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Effect of First Heater Temperature Variations on the Polyester Yarn Properties of False -Twist Texturing Techniques

Abstract
In this study, poly (ethylene terephthalate) PET POY, with 140 dtex 36 f and 295 dtex 36 f, were used for the production textured yarns of 83 dtex 36 f and 167 dtex 36 f. The yarn were textured at a first heater temperature of 175 °C, 190 °C and 205 °C set in both false-twist texturing machines, the Muratec 33 H (Belt-type nip twisters) and Barmag FK 6 M-1000 (Disk-type twisters)Afterwards the resulting 83 dtex 36 f and 167 dtex 36 f textured yarns were examined by measuring their tenacity, elongation at break, crimp contraction, crimp module, crimp stability, and shrinkage of yarns in boiling water. Afterwards, conclusions were drawn using the test values. The result was that, as the first heater temperature increases, the value of crimp contraction, crimp module and crimp stability of textured yarns increases, while the shrinkage values decrease. Generally, it was observed that regardless of the first heater temperature the tenacity and elongation change only slightly.

Key words: *texturing machines, textured yarns, heater temperature, breaking tenacity, crimp contraction, polyester (PET), elongation at break.*

Introduction

Loose fibres, spun and filament yarns are some of the different forms of textile materials. During high speed spinning, the physical properties and microstructure of fibres, e.g., breaking tenacity, elongation, density and crystallinity are improved by the effect of orientation-induced crystallisation [1, 2]. Texturing is a process of twisting the regular structure of synthetic filaments into more irregular and bulkier structures. During changing the shape of yarn by a mechanical process, most texture methods are dependent on thermic processes. The false-twist heat texturing process consists of deforming a continuous filament yarn by twisting and drawing at different parameters [3]. Some researchers [4 - 6] have indicated that for false-twist textured yarns the inclination angle is an important parameter in determining the yarn path's frictional force for a single friction disk and a triple-stack multiple-disk unit, which determines the yarn tension, disk surface and disk profile.

Foster et. al. [7], on the other hand, studied false-twist texturing yarns and analysed the effects of heating on the bulky structures of yarn with respect to its cooling and other factors. The belt-twisting principle has been used in the textile industry for many years and has also been applied to textured yarn production [8]. A belt-type nip twister consists of two endless belts that are placed against each other with a certain crossing angle and are driven, respectively; while the yarn is nipped between the belts, it becomes false twisted (***Figure 1***) [9].

In this study, 83 dtex 36 f and 167 dtex 36 f textured yarns were produced on Muratec 33 H and Barmag FK 6 M-1000 false-twist texturing machines with three different first heater temperatures, at two different texturing speeds and with two different draw ratios. The changes in yarn tenacity, yarn elongation and other yarn properties were investigated during the texturing process of the yarns. Afterwards the changes in yarn parameters were presented in tables, and results were statistically analysed. From the results it was observed that yarn tenacity, crimp contraction, crimp module and crimp stability values increased, while hand shrinkage and yarn elongation values decreased.

Experimental

Materials

In this study, polyester POY rovings of 140 dtex 36 f and 295 dtex 36 f were used to produce textured yarns on Muratec 33 H and Barmag FK6 M-1000 false-twist texturing machines at first heater temperatures of 175 °C, 190 °C and 205 °C Then the resulting yarns were examined by measuring their breaking tenacity, breaking elongation, crimp contraction, crimp module, crimp stability and shrinkage [6]. The outcomes were also assessed at different first heater temperatures, explanations of which are given

Methods

In this study, firstly textured yarns of 83 dtex 36 f and 167 dtex 36 f were produced at a first heater temperature

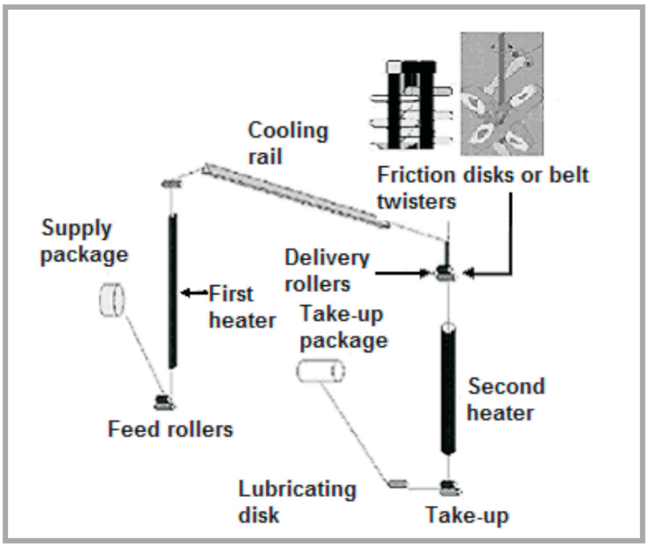

Figure 1. *Schematic illustration of false – twist texturing machine.*

Table 1. *Production properties of PES POY.*

Spin speed, m/min	3200
Draw ratio	1.3
Cross-sectional type	round

of 190 °C, at draw ratios of 1.680 and 1.769 both by the nip and friction twisting techniques using 140 dtex 36 f and 295 dtex 36 f POY (partially oriented yarns). Afterwards yarns of the same count were again produced at 175 °C and 205 °C. A total number of 36 textured yarns were produced each of them made of 36 filaments [6]. Yarn tests were carried out at 20 ± 2 °C and 65 ± 2% RH after the samples reached equilibrium. The same tensile properties of POY and conditions of the texturing machines are given ***Tables 1, 2*** and ***3***.

The linear irregularity of POY

The POY irregularity was tested on an Uster Tester 4. All partially oriented yarns were passed through the tester at 100 m/min.

Yarn breaking tenacity and elongation

In this study, two different counts of textured yarns were produced with the same number of filaments, which are abbreviated as NT1, NT2, NT3, NT4, NT5, NT6, DT1, DT2, DT3, DT4, DT5 and DT6 in the tables and graphs. The yarn count, breaking tenacity and breaking elongation parameters are given in ***Table 4***. The breaking tenacity and elongation of the yarns were determined on a Textechno Statimat ME instrument. The clamping length was 500 mm, the pre-tension 10 cN, and the average time of breaking was 20 s. 300 mm/min was chosen for the testing speed [10].

Crimp contraction, crimp module and crimp stability

A Textechno Texturmat ME instrument was used for testing the crimp contraction, crimp module and crimp stability. While the specimens were subjected to a pre-tensioning load (0.001 cN/dtex), a crimp was developed in textured filament yarns in the form of a skein by treatment with hot air for 10 minutes at 120 °C before testing. Then, all the skeins were conditioned for 30 minutes at 20 ± 2 °C and 65 ± 2% RH. Test results of the yarn are listed in ***Table 5*** (see page 32). The crimp contraction, crimp elasticity and crimp stability percentages of the yarn were estimated as;

- Yarn crimp contraction
  (CC %) = $[(L_g - L_z) / (L_g)] \times 100$
- Yarn crimp module
  (CM %) = $[(L_g - L_f) / (L_g)] \times 100$
- Yarn crimp stability
  (CS %) = $[(L_g - L_b) / (L_g - L_z)] \times 100$

Table 2. *Properties of PES POY.*

Count (linear density)	295 dtex 36 f	140 dtex 36 f
Tenacity, cN/dtex	2.3	2.5
Elongation, %	131.5	119.5
Intermingling (IMG), number/m	7	5
Shrinkage, %	68.2	68.1
Linear irregularity, U_m	0.5	0.8

The crimp contraction is, when the crimp is developed, the reduction in length of a textured filament yarn, which is a result of its crimped structure. It is expressed as the difference ratio between the straightened length L_g and the contracted length L_z to the straightened length L_g .In the range of crimp elasticity, the crimp module characterises the elongation behaviour of the textured yarn. The crimp module is the difference ratio between the straightened length L_g and the length L_f of the yarn under a specific tensile force to the straightened length L_g. The crimp stability is expressed as the crimp

Table 3. *Conditions of the texturing machine; B/Y: ratio of belt speed and yarn speed, D/Y ratio: ratio of disk surface speed and yarn speed, f: filament, temp: temperature, L: length, [1] Polyester yarn passes the first heater in 0.2 seconds. [2]The yarn temperatures are reduced to 70-80 °C on the cooling rail (see cooling rail in Figure 1) length.*

Twist application methods	Yarn count (linear density) dtex 36 f	First[1] heater temp., °C	First heater type	First heater length, m	Second heater temp., °C	Second heater type	Second heater length, m	Cooling[2] rail temp., °C	Cooling rail type	Draw ratio	Belt angles	Texturing speed, m/min	Disk combination C: ceramic, M: metal and Dt: Disk thickness mm
Muratec 33H (Belt-type nip twisters) B/Y ratio: 1.55 Pressure: 2.5 bar	83 dtex 36 f	175, 190, 205	contact	2.5	160	semi-cont.	1.60	70 - 80	plate	1.680	102.5°	775	-
	167 dtex 36 f	175, 190, 205	contact	2.5	160	semi-cont.	1.60	70 - 80	plate	1.769	100°	750	-
Barmag FK6 M-1000 (Disk-type twisters) D/Y ratio: 1.9 Pressure: 2.4 bar	83 dtex 36 f	175, 190, 205	contact	2.5	160	convection	1.46	70 - 80	plate L: 2.1 m	1.680	-	775	1C-5C-1C, Dt:6
	167 dtex 36 f	175, 190, 205	contact	2.5	160	convection	1.46	70 - 80	plate L: 2.1 m	1.769	-	750	1C-5C-1M, Dt:9

Table 4. *Yarn count and tensile parameters.*

Twist application system	Yarn abbreviations	Yarn count dtex 36 f	First heater temperature, °C	Second heater temperature, °C	Breaking tenacity, cN/dtex		Elongation at braek, %	
					Draw ratio		Draw ratio	
					1.680	1.769	1.680	1.769
Murata 33H (Belt–type nip twisters) Belt angle: 102.5°	NT1	90.0	175	160	3.53	-	30.1	-
	NT2	90.0	190	160	3.69	-	29.7	-
	NT3	80.9	205	160	3.93	-	29.4	-
Murata 33H (Belt–type nip twisters) Belt angle: 100°	NT4	170.5	175	160	-	3.47	-	26.1
	NT5	170.5	190	160	-	3.56	-	26.0
	NT6	170.6	205	160	-	3.73	-	25.9
Barmag FK6M–1000 (Disk-type twisters) 1C-5C-1M	DT1	80.9	175	160	3.23	-	18.2	-
	DT2	80.9	190	160	3.29	-	17.8	-
	DT3	90.0	205	160	3.31	-	17.6	-
Barmag FK6M–1000 (Disk-type twisters) 1C-5C-1M	DT4	170.8	175	160	-	3.33	-	19.1
	DT5	170.7	190	160	-	3.39	-	18.9
	DT6	170.8	205	160	-	3.54	-	18.8

Table 5. *Parameters of yarn crimp contraction, module, stability and shrinkage.*

Twist application system	Yarn abbrevia-tions	Crimp contraction CC, %		Crimp module CM, %		Crimp stability CS, %		Shrinkage, %	
		Draw ratio		Draw ratio		Draw ratio		Draw ratio	
		1.680	1.769	1.680	1.769	1.680	1.769	1.680	1.769
Murata 33H (Belt–type nip twisters) Belt angle: 102.5°	NT1	16.7	-	10.6	-	80.7	-	5.4	-
	NT2	18.3	-	12.3	-	83.0	-	4.7	-
	NT3	22.7	-	16.0	-	83.7	-	4.5	-
Murata 33H (Belt–type nip twisters) Belt angle: 100°	NT4	-	17.3	-	10.6	-	78.0	-	7.6
	NT5	-	21.3	-	13.7	-	80.3	-	6.4
	NT6	-	25.3	-	14.3	-	82.3	-	6.0
Barmag FK6M–1000 (Disk-type twisters) 1C-5C-1M	DT1	18.3	-	13.3	-	82.3	-	6.4	-
	DT2	22.3	-	15.3	-	83.7	-	5.5	-
	DT3	27.0	-	18.0	-	85.0	-	4.7	-
Barmag FK6M–1000 (Disk-type twisters) 1C-5C-1M	DT4	-	18.0	-	12.0	-	82.0	-	8.5
	DT5	-	23.7	-	15.7	-	84.0	-	7.4
	DT6	-	29.3	-	19.0	-	85.0	-	6.6

contraction ratio, which is calculated on the basis of L_b following the application of a tensile force, [9, 11].

Yarn shrinkage in boiling water

The Textechno Texturmat ME instrument was used for testing the shrinkage of yarns in boiling water. By winding fourteen turns (for 83 dtex 36 f) and eight turns (for 167 dtex 36 f) of the yarn on a wrap reel at a tension of 0.2 g/denier, hanks were prepared for measuring residual yarn shrinkage. The length of the skeins L_0 in mm was measured at a tension of 500 g. Then the hanks were placed in a boiling water bath for 10 minutes, then dried in a free state at 95 ± 2 °C. The hanks were conditioned for 120 minutes at 20 ± 2 °C and 65 ± 2% RH after drying. The skeins length L_f in mm was again measured under the same tension (500 g) and the yarn shrinkage percent was estimated as [12].

$$\text{Yarn shrinkage, \%} = [(L_0 - L_f) / (L_0)] \times 100$$

Test results of the yarns are given in ***Table 5***.

IMG counting test (Intermingling)

An Enka tecnica Itemat Lab TSI instrument was used for the img counting test. A pre-tension of 10 cN and an input cylinder speed of 100 m/min were chosen for testing.

Microscopy studies

In this study, a Projectina light microscope was used. The micrographs of cross-sections of the textured yarns were observed. The reason for choosing 190 °C only for the heaters on the nip and the friction twisting system was to determine cross-sectional changes at this temperature

Results and discussion

Effects of heater temperature variations on yarn tenacity

The experimental results clearly show that the first heater's temperature has an insignificant influence on the yarn count, tenacity and elongation. However, the tenacity and elongation values of yarns produced using the belt type nip-twister system are higher than those of yarns produced with the disk-type twister system. Test results are shown in ***Figure 2***.

Effects of heater temperature variations on the crimp contraction, crimp module and crimp stability

According to the parameters studied, the best relationship was found among the heater temperatures – crimp contraction, crimp elasticity and crimp stability. It is observed that in general the crimp contraction, crimp module and crimp stability increases as the first heater temperature increases. ***Figure 3*** present that among the NT1, NT2, NT3 coded textured yarns, the DT1, DT2, DT3 coded yarns have the lowest crimp contraction, crimp module and crimp stability values. It is also suggested that, due to

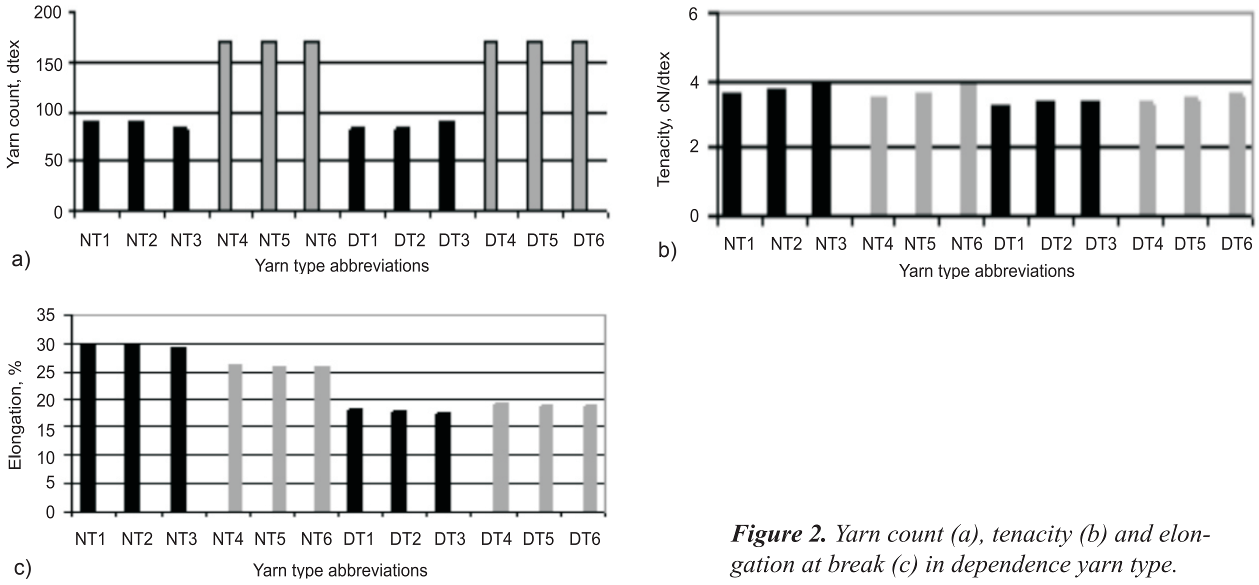

Figure 2. *Yarn count (a), tenacity (b) and elongation at break (c) in dependence yarn type.*

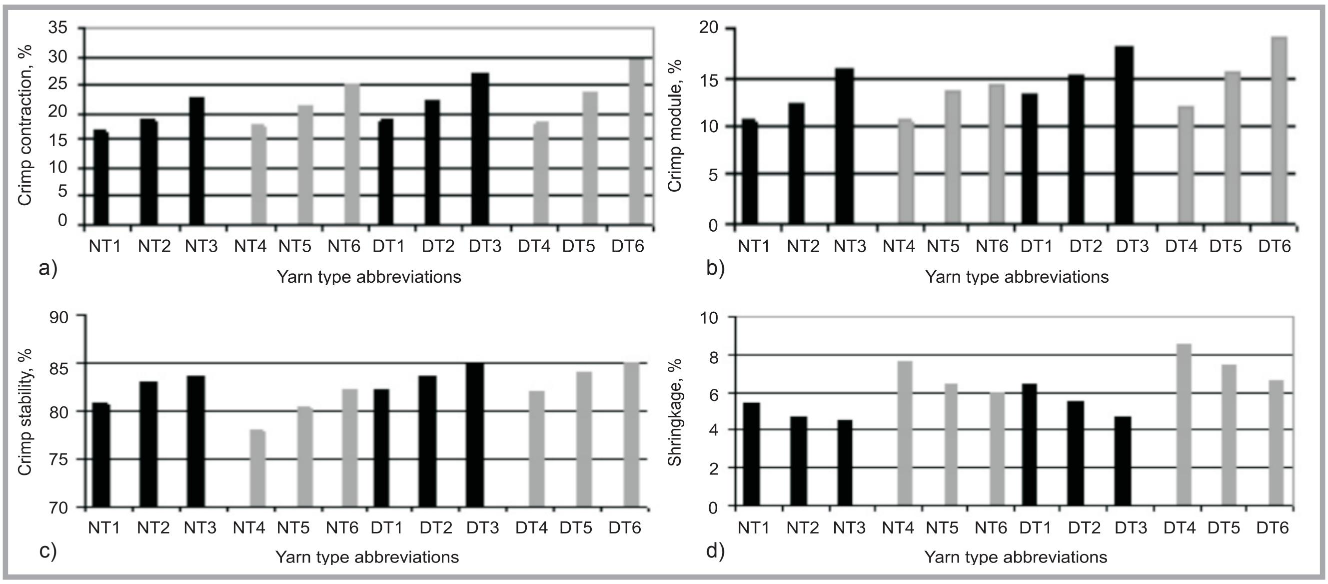

Figure 3. *Crimp contraction (a), crimp module (b), crimp stability (c) and shrinkage (d) in dependence yarn types.*

the rise in the heater's temperature, the amorphous portion in the fibre structure decreases because of the formation of crystallites. What is more, the orientation in the amorphous regions decreases [13], while their specific volume increases. Due to the heater temperature, the yarn-crimp contraction increases, as is shown in ***Figure 3.a***. The phenomenon could be explained in the following way: two different types of deformation imposed on the twisted continuous filament yarns. One is a twist along the length of the filaments, and the other involves bending some filaments, thus they follow a helical path about the yarn axis. Besides this, filaments in the twisted yarn migrate from the yarn surface to the yarn centre and back again in a helix. Therefore, the length of the filaments is not deformed evenly. The filament parts which stay on the yarn axis will be relatively straight and will be deformed in a purely torsional way. As well as a torsional deformation, on the yarn surface there will exist a helical deformation. The distance of the helix radiuses to the yarn axis will be equal [9].

Table 6. *Comparison of student-t test analyses between Barmag FK 6 M -1000 (B) and Muratec 33 H (M) false-twist texturing machines for first heater temperature - 190 °C (standard value); s - significant, ns - not significant; 190 °C, references value (for standard production) [6].*

Parameters	Yarn count dtex 36 f		Tenacity, cN/dtex		Elongation, %		Crimp contraction, CC %		Crimp module, CM %		Crimp stability, CS %		Shrinkage, %	
Confidence limits	95%	99%	95%	99%	95%	99%	95%	99%	95%	99%	95%	99%	95%	99%
83 dtex 36 f	ns	ns	s	s	s	s	s	s	s	s	ns	ns	s	s
167 dtex 36 f	s	s	s	ns	s	s	s	s	s	s	s	s	s	s

Table 7. *Student-t test analyses of Barmag FK 6 M -1000 (B) and Muratec 33 H (M) false-twist texturing machines; s - significant, ns - not significant; 190 °C, references value (for standard production) [6].*

Parameters	**Yarn count, dtex**								**Tenacity, cN/dtex**								**Elongation, %**							
First heater temperature, °C	**At 190 °C and 175 °C**				**At 190 °C and 205 °C**				**At 190 °C and 175 °C**				**At 190 °C and 205 °C**				**At 190 °C and 175 °C**				**At 190 °C and 205 °C**			
Confidence limits	**95%**		**99%**		**95%**		**99%**		**95%**		**99%**		**95%**		**99%**		**95%**		**99%**		**95%**		**99%**	
Within the texturing machines	**B**	**M**	**B**	**M**	**B**	**M**	**B**	**M**	**B**	**M**	**B**	**M**	**B**	**M**	**B**	**M**	**B**	**M**	**B**	**M**	**B**	**M**	**B**	**M**
83 dtex 36 f	ns	ns	ns	ns	ns	ns	ns	ns	ns	s	ns	s	ns	s	ns	s	ns	s	ns	s	ns	s	ns	ns
167 dtex 36 f	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	s	s	ns	s	ns	ns	ns	s	ns	s	ns	s

Table 8. *Student-t test analyses of Barmag FK 6 M -1000 (B) and Muratec 33 H (M) false-twist texturing machines; s - significant, ns - not significant; 190 °C, references value (for standard production) [6].*

Parameters	**Crimp contraction CC, %**								**Crimp module CM, %**								**Crimp stability CS, %**								**Shrinkage, %**							
First heater temperature, °C	**At 190 °C and 175 °C**				**At 190 °C and 205 °C**				**At 190 °C and 175 °C**				**At 190 °C and 205 °C**				**At 190 °C and 175 °C**				**At 190 °C and 205 °C**				**At 190 °C and 175 °C**				**At 190 °C and 205 °C**			
Confidence limits	**95%**		**99%**		**95%**		**95%**		**99%**		**95%**		**95%**		**99%**		**95%**		**99%**		**95%**		**99%**		**95%**		**99%**		**95%**		**99%**	
Within the texturing machines	**B**	**M**	**B**	**M**	**B**	**M**	**B**	**M**	**B**	**M**	**B**	**M**	**B**	**M**	**B**	**M**	**B**	**M**	**B**	**M**	**B**	**M**	**B**	**M**	**B**	**M**	**B**	**M**	**B**	**M**	**B**	**M**
83 dtex 36 f	s	s	s	ns	s	s	S	s	s	s	s	ns	s	s	s	s	s	s	ns	s	s	ns	s	ns	s	s	s	s	s	ns	s	ns
167 dtex 36 f	s	s	s	s	s	s	S	s	s	ns	s	s	s	s	s	ns	s	s	s	s	ns	s	ns	s	s	s	s	s	s	s	s	s

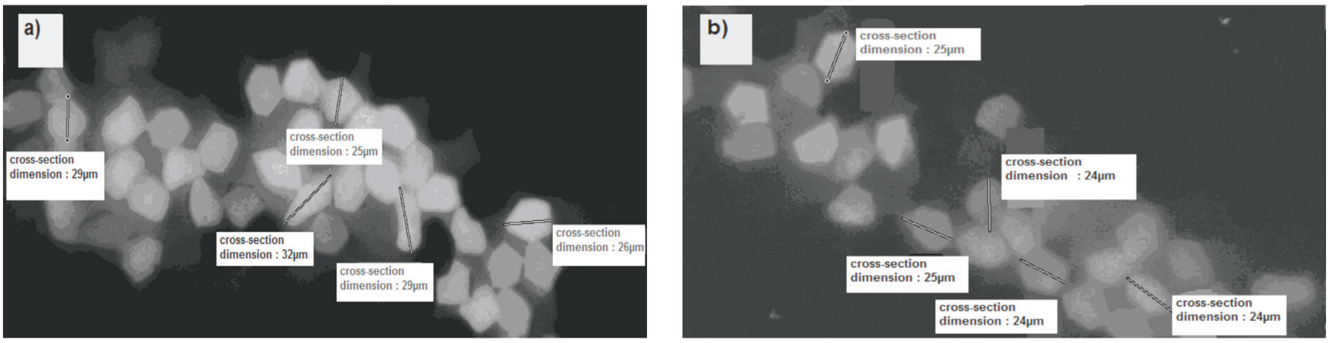

Figure 4. *Cross-sectional type of textured yarns; a) 167 dtex 36 f (Disk-type twisters), b) 167 dtex 36 f (Belt-type nip twisters).*

Figure 3.c shows increases in the crimp stability values of textured yarns due to the increase in the draw ratio.

Effects of boiling water on shrinkage

The experimental results show that shrinkage values decrease as the temperature of the first heater zone increases. In this study, shrinkage was greater for the disk-type twister system than that using the belt-type nip twister system. The results are confirmed by ***Figure 3.d*** (see page 33). This is caused by the dissolving of the polymers during the contact of hot water with the textured yarns, and then, according to this process, the polymer molecules become distant.

Cross-sectional observation

As mentioned earlier, variations in the circular shape could be best observed on POY filament images and therefore only the cross sections of 167 dtex 36 f textured yarns were studied using the Projectina light microscope tocorrelate a relationship with the texturing techniques. ***Figure 4.a-b*** shows that the filament cross-section within the textured yarn and dimensions show a deviation from the round cross-section of the POY, in other words a deformation can be observed in the yarn. Yarn deformation in the disk-type twisting unit is higher than that of the belt-type nip twisting unit because the contact between the yarns and rotating surface of the twisters is a frictional one. This frictional contact increases on the disk-type twisting unit with the number of twisting elements and, therefore, yarn deformation in the cross-section is greater in the disk-type twisting unit than in the belt-type nip twisting unit. Hence, the elliptical form of filaments within the textured yarn of the disk-type twisting unit will have more of a glitter effect than that of the belt-type nip twisting. The photographs are shown in ***Figure 4***.

Statistical Analysis

The results of the textured yarns produced were then, with SPSS 11.5 for Windows, examined using student-t test analyses of the effect of the yarn count, breaking tenacity, breaking elongation, crimp contraction, crimp module and crimp stability of the yarns. The outcomes are shown in ***Tables 6, 7*** and ***8***.

Conclusions

The experimental results clearly show that the first heater temperature has a significant influence on different parameters of textured yarns. It is observed that the crimp contraction, crimp module and crimp stability values of textured yarns increases as the temperature of the first heater increases, whereas shrinkage values decrease. Generally, it is observed that the tenacity increases with an increase in the first heater temperature . Because of the rise in temperature, crystallites increase within the yarn, which becomes more orientated. On the other hand, elongation decreases as the temperature increases, which is because of the dryness of polyester yarn, due to an increase in heat, and has no more ability to elongate. It is observed that as the temperature of the first heater increases, the yarn crimp contraction, crimp module and crimp stability increase, while the shrinkage values of textured yarns decrease. The tenacity and elongation of belt-type nip twisters yarns are higher than those of disk-type twisters yarns. However, the values of CC%, CM%, CS% and shrinkage are higher for disk-type twister systems than those for the belt-type nip twister system. Based on the result of tests caried out it can be stated that considering the tenasity and elongation at break, the use of Muratec (Belt-type nip twister) machines is advantageous and can be recommended, whereas taken into account the CC %, CM %, CS %, and shrinkage values the Barmag Disk-type twisters are advantageous and can be recommended.

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