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Influence of Thermo-Setting on the Quality of Air-Jet Textured Threads

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Air-jet texturing is one of the most perspective methods for manufacture of threads in order to obtain sewing threads of high quality and with excellent mechanical features. The goal of research is to analyse the dependence of qualities of polyester air-jet textured threads on thermo-setting. These threads designed for sewing various outfit were manufactured by the Department of Textile Technology at Kaunas University of Technology. Tensile and cycle flexing–abrasion tests as well as tests of enervated threads were performed. The results demonstrated that thermo-setting of tested threads has an influence on the tensile characteristics of threads. The parameters of manufacture process – overfeed and air pressure, have a great influence on the tensile characteristics of the air-jet textured threads.

Keywords: air-jet texturing, polyester, thermo-setting, flexing–abrading, tensile properties, sewing threads.

INTRODUCTION

In these latter years a range of sewing threads has been increasing significantly. Such growth of the range was determined by some reasons, i.e. by the development of new fibres, development and improvement of new thread manufacture processes, and continuously increasing industry demand for various sewing threads designed for sewing more assorted articles [1].

Air-jet texturing is one of the most perspective ways for manufacture of threads in order to obtain sewing threads of high quality and with excellent mechanical features [2 – 4]. Control of air-jet texturing parameters enables to manufacture threads possessing desirable features. Similarly to the features of other threads the types of fibres used in the manufacture process, composition of threads and finishing are very important for the quality of sewing threads as well. In the process of air-jet texturing a great impact on the composition of threads is made by various process parameters, i.e. by air pressure, the ratio of speeds for feeding core-effect threads, also by the existence or absence of thermo-setting and by its temperature [5, 6]. In thermo-chambers at high temperature threads are stabilised and their structure given in the process of texturing is fixed. Setting is in process due to the changes of micro molecular composition and relaxation of intermolecular tension. Thermo-setting is used for fixing thermally plastic polymers solely, e.g. polyester, polypropylene. Each of them has its specific thermo-setting temperature [1, 7, 8].

The goal of research is to analyse the dependence of qualities of polyester air-jet textured threads on thermo-setting.

EXPERIMENTAL

Materials. During this research the polyester sewing threads manufactured by the Department of Textile Technology at Kaunas University of Technology were analysed. Threads were manufactured by Eltex air-jet texturing machine. In the process of manufacture the following three process parameters making an essential impact on the quality of a final product were varied: effect thread overfeed, pressure of air feed in an air-jet texturing nozzle, and thermo-setting.

In the process of thread manufacture two multi-filament threads were feed to the core and one to the effect. On the whole three filament threads were fed. Core threads were dampened in all cases. Effect threads overfeed (X_1) varied from 15 to 27 %. Besides, the pressure of air feed (X_2) in an air-jet textured nozzle was changed from 58.86×10^4 Pa to 117.72×10^4 Pa. Mechanical indicators of threads are analysed applying an experimental planning method and Box plan, the number of levels –2, the number of factors –2 [9]. After processing the experiment data regression equations of second order are obtained.

Dependence of threads with structural effects on two technological manufacturing parameters (overfeed (X_1) and air pressure (X_2) in the nozzle) of the analysed air-jet textured threads when thermo-setting is fixed, is presented graphically on a two-dimensional plane, which becomes a designing plane, whereas designing results become the coordinates of a two-dimensional plane defined by two variable factors.

The general relation between the response Y (tensile characteristics) and manufacturing parameters X_1 and X_2 [9] :

$$Y = B_0 + B_1X_1 + B_2X_2 + B_{12}X_1X_2 + B_{11}X_1^2 + B_{22}X_2^2 . \quad (1)$$

The regression coef1ficients of equations are given in the Table 1.

For the manufacturing an air-jet textured thread HemaJet® T321 air-jet textured nozzle was used. “Torlen FY HT” polyester threads of increased strength (Table 2) were used as raw material. These threads were selected in order to improve mechanical properties of a ready-made product. According to the assumption the best setting takes place at the temperature, which is between the polymer glass transition temperature and melting temperature. Thermo-setting temperature of 190 °C was chosen.

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Table 1. The regression coefficients of PES threads

Characteristics	B_0	B_1	B_2	B_{12}	B_{11}	B_{22}
	Sewing threads without thermo-setting					
Breaking force, N	12.30	0.24	0.49	0.05	0.14	0.16
Elongation at break,%	8.85	0.06	0.32	0.05	0.20	0.01
Breaking tenacity, cN/tex	27.77	0.74	1.01	0.11	0.31	0.28
	Sewing threads with thermo-setting					
Breaking force, N	13.18	0.35	0.34	0.10	0.33	0.09
Elongation at break,%	8.53	0.03	0.26	0.19	0.11	0.22
Breaking tenacity, cN/tex	29.61	0.99	0.87	0.21	0.74	0.16

Table 2. The main parameters of PES threads used as raw material

Parameter	Value
Linear density of thread, dtex	133
Number of filaments	32
Breaking tenacity, cN/tex	54
Elongation at break,%	16
Filament cross-section profile	Circular

Methods. Tensile tests were implemented according to DIN EN ISO 2062, 05/1995 standard [10]. Tensile tests were performed on CRE-type testing machine ZWICK/Z005 at a rate of extension 500 mm/min, the gauge length 500 mm, pretension 0.5 cN/tex. The number of tests per one package was 20. Cyclic flexing–abrasion tests were performed by FY-8 device, in which needles of a sewing machine were attached additionally. Thus, threads are enervated both by flexing and abrading. In addition, the developed test conditions are analogous to the impact of a sewing machine. Test conditions were following: load of threads 1.5 N, 2.0 N, 2.5 N, the number of circles 20, 50, 100, "Shmertz" needle of Nm 90, needle-moving speed of 120 1/m, the number of tests 10, the number of needles 5. The samples were used for testing after storage for at least 72 hours in a conditioned laboratory (65 ±2 % RH, 20 ±2 °C).

RESULTS AND DISCUSSIONS

Tensile characteristics of enervated and non-enervated PES sewing threads are provided in the Table 3.

In the manufacture process tested samples with thermo-setting have 7 – 14 % higher values of breaking force. Consequently, thermo-setting has influence on breaking force of tested samples. This situation may be explained by the fact that when a polymer molecule is subjected to high temperature the polymerisation degree of a macromolecule decreases, and due to this break force decreases as well. In the thermo-chamber structure of jet-bulked threads is fixed. After thermo-setting the crimped structure of filaments remains and this structure is more resistant to the extension impact. The data from the Table 3 indicate the significantly loss of breaking strength after thermo-setting (Student's coefficient $t_F = 2.53$, $t_{95} = 2.02$, $t_{99} = 2.70$, i.e. $t_{95} < t_F < t_{99}$) [11].

The breaking tenacity is an especially important indicator when threads are used for sewing. Breaking tenacity of sewing threads should be as high as possible. This fact would enable to use thinner threads featuring the same strength characteristics for joining parts of article during sewing.

Table 3. Tensile characteristics of sewing threads

Characteristics	Sewing threads without thermo-setting (A)								
No. of sewing threads	A1	A2	A3	A4	A5	A6	A7	A8	A9
Resultant linear density, tex	44.30	44.30	45.00	44.30	44.70	44.30	45.00	44.70	45.00
Breaking force, N	12.30±0.4	11.83±0.4	12.90±0.5	13.16±0.5	12.29±0.6	13.06±0.6	12.19±0.4	13.36±0.6	11.96±0.6
Elongation at break,%	8.85±0.3	8.50±0.3	9.12±0.4	9.16±0.2	8.77±0.3	9.45±0.2	9.32±0.1	9.52±0.3	8.44±0.2
Breaking tenacity, cN/tex	27.77±0.6	26.77±0.6	28.73±0.6	29.73±0.8	28.20±0.8	29.62±0.8	27.13±0.6	29.94±1.0	26.70±0.8
	Sewing threads with thermo-setting (B)								
No. of sewing threads	B1	B2	B3	B4	B5	B6	B7	B8	B9
Resultant linear density, tex	44.70	44.70	44.30	45.00	44.30	44.30	44.30	45.00	45.00
Breaking force, N	13.18±0.4	12.68±0.4	13.84±06.	13.05±0.4	14.60±0.6	14.17±0.6	13.33±0.6	13.22±0.5	13.68±0.6
Elongation at break,%	8.55±0.2	7.91±0.3	8.49±0.3	8.32±0.2	8.53±0.1	8.22±0.1	7.96±0.2	7.61±0.2	8.61±0.2
Breaking tenacity, cN/tex	29.61±0.8	28.46±0.6	31.31±1.0	29.05±0.8	33.07±1.0	32.05±1.0	30.16±0.8	29.46±0.8	30.50±0.9

Table 4. Cycle tension and flexing loads characteristics

Enervation load	No. of cycle	Breaking force, N								
		Sewing threads without thermo-setting (A)								
		A1	A2	A3	A4	A5	A6	A7	A8	A9
1.5	20	12.70	13.00	13.60	13.90	12.80	13.70	12.50	13.40	12.20
1.5	50	12.60	10.80	13.30	14.00	12.30	13.80	11.80	12.00	5.60
1.5	100	11.40	–	13.00	12.50	7.00	19.90	12.30	3.90	7.40
2.0	20	12.20	12.30	12.90	12.70	12.50	13.00	12.60	11.50	11.40
2.0	50	9.00	11.70	13.30	–	–	–	9.90	–	–
2.0	100	3.60	–	12.50	–	–	–	–	–	–
2.5	20	10.60	12.80	13.10	7.70	9.00	6.50	12.10	6.60	11.30
2.5	50	–	–	10.70	–	–	–	4.90	–	–
		Sewing threads with thermo-setting (B)								
		B1	B2	B3	B4	B	B	B	B	B
1.5	20	13.90	13.10	13.40	13.10	14.60	14.70	14.30	13.50	13.50
1.5	50	13.20	12.90	10.20	12.90	14.40	10.40	13.60	5.60	13.10
1.5	100	12.50	12.20	2.10	12.90	11.80	–	9.50	–	10.20
2.0	20	13.90	13.00	12.70	13.60	15.00	13.80	13.60	11.10	14.60
2.0	50	11.10	12.10	–	13.00	11.00	–	13.10	–	12.70
2.0	100	10.70	–	–	8.40	6.50	–	–	–	–
2.5	20	14.60	12.40	5.10	13.05	14.60	–	13.70	–	13.70
2.5	50	–	–	–	10.90	10.10	–	–	–	1.8

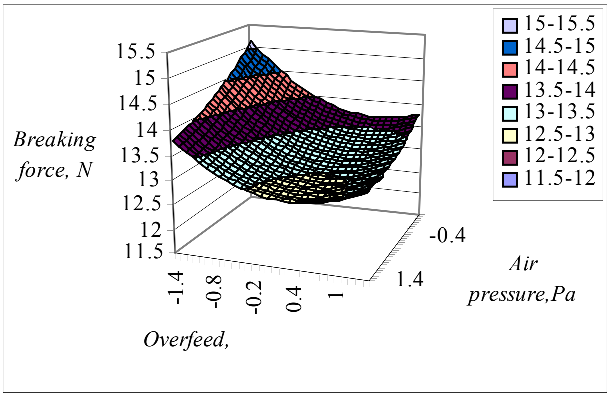

Fig. 1. Dependence between breaking force and manufacturing parameters of threads with thermo-setting

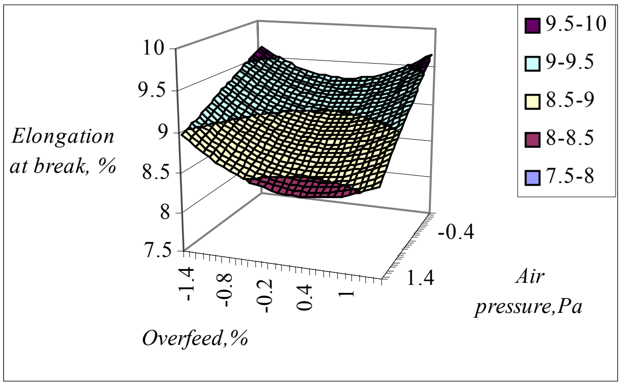

Fig. 3. Dependence between elongation at break and manufacturing parameters of threads with thermo-setting

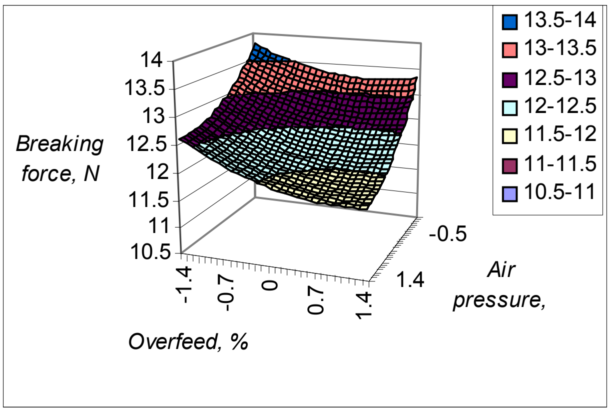

Fig. 2. Dependence between breaking force and manufacturing parameters of threads without thermo-setting

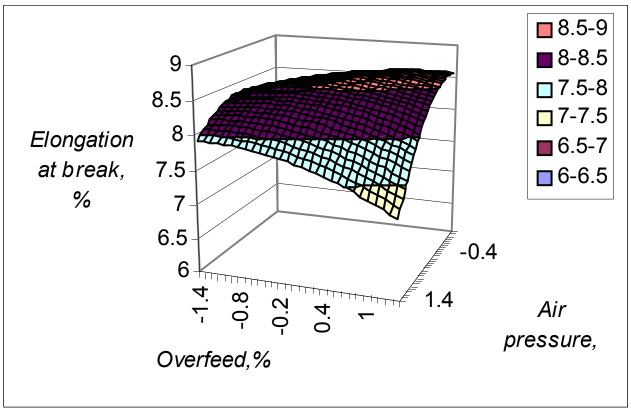

Fig. 4. Dependence between elongation at break and manufacturing parameters of threads without thermo-setting

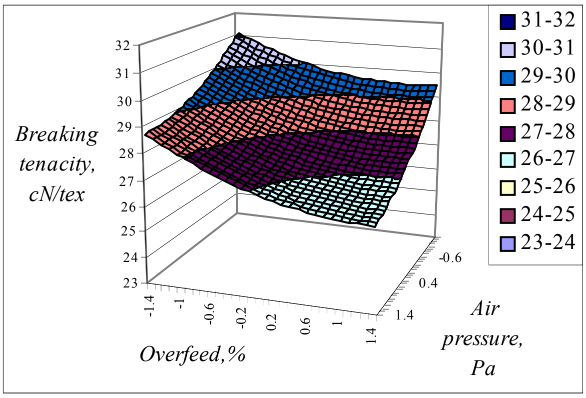

Fig. 5. Dependence between breaking tenacity and manufacturing parameters of threads with thermo-setting

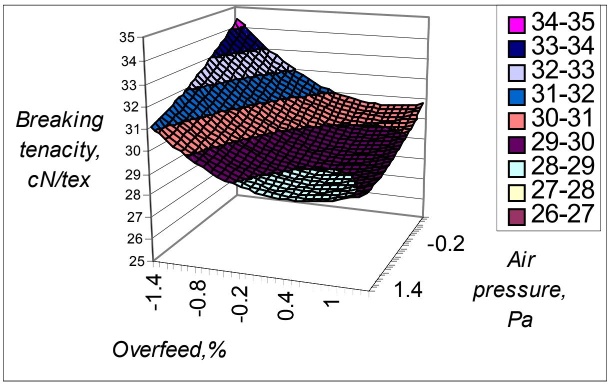

Fig. 6. Dependence between breaking tenacity and manufacturing parameters of threads without thermo-setting

The tested samples manufactured with thermo-setting have from 6 till 17 % the highest values of breaking tenacity, than that of threads without thermo-setting except samples B4, B8.

As results of tensile characteristics show the lowest elongation at break is typical of versions B2, B4, B6, B7, B8, which are manufactured with thermo-setting, whereas the highest elongation at break is typical of versions A1, A3, A4, A6, A7, A8, which are manufactured without thermo-setting. The elongation at break of threads with thermo-setting is from 4 till 20 % lower than threads without thermo-setting. The data from the Table 3 indicate the significantly loss of elongation at break after thermo-setting (Student's coefficient $t_F = 2.48$, $t_{95} = 2.02$, $t_{99} = 2.70$, i.e. $t_{95} < t_F < t_{99}$) [11]. In the process of thermo-setting intermolecular tension is relaxed, which occurs when filaments (and polymer macromolecules at the same time as well) form loops. Hence, elongation of break of threads manufactured without thermo-setting is obtained only due to elongation of polymer macromolecules themselves.

In the sewing process threads are subjected by cycle tension and flexing loads, they are abraded while contacting with material and surfaces of a needle eye. Therefore, strength of threads decreases, whereas fibres filaments are damaged mechanically. In order to assess the influence of such impacts on the change of thread strength cyclic flexing–abrasion tests were performed. Testing of enervated threads demonstrated that in many cases after subjecting to the enervation load of 1.5 N breaking force of threads increased after 20 cycles. This may be explained by the fact that filaments of the enervated threads became straight, but physically they were not impacted to such a degree, which would decrease their breaking force. After subjecting to 2 N enervation load and 20 cycles increase the breaking force of tested threads manufactured without thermo-setting. Enervating threads under more difficult conditions clear differentiation of their characteristics can be seen, i.e. the breaking force tended to increase in the samples manufactured without thermo-setting.

As the diagrams show, the threads with thermo-setting breaking force (Fig. 1) tend to increase by decreasing air pressure and overfeed. The threads without thermo-setting (Fig. 2) breaking force increases by decreasing air pressure and overfeed too.

The change of a breaking force of the threads without thermo-setting demonstrates that increase of overfeed and pressure or corresponding decrease of both parameters lead to higher decrease of breaking force.

As data in Fig. 3 show that for threads with thermo-setting elongation at break depends directly on the parameters of manufacture, i.e. the decrease of effect thread overfeed and decrease of air pressure lead to higher elongation at break, whereas at thread without thermo-setting elongation at break increases with the increase of air pressure (Fig. 4). Maximum elongation at break is achieved having minimum values of overfeed. The threads with thermo-setting breaking tenacity (Fig. 5) increase by decreasing air pressure and overfeed and the threads without thermo-setting (Fig. 6) breaking tenacity tend to increases by decreasing air pressure and overfeed too.

CONCLUSIONS

The results demonstrated that thermo-setting of tested threads has an influence on the tensile characteristics of threads.

Tested samples with thermo-setting have 7 – 14 % higher values of breaking force. The tested samples with thermo-setting have from 6 till 17 % the highest values of breaking tenacity. The threads with thermo-setting have 4 – 20 % lower elongation at break, than threads without thermo-setting.

Breaking force of enervated in cyclic flexing–abrasion tests threads tend to increase from 5 till 12 % in the case of samples, which were manufactured using thermo-setting.

The threads without thermo-setting breaking force increase by decreasing as threads with or without thermo-setting. The parameters of manufacture process – overfeed and air pressure, have a great influence on the tensile characteristics of the air-jet textured threads. Breaking force, breaking tenacity and elongation at break increase with decreasing of overfeed and air pressure in the case of thread with thermo-setting. Breaking force, breaking tenacity increase with decreasing of overfeed and air pressure in the case of thread with thermo-setting, except the indicator of elongation at break. For the tested threads without thermo-setting maximum elongation at break is achieved having minimum values of overfeed.

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