THE INFLUENCE OF THE TEXTURING SPEED AND THE DEGREE OF STRETCHING ON BREAKING CHARACTERISTICS OF THE TEXTURED PES YARN

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Mechanical properties of textured PES yarns depend on their structural characteristics and texturing process parameters. In this work, the results of breaking characteristics of textured PES yarns formed with various technological production parameters are presented. The samples of textured PES yarns were produced on a modern machine with a short heating zone. The textured yarn was formed at the first heater temperatures of 350 °C, 400 °C and 450 °C with the constant temperature of the second heater of 180 °C and with D/Y ratio of 2.20. The texturing speed was changed in the range of 500 m/min up to 1100 m/min with stretching degrees of 1.665, 1.675 and 1.685. The results obtained can be used for the selection of optimal production parameters of PES yarn at various texturing speeds. Also, the relationships which can be applied in industry for predicting breaking characteristics depending on texturing process parameters are presented.

Keywords: textured yarn, texturing speed, breaking force, breaking elongation

Introduction

The modern false twist texturing equipment is characterized by a high degree of automation, by the use of high temperature heaters about 1 meter in length instead of the old 2.5 m long heaters, which significantly reduced the size of the equipment and facilitated handling and servicing. The use of the short heating zone with the increased heater temperature (indirect heating) and reduced heating time of about 0.1 second, which ensures filament thermoplasticity sufficient for fixing yarn crimping, and with satisfactory mechanical characteristics of the textured yarn, has enabled the increased texturing speed. Polyester filament can be textured under laboratory conditions with a speed of 1500 m/min but in manufacturing plants the speed does not exceed 1000 m/min, because above this speed the process instability is increased (strain instability, higher filament breaking etc.) which results in uneven dyeing of the textured filament yarn [1-4]. In the texturing process, structural changes occur in the fiber polymer [5], mostly the disorientation of macromolecular chains. On the one hand, the torsion stress promotes disorientation of macromolecular chains and on the other hand the tension load leads to further orientation of crystal and amorphous areas. Another important characteristic of supra-molecular structures is the orientation of molecules in one direction which is expressed as the orientation degree. As a parameter of the supra-molecular structure, the orientation degree has a great impact on breaking force, breaking elongation [6] and other mechanical properties. Therefore, the aim of this work is to present the results of the analysis of breaking characteristics of textured PES yarns produced at various texturing speeds and stretching degrees in the process.

Materials and methods

The experimental part of the work includes the analysis of POY multifilament yarn with the yarn fineness of 167f36x1dtex. Texturing of PES yarn was made at various temperatures of the first heater, maintaining the constant temperature of the second heater and at various stretching degrees in the texturing zone with minimal waving of tension.

The texturing was performed on the machine for stretching friction texturing with a high temperature heater: FTF-15 (ICBT, France).

Automatic dynamometer USTER TENSORAPID 4 was used for the determination of mechanical characteristics of the experimental material [7].

Results and discussion

Table 1 shows the test results of the mechanical characteristics of PES filament yarns. The test results of breaking forces (F¬b) and breaking elongations (εb) of PES yarns made at various production process parameters are presented.

The texturing speed causes changes in the structure of filament PES yarns that affect the mechanical properties of the yarns. By changing the texturing speed, contact times between the yarn and the heater, cooling and stabilization times of textured PES yarns are changed.

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Table 1. Test results for PES filament yarns, D/Y=2.20

v_i (m/min)	i	F_b (cN)	ε_b (%)	F_b (cN)	ε_b (%)	F_b (cN)	ε_b (%)
		T=350 °C		T=400 °C		T=450 °C	
1100	1,665	598,5	19,78	615,7	19,59	627,2	21,50
1100	1,675	602,9	18,46	596,9	19,13	645,6	21,14
1100	1,685	626,6	19,66	606,7	18,12	648,4	20,61
1000	1,665	605,8	20,67	632,0	20,57	644,8	21,00
1000	1,675	560,0	18,46	635,5	20,56	664,8	20,92
1000	1,685	635,1	21,24	648,9	21,07	652,5	22,45
900	1,665	619,6	27,83	646,6	26,91	669,5	26,59
900	1,675	598,5	20,41	591,8	21,46	636,3	22,65
900	1,685	639,9	25,62	656,5	24,13	665,0	23,27
700	1,665	643,8	25,01	688,8	25,77	700,6	26,05
700	1,675	617,5	23,67	690,6	25,49	691,7	25,25
700	1,685	637,5	23,49	688,1	24,96	699,0	25,10
600	1,665	650,0	26,38	670,1	26,22	683,7	26,33
600	1,675	649,5	25,40	671,3	25,68	682,8	25,68
600	1,685	651,9	24,47	670,1	24,72	686,7	24,86
500	1,665	661,1	25,04	682,1	25,99	701,6	25,07
500	1,675	663,2	24,83	677,7	24,75	709,0	25,08
500	1,685	659,8	23,78	678,4	24,25	702,1	23,83

D/Y - the ratio of peripheral speed of friction discs and the speed of the yarn
vi - Texturing speed (m/min)
i - Stretching degree
Fb - Breaking force (cN)
εb - Breaking elongation (%)

Figures 1 to 3 show the changes of breaking characteristics of textured filament PES yarns at various texturing speeds, first heater temperatures and stretching degrees.

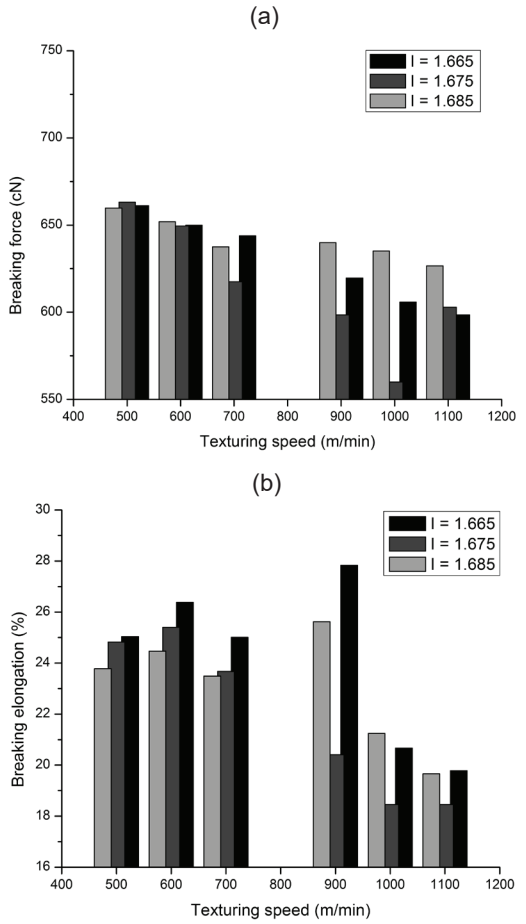

Figure 1. The influence of the texturing speed on the yarn breaking force (a) and breaking elongation (b); T = 350 °C

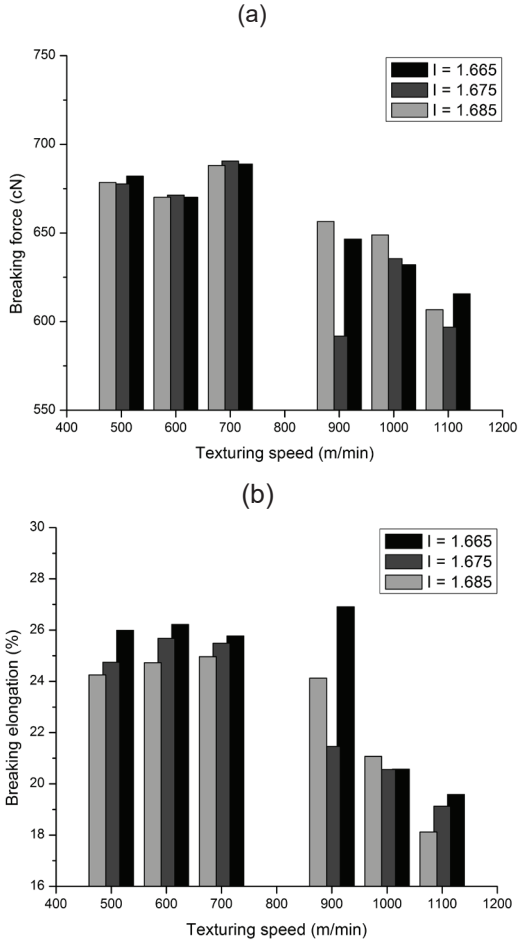

Figure 2. The influence of the texturing speed on the yarn breaking force (a) and breaking elongation (b); T = 400 °C

The results show that with the increase of the texturing speed, a trend of the decrease of breaking force values was observed for the analyzed textured yarn. Using a stretching degree of 1.675 in most cases, the trend of decreasing the breaking force was observed with increasing the texturing speed up to 900 m/min and then the trend of the increase of the breaking force was observed.

At the same time, on histograms 1-a through 3-a, the impact of the stretching degree in the texturing process on breaking force values of textured PES filament yarns can be noticed. The results show that at the stretching degree of 1.685, the analyzed yarns have mostly higher values of the breaking force at the first heater temperatures of 350 °C and 400 °C, at speeds of 900 m/min, 1000 m/min and 1100 m/min. Also, at 450 °C and a stretching degree of 1.685, a higher breaking force value of textured PES yarn was recorded at the speed of 1100 m/min. This can be explained by the fact that with stretching filament PES yarns the orientation of macromolecules is improved in the direction of stretching forces, contributing to better mechanical characteristics of the yarns.

The results show that breaking elongation (Figs. 1-b through 3-b) has the trend of the increase of up to the

texturing speed of 900 m/min, with stretching in the texturing zone of 1.665 and at various first heater temperatures. Unlike these results, by using stretching degrees of 1.675 and 1.685, the trend of the decrease of breaking elongation of the analyzed PES yarns with the increase of the texturing speed is observed. The stretching degree also has a significant influence on the value of breaking elongation of the textured PES yarn. At lower speeds (500 m/min, 600 m/min and 700 m/min) it can be seen that at the lower stretching degree of the textured yarn, breaking elongation has higher values. This indicates that yarns with better orientation of macromolecular chains in the direction of the yarn axis have lower values of breaking elongation. At the speed of 900 m/min, the maximum value of breaking elongation can be seen at the stretching degree of 1.665 confirming the previous observation, but the other two yarns show some deviation of the results at this speed. Also, at speeds of 1000 m/min and 1100 m/min there are some deviations of breaking elongation results, and the reason for this should be looked for in settings of other technological parameters of the machine, in accordance with the shorter retention time in the first heater and insufficient time for macromolecular chains to be oriented in the direction of the yarn axis.

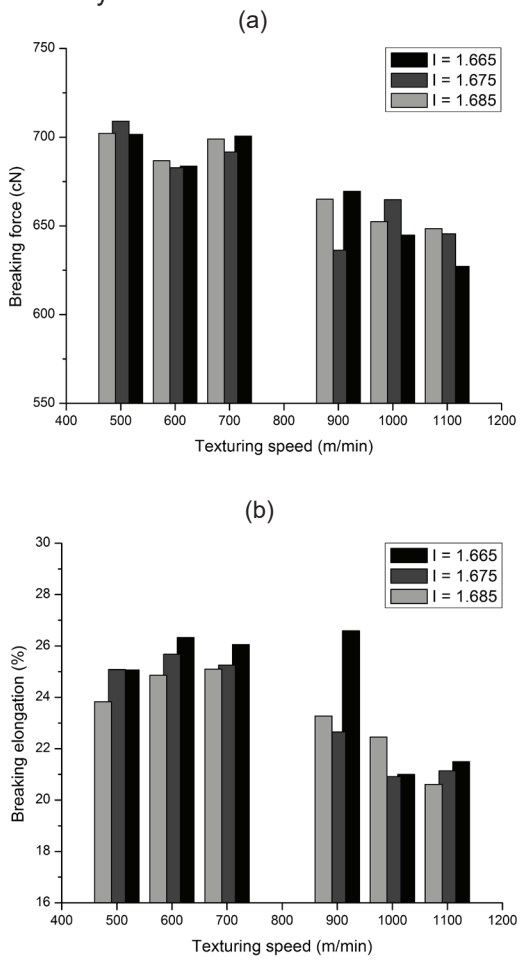

Figure 3. The influence of the texturing speed on the yarn breaking force (a) and breaking elongation (b); T = 450 °C

In Table 2, the parameters of the regression equation are shown, which can be used for predicting the texturing yarn breaking forces with the stretching degree of 1.665 depending on the texturing speed with the given first heater temperature, while Table 3 contains corresponding equation parameters for the stretching degree of 1.685 in the texturing process.

Table 2. Regression equation parameters (stretching degree 1.665)

T (°C)	$F_b = a + bv$ (cN)				
	R^2	*a*	Standard error	*b*	Standard error
350	0,99206	715,62857	3,55359	-0,10729	0,00429
400	0,811	746,62619	19,83547	-0,11343	0,02394
450	0,8249	766,11905	19,83444	-0,11861	0,02394

Table 3. Regression equation parameters (stretching degree 1.685)

T (°C)	$F_b = a + bv$ (cN)				
	R^2	*a*	Standard error	*b*	Standard error
350	0,80488	679,17143	8,32408	-0,04671	0,01005
400	0,64151	740,71667	27,12734	-0,10325	0,03274
450	0,87354	750,90238	13,08121	-0,09411	0,01579

T - First heater temperature (°C)
Fb - yarn breaking force (cN)
v - texturing speed (m/min)

The results shown can be used for the selection of optimal texturing of filament PES yarns.

Conclusions

The changes of process parameters in the production of the textured yarn affect the changes in the structure of POY PES yarn, reflecting also in its breaking characteristics.

The most significant texturing process parameters are: texturing speed and heater temperature. Also, the yarn stretching degree in the texturing process has the significant influence on mechanical properties of the textured yarn.

The results obtained indicate that with increasing the texturing speed, the decrease of breaking forces of textured PES yarns occurs. Moreover, the impact of the stretching degree on the values of breaking forces of the analyzed yarns is obvious at higher texturing speeds. In contrast to these findings, the analysis shows that expected changes of breaking elongations, when applying various stretching degrees in the texturing process, occur at lower speeds.

The results obtained have shown that optimal texturing process parameters must be selected as a compromise solution in accordance with required quality parameters of textured PES yarns, as well as economy and productivity of the technological texturing process.

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Izvod

UTICAJ BRZINE TEKSTURIRANJA I STEPENA ISTEZANJA NA PREKIDNE KARAKTERISTIKE TEKSTURIRANE PES PREĐE

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Mehanička svojstva teksturiranih PES pređa zavise od njihovih strukturnih karakteristika i parametara tehnološkog procesa teksturiranja. U radu su prikazani rezultati prekidnih karakteristika teksturiranih PES pređa formiranih pri različitim tehnološkim parametrima proizvodnje. Uzorci teksturiranih PES pređa proizvedeni su na savremenoj mašini sa kratkom zonom zagrevanja. Teksturirane pređe su formirane sa primenjenim temperaturama prvog grejača 350 °C, 400 °C i 450 °C uz konstantnu temperaturu drugog grejača 180 °C i D/Y odnosa od 2,20. Brzine teksturiranja su menjane u opsegu 500 m/min do 1100 m/min uz stepene istezanja 1,665, 1,675 i 1,685. Dobijeni rezultati mogu poslužiti za izbor optimalnih parametara proizvodnje teksturiranih PES pređa, pri različitim brzinama teksturiranja. Takođe, prikazane su zavisnosti koje se mogu primeniti u industriji, za predviđanje prekidnih karakteristika u zavisnosti od procesnih parametara teksturiranja.

Ključne reči: teksturirane pređe, brzina teksturiranja, prekidna sila, prekidno izduženje