changes in the breaking force of air-textured PES/PTFE sewing thread is regular, i.e. with increasing feeding speed of the wrapping component, the breaking force increases up to a certain area of maximal values, and then starts decreasing.

Meanwhile, the increase in the pressure in the texturing head results in an intensive decrease in the breaking force. However, the increase in the feeding speed of the core component results in an increasing breaking force F_{tr} at higher values of overfeed.

It was noticed that changes in the breaking tenacity in the studied air-textured PES/PTFE sewing thread was rather characteristic.

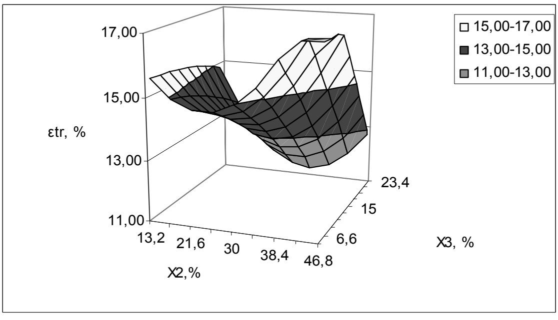

Fig. 6 The dependence of the elongation at break of the air-textured PES/PTFE sewing thread on the feeding speeds of the core and the wrapping components.

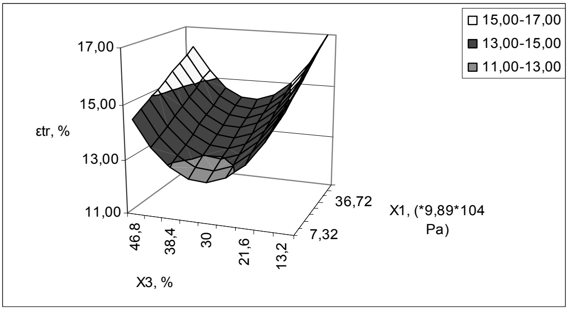

Fig. 7 The dependence of the elongation at break of the air-textured PES/PTFE sewing thread on the feeding speed of wrapping components and the pressure in the texturing head

The presented dependences of the elongation at break show that in the presence of X_1=9 (×9,89×10^4 Pa) and the decreasing pressure value as well as the increasing feeding speed of the core component, the values of the elongation at break of the studied air-textured PES/PTFE sewing thread increased all the time.

When X_2=15%, and the feeding speed of the effect component and pressure in the texturing head were on the decrease, the values of the elongation at break of the studied air-textured PES/PTFE sewing thread at first dropped, and then started to increase. It is difficult to say unambiguously why the relative elongation at break of the air-textured thread changed comparatively differently. Undoubtedly, such changes in the indicator of the dependence of the elongation at break of the air-textured PES/PTFE sewing thread on the feeding speed of the core and wrapping components were greatly influenced by the core component whose interaction with the wrapping component, as well as the values of the selected technological parameters of production condition the character and the tendencies of the changes in the relative elongation at break.

If the pressure in the texturing head is maintained at constant levels (X_1 =9(×9,89×10^4 Pa)), but the feeding speed of the wrapping thread is decreased, the work of break of the air-textured PES/PTFE sewing thread at first slightly decreases, and then starts to increase. In addition to that, when the values of the factor X_3 are the lowest, the change in the optimisation parameter is much more intensive. With respect to separate axes, when the feeding speed of the core component is maintained at a constant level (X_2 =15%), and the values of the feeding speed of the wrapping component are fixed, the values of the work of break at first decrease, and then start increasing.

It was noticed that the tendencies of the changes in the breaking force of the seam of the studied air-textured PES/PTFE sewing thread were similar. When X_1=9 (×9,89×10^4 Pa), and the pressure value and the feeding speed of the core component were increasing, the values of the breaking force of the studied air-textured PES/PTFE sewing thread at first increased, and later started to decrease.

When X_2=15%, and the feeding speed of the effect component and the pressure in the texturing head were increasing, the values of the breaking force of the studied air-textured PES/PTFE sewing thread seams at first increased, and later started to decrease.

The graphical dependences of the technological production parameters of air-textured PES/PES thread with and without thermo-setting are presented in further figures.

As the character and tendencies of the breaking force of air-textured PES/PES sewing thread with and without thermo-setting differed, the minimal and maximal values for different variants were set for different values of the studied factors.

The studies showed that the application of higher pressure during the air-texturing process conditioned the decrease in the elongation at break of the air-textured thread.

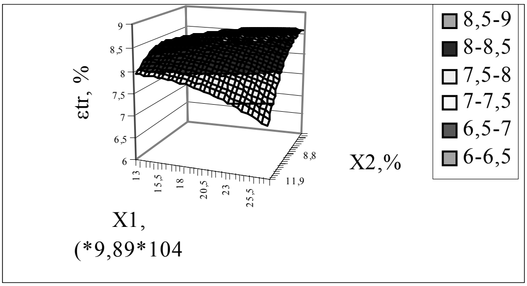

Fig. 8 The dependence of the elongation of breaking of air-textured PES/PES sewing thread without thermo-setting on the feeding speed of the wrapping component and the pressure in the texturing head

The character and the tendencies of the breaking force of air-textured thread differed, and therefore the minimal and maximal values for different threads were set for different values of the studied factors. The minimal breaking force of air-textured thread was obtained at the following coded factor values: PES/PTFE sewing thread - X_1 =9 (×9,89×10^4 Pa), X_2 =15%; X_3 =23.4%, and PES/PES sewing thread without thermo-setting - X_1 =20%; X_2

=11.9 (×9,89×10^4 Pa),. The maximal breaking force of air-textured thread was obtained at the following coded factor values: X_1 =7.32 (×9,89×10^4 Pa), X_2 =30%; X_3 =15%, PES/PES sewing thread without thermo-setting - X_1 =12.93%; X_2 =9 (×9,89×10^4 Pa), and PES/PES sewing thread with thermo-setting - X_1 =20%; X_2 =23.4 (×9,89×10^4 Pa).

The breaking tenacity of air-textured sewing thread was found to be minimal when the coded factor values were the following: PES/PTFE sewing thread - X_1 = 7.32 (×9,89×10^4 Pa), X_2 = 23.4 %; X_3 =13.2 %. PES/PES sewing thread without thermo-setting - X_1 =12.93 %; X_2 =11.90 (×9,89×10^4 Pa), and PES/PES sewing thread with thermo-setting - X_1 =20 %; X_2 =11.90 (×9,89×10^4 Pa). The maximal breaking force of air-textured sewing thread was found to be at the following coded factor values: X_1 = 7.32 (×9,89×10^4 Pa), X_2 = 15%; X_3 = 46.8%, PES/PES sewing thread with thermo-setting - X_1 = 12.93%; X_2 = 9 (×9,89×10^4 Pa), and PES/PES sewing thread without thermo-setting - X_1 = 20%; X_2 = 6.1(×9,89×10^4 Pa).

It is difficult to state unambiguously why the relative elongation at break of the air-textured sewing thread was changing comparatively differently. Undoubtedly, such changes in this indicator were greatly influenced by the core component whose interaction with the wrapping component, as well as the values of the selected technological parameters of production conditioned the character and the tendencies of the changes in the relative elongation at break.

When the coded factor values of the PES/PTFE sewing thread were X_1 =9 (×9,89×10^4 Pa), X_2 = 23.4%; X_3 = 30%, PES/PES sewing thread without thermo-setting - X_1 = 9 (×9,89×10^4 Pa); X_2 = 11.90%, and PES/PES sewing thread with thermo-setting - X_1 = 27.03 (×9,89×10^4 Pa); X_2 = 11.90%, the relative elongation at break was minimal. Maximal values of the studied indicator for air-textured thread were obtained at different coded values of the factors of air-textured sewing thread, i.e. for the PES/PTFE sewing thread they were X_1 = 10.68 (×9,89×10^4 Pa), X_2 = 23.4%; X_3 = 46.8%, for the PES/PES sewing thread with thermo-setting - X_1 = 9 (×9,89×10^4 Pa), X_2 = 6.1%, and for the PES/PES sewing thread with thermo-setting - X_1 = 27.03 (×9,89×10^4 Pa), X_2 = 6.1%.

In separate cases, it can be presumed that the force required to untwine the elementary filaments is greater than their breaking force. The decrease in the air pressure and overfeed of the wrapping yarn results in the increase of the breaking tenacity of the thread.

The elongation at break is directly dependent on the production parameters; the increase of overfeed of the effect yarn and the increase in the air pressure bring about the decrease in the elongation at break. The lowest elongation at break in the air-textured PES/PES sewing thread with thermo-setting is achieved at the greatest overfeeds and pressure. The reduction of air pressure results in the increase of the elongation at break.

The breaking force, the breaking tenacity, and the elongation at break of thread that was produced without the use of thermo-setting increase with the decrease in the values of overfeed and air pressure.

The breaking force and the breaking tenacity of thread that was produced with the use of thermo-setting increase with the decrease in the values of overfeed and air pressure, while the elongation at break increases at minimal values of overfeed.

Conclusions

The following conclusions can be made after the analysis of scientific literature and the performance of original studies, i.e. the creation of designing methods that relate air-textured sewing thread composed of polyester and polytetrafluorethylene yarn, the technological production parameters, and mechanical and other indicators of the thread (including linear density, breaking force and breaking tenacity, work of break, friction coefficient, and seam breaking force), on whose basis the dependences between the properties of multifilament air-textured sewing thread and its technological production parameters were studied:

1. The greatest influence on various indicators air-textured sewing yarn is exerted by three technological parameters of the production of this yarn: the value of the pressure in the texturing head X_1, the feeding speed of the core component X_2, and the feeding speed of the wrapping component X_3.
2. Air-textured PES/PES sewing thread whose production process involved the application of thermo-setting exhibits by 7-14% greater breaking force, by 6-17% greater breaking tenacity, and by 4-20% lower elongation at break, compared to air-textured PES/PES sewing thread whose production process did not involve thermo-setting. This can be explained by the differences of the morphological structure between air-textured sewing thread with and without thermo-setting, occurring after thermo-setting.
3. The breaking force of the air-textured PES/PES sewing thread affected during abrasion-reeling has a tendency to increase from 5% to 12% in products manufactured with the use of thermo-setting.
4. The greatest friction coefficient is exhibited by air-textured sewing thread containing only PES components and produced with the use of thermo-setting. The lowest friction coefficient is observed in air textured PES/PTFE sewing thread. Thread with the PTFE component is characterized by sleekness and smoothness of the surface, since PTFE is a much more slippery component than PES. Therefore the introduction of the PTFE component into the composition of PES thread results in the reduction of its friction coefficient.

5. The greatest seam resistance in fabric is demonstrated by seams sewn with PES thread without thermo-setting. The friction of the air-textured PES/PTFE sewing thread is low, resulting in a lower resistance of seams sewn with this thread. Seam resistance in fabric is greatly influenced by the magnitude of the friction forces between threads in the seam loops.

6. The analysis of the designing methods and the results of the prognostication of air-textured sewing thread showed that nearly all the studied technological production parameters exerted significant influence on the indicators of air-textured thread.

7. Since the character and the tendencies of the breaking force of different air-textured PES/PES with thermo-setting, PES/PES without thermo-setting, and PES/PTFE sewing thread differed, the minimal and maximal values for different variants were set for different values of the studied factors. The breaking force, breaking tenacity, and elongation at break of the air-textured PES/PES sewing thread produced without thermo-setting increased with the decrease in the values of the feeding speed of the wrapping component and the air pressure in the texturing head. The breaking force and breaking tenacity of the air-textured PES/PES sewing thread produced with thermo-setting increased with the decrease in the values of the overfeed and air pressure, and the elongation at break increased at minimal values of overfeed.

8. The breaking force of the air-textured PES/PTFE sewing thread changed regularly, i.e. the increase in the feeding speed of the wrapping component resulted in the increase of the breaking force up to a certain area of maximal values, and after that started to decrease. Meanwhile, the increase in the pressure in the texturing head resulted in an intensive reduction of the breaking power. However, the increase in the feeding speed of the core component, the breaking force (F_{tr}) starts to increase of the presence of greater values of overfeed.

9. The values of the seam breaking force of air-textured PES/PTFE sewing thread at first increased, and later begin to drop with an increase in the feeding speed of the effect component, an increase in the pressure in the texturing head, and an increase in the feeding speed of the core component.

10. To obtain maximum value of breaking force of threads and seems the following technological parameters are recommended: pressure of air in air-jet texture nozzles 9-10 ($\times 9{,}89\times 10^4$ Pa); overfeed of core yarns 15%; overfeed of wrapping yarn 20-30%.

11. The results obtained from this research work provide us with the data on the air-textured sewing threads that were not investigated till nowadays. These results on the changes of the indicators of air-textured sewing thread are of equally high importance for both scientific and practical sectors, i.e. Lithuanian textile enterprises.

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Reziumė

Plečiantis siuvimo siūlų asortimentui, kylant jų kokybės reikalavimams ir tobulėjant jų gamybos technologijoms, svarbu žinoti siuvimo pramonės reikalavimus tokiam produktui ir atsižvelgiant į juos, pasiūlyti naujus siuvimo siūlų asortimento variantus, pritaikytus konkretiems tikslams.

Kuriant naujas technologijas, būtina gerai žinoti perdirbamų medžiagų sandarą bei savybes. Svarbu išnagrinėti siūlų struktūros, jų tąsumo, varginimo bei kitas charakteristikas, turinčias įtakos eksploatacinėms siuvinio savybėms, jo estetiniai išvaizdai.

Temos aktualumas. Pastaraisiais metais siuvimo siūlų asortimentas nepaprastai išsiplėtė. Tokį asortimento išsiplėtimą lėmė keletas reiškinių- naujų pluoštų atsiradimas, naujų siūlų gamybos procesų atradimas ir tobulinimas, vis didėjantis siuvimo pramonės pareikalavimas įvairiems siuvimo siūlams, skirtiems vis įvairesniems gaminiams siūti. Taip pat vis didėjantis siuvimo mašinų darbinis greitis reikalauja atsparesnių aukštoms temperatūroms bei mechaniniam poveikiui siūlų.

Naujiems siuvimo siūlams naudojamos įvairios pluoštinės sudėties – sintetinės ir natūralios. Derinant tarpusavyje skirtingas pluoštines sudėtis ar komponentus, gaunami siuvimo siūlai, pasižymintys visapusiškai geresnėmis mechaninėmis savybėmis.

Kaip ir kitų siūlų, taip ir siuvamųjų siūlų savybėms didelę reikšmę turi gamyboje naudojamų pluoštų rūšys, siūlų sandara bei apdaila. Tekstūravimo oru procese siūlų sandarai ir jų savybėms didžiulę reikšmę turi įvairūs proceso

parametrai- oro slėgis, šerdinių-apvejančiųjų siūlų tiekimo greičių santykis, taip pat termofiksacijos buvimas ar nebuvimas bei jos temperatūra.

Šiuo darbu siekiama išplėsti oru tekstūruotų siuvimo siūlų asortimentą, tinkantį darbo drabužiams siūti.

Darbo tikslas ir uždaviniai. Darbo tikslas – sukurti heterogeninius oru tekstūruotus siuvimo siūlus, skirtus siūti greitaeigėse siuvimo mašinose ir apsauginiams drabužiams, ištirti ir prognozuoti pagamintų siuvimo siūlų mechaninius ir kitus rodiklius, sudarant matematinius modelius, apibūdinančius siūlų rodiklių bei technologinių gamybos parametrų priklausomybę.

Šiame darbe siekiama išspręsti šias užduotis:

1. Parinkti oru tekstūruotų siuvimo siūlų technologinių gamybos parametrų matematinį eksperimento planą ir kokybės įvertinimo rodiklius;
2. Taikant matematinį eksperimento planavimo metodą, pagaminti oru tekstūruotus siuvimo siūlus, naudojant skirtingos pluoštinės sudėties bei savybių komponentus;
3. Ištirti pagamintų oru tekstūruotų siuvimo siūlų mechaninius ir kitus rodiklius – trūkimo bei savitąją trūkimo jėgą, santykinę trūkimo ištįsą, trūkimo darbą, trinties koeficientą bei siūlės trūkimo jėgą;
4. Ištirti termofiksacijos įtaką oru tekstūruotiems poliesteriniams siuvimo siūlams.
5. Sukurti matematinius metodus, siejančius įvairius oru tekstūruotų siuvimo siūlų rodiklis ir siūlų gamybos technologinius parametrus, ištirti matematinius modelius informatyvumo požiūriu;
6. Prognozuoti oru tekstūruotų siuvimo siūlų mechaninius rodiklius, grafiškai interpretuojant matematinius modelius;
7. Ištirti sukurtų ir pagamintų oru tekstūruotų siuvimo siūlų savybių priklausomybę nuo gamybos parametrų.

Darbo mokslinis naujumas. Tekstūruoti oru siuvimo siūlai- naujas tekstilės pramonėje gaminys. Jie nėra plačiai naudojami drabužių siuvime, tačiau turi didelę panaudojimo perspektyvą dėl savo gerų savybių, našaus gamybos proceso bei mažų gamybos kaštų. Šiuo metu nėra tiksliai įvardinta, kokius oru tekstūruotus siūlus geriausiai naudoti siuvimo pramonėje, kokie siūlai geriausiai elgiasi siuvimo mašinoje, geriausiai atrodo bei dėvisi gaminyje. Yra įmanoma naudoti daugelį variantų - suktus, nesuktus, stipriai ar mažai išreikštomis kilpomis. Įvairūs gamintojai siūlo įvairius variantus.

Tekstūravimo oru procesas yra labai našus, palyginus su įprastais siuvimo siūlų gamybos procesu- verpimu. Tekstūravimui oru nenaudojamos tokios operacijos, kaip pluošto karšimas, sluoksnos formavimas, šukavimas, pusverpalio gamyba. Tekstūruoti oru siūlai gaminami naudojant kompleksinius nesuktus siūlus kaip pluoštinę sudėtį. Galima gaminti spalvotus siūlus, naudojant masėje dažytus kompleksinius siūlus. Šiuo atveju yra sutaupomi papildomi resursai siūlų dažymui. Deja, šią ypač patrauklią galimybę riboja masėje dažytų kompleksinių siūlų pasiūla rinkoje.

Tiriant parenkami metodai bei įranga, atitinkanti nustatytus standartus bei reikiama tyrimų metodika. Tiriant tarpusavyje lyginamos siūlų, pagamintų renkantis skirtingus gamybos parametrus, savybės. Taip yra pagrindžiamas gamybos proceso parametrų parinkimas, motyvuojamas vienokių ar kitokių procesų parametrų svarbumas, parametrų reikšmės.

Šiame darbe sukurtų ir pagamintų oru tekstūruotų siuvimo siūlų komponentams panaudoti poliesteriniai ir politetrafluoretileniniai siūlai. Žinoma, kad politetrafluoretileno gijos pasižymi mažu trinties koeficientu, atsparumu aukštai temperatūrai ir cheminėms medžiagoms, bet nėra stiprios. Apie tokių siūlų naudojimą oru tekstūruotiems siuvimo siūlams gaminti tyrimų nėra. Todėl buvo tikslinga pagaminti oru tekstūruotus siuvimo siūlus, sudarytus iš poliesterinių ir politetrafuoretileninių komponentų, taip panaudojant politetrafuoretileno gijų privalumus. Svarbus uždavinys yra oru tekstūruotų siuvimo siūlų, į kurių sudėtį įeina politetrafuoretileniniai siūlai, savybių išnagrinėjimas, parenkant oru tekstūruotų siuvimo siūlų gamybos parametrus.

Darbe, panaudojant matematinį eksperimento planavimo metodą, ištirtos kompleksinių oru tekstūruotų siuvimo siūlų savybių ir oru tekstūruotų siūlų technologinių gamybos parametrų priklausomybės. Regresijos lygtys leido prognozuoti oru tekstūruotų siuvimo siūlų savybes.

Tyrimų rezultatai leido gauti duomenų apie dar netirtus oru tekstūruotus poliesterinius/politetrafluoretileninius bei jau gerai žinomus praktikoje poliesterinius/poliesterinius siuvimo siūlų mechaninius ir kitus rodiklius, jų kitimo dėsningumus, tendencijas bei pobūdį. Šie duomenys apie oru tekstūruotų siuvimo siūlų rodiklių kitimą labai svarbūs ne tik mokslui, bet ir praktikai - Lietuvos tekstilės pramonės įmonėms – siekdamos pelningai dirbti, įmonės turi efektyviau naudoti naujausias technologijas.

Išvados

Išanalizavus literatūrą, parinkus matematinį eksperimento planavimo metodą, pagal kurį pagaminus oru tekstūruoti siuvimo siūlus, naudojant skirtingos pluoštinės sudėties bei savybių komponentus, ištyrus šių siuvimo siūlų savybių ir oru tekstūruotų siūlų technologinių gamybos parametrų priklausomybes, galima daryti tokias išvadas:

1. Didžiausią įtaką oru tekstūruotų siuvimo siūlų mechaninėms turi trys šių siūlų gamybos technologiniai parametrai – slėgio tekstūravimo galvutėje, šerdinio komponento tiekimo greitis ir apvejančio komponento tiekimo greitis.
2. Atlikus oru tekstūruotų siuvimo siūlų tempimo bandymus nustatyta, kad poliesteriniai siuvimo siūlai, kurių gamybos procese naudota termofiksacija, turi 7-14% didesnes trūkimo jėgas, 6-17% didesnes savitąsias trūkimo jėgas ir 4-20% mažesnę trūkimo ištįsą, nei oru tekstūruoti siuvimo siūlai, kurių gamybos procese nenaudota

termofiksacija, nes termofiksuotų ir netermofiksuotų tekstūruotų oru siūlų morfologinės struktūros, po termofiksacijos, skiriasi.

3. Lankstymo – dildymo metu paveiktų oru tekstūruotų poliesteriniai siuvimo siūlų trūkimo jėga didėja nuo 5 iki 12 % siūluose, kurie buvo pagaminti naudojant termofiksaciją.
4. Didžiausią trinties koeficientą turi oru tekstūruoti siuvimo siūlai, kurių sudėtyje yra tik poliesterinis komponentas, ir pagaminti naudojant termofiksaciją. Mažiausią trinties koeficientą turi oru tekstūruoti poliesteriniai/politetrafluoretileniniai siuvimo siūlai. Siūlai, kuriuose yra politetrafluoretileno komponentas, pasižymi paviršiaus glotnumu ir lygumu, jis yra daug slidesnis komponentas nei poliesterinis. Todėl ir įvedus į poliesterinio siūlo sudėti politetrafluoretileno komponentą jo trinties koeficientas mažėja.
5. Atlikus siūlių stiprumo bandymus nustatyta, kad didžiausią siūlės stiprumą audinyje turi iš poliesterio pagamintų, kai termofiksacija išjungta, siūlų sudaryta siūlė. Oru tekstūruotų poliesterinių/politetrafluoretileninių siuvimo siūlų trintis maža, todėl ir iš šių siūlų sudarytų siūlų stiprumas yra mažesnis. Siūlės stiprumui audinyje didelę įtaką turi trinties jėgų dydis tarp siūlų siūlės kilpose.
6. Projektavimo metodų analizė ir oru tekstūruotų siuvimo siūlų prognozavimo rezultatai parodė, kad beveik visi tirtieji technologiniai gamybos parametrai turi reikšmingos įtakos oru tekstūruotų siuvimo siūlų rodikliams.
7. Oru tekstūruotų poliesterinių siuvimo siūlų, kurių gamybos procese nenaudota termofiksacija, trūkimo jėga, savitoji trūkimo jėga ir trūkimo ištįsa didėja, mažėjant apvejančio komponento tiekimo greičiui ir oro slėgio tekstūravimo galvutėje reikšmėms. Oru tekstūruotų PES/PES siuvimo siūlų, kurių gamybos procese naudota termofiksacija, trūkimo jėga, savitoji trūkimo jėga didėja , mažėjant paskubos ir oro slėgio reikšmėms. O trūkimo ištįsa didėja esant minimalioms paskubos reikšmėms.
8. Oru tekstūruotų poliesterinių/politetrafluoroetileninių siuvimo siūlų trūkimo jėga kinta dėsningai, t. y. didėjant apvejančio komponento tiekimo greičiui, trūkimo jėga didėja iki tam tikros maksimalių verčių srities ir ją pasiekusi pradeda mažėti. Tuo tarpu didinant slėgį tekstūravimo galvutėje trūkimo jėga intensyviai mažėja. Bet didinant šerdinio komponento tiekimo greitį F_{tr} pradeda didėti,esant didesnėms paskubos vertėms.
9. Oru tekstūruotų poliesterinių /politetrafluoretileninių siuvimo siūlų siūlių trūkimo jėgos reikšmės iš pradžių padidėja, o vėliau pradeda mažėti, didėjant efektinio komponento tiekimo greičiui, didėjant slėgiui tekstūravimo galvutėje bei didėjant šerdinio komponento tiekimo greičiui.
10. Oru tekstūruotų poliesterinių/politetrafluoretileninių siuvimo siūlų gamybai, su tikslu gauti didžiausią siūlų ir siūlės trūkimo jėgą, rekomenduojama taikyti tokius gamybos technologinius parametrus – oro,

paduodamo į tekstūravimo galvutę, slėgį 9-10 ($\times 9{,}89\times 10^4$ Pa); šerdinio siūlo paskubą 15%; apvejančio siūlo paskubą 20-30%.

11. Tyrimų rezultatai leido gauti duomenų apie dar netirtus oru tekstūruotus poliesterinius/politetrafluoretileninius siuvimo siūlus. Gautus tyrimo rezultatus galima panaudoti, projektuojant pageidaujamų savybių oru tekstūruotus siuvimo siūlus. Šie duomenys apie oru tekstūruotų siuvimo siūlų rodiklių kitimą labai svarbūs ne tik mokslui, bet ir praktikai - Lietuvos tekstilės įmonėms.

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