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# The Effects of Heat-Setting on the Properties of Polyester/Viscose Blended Yarns

## Abstract

30 tex and 20 tex yarn bobbins consisting of 67% PES - 33% viscose were subjected to heat-setting at 90 °C & 110 °C, and under a pressure of 630 mmHg in order to investigate the effects of heat-setting conditions on the properties of twisted yarns. Both heat-set and unset yarns were dyed. The tensile strength properties (tenacity and elongation at break) of each yarns were measured before heat-setting, after heat-setting and after dyeing. The inner, middle and outer sections of the yarn bobbins were measured with a spectrophotometer to find differences in color. As a result, heat-setting and dyeing processes were found to be effective in the tenacity and elasticity of yarns.

**Key words:** heat setting, twist setting, twisting, temperature, polyester (PES), viscose, tenacity, work of rupture.

## Introduction

Moisture in the atmosphere has a great impact on the physical properties of textile yarns and fibres. Relative humidity and temperature decides the amount of moisture in textile materials. Exposing yarn to high moisture during production generally yields negative results, as well as being undesirable for technical processing. On the other hand, a high degree of moisture adequately exposed to yarn improves its physical properties and enables the standard humidity of yarn to be reached. Yarns with lower moisture content than the standard value result in monetary loss in sale. Therefore, conditioning and heat-set is to provide an economical device for supplying the necessary moisture in a short time [1].

Each step in the manufacturing process, such as twisting, spinning, weaving, knitting etc., causes tension in fiber and yarns. Yarns tend to snarl in order to relax themselves and get rid of this tension. Tension and snarling are likely to lead to problems in the following manufacturing processes [2]. The purposes of conditioning and heat-setting (twist-setting) are to relax yarns, to prevent them from snarling, to enable them to be worked efficiently in the following processes and to fix yarn-twisting. Today, besides conventional system, other systems which can eliminate the downsides of the con-

ventional systems and operate under vacuum with saturated steam are used in conditioning and heat-setting. With the aid of steaming in these systems, yarns are conditioned or heat-set with saturated steam under vacuum [3].

The Heat-setting process, a treatment with steam under vacuum, improves efficiency and quality in weaving and knitting plants by reducing yarn tension, softening yarns, moisturising them homogenously, eliminating electrostatic effects and reducing fly and dust [4].

Unset yarns squeeze bobbins during dyeing with a pressure from the outside section towards the inside section, as a consequence of which bobbins get deformed. The higher the temperature of heat setting is the less the bobbins get deformed [5]. Improper heat setting is considered to be a factor which increases skewness in weaving, a situation in which warp and weft yarns cannot be tied together with a right angle, although they are straight [6], and it increases diagonal run in knitwear [7].

Since saturated steam used in heat-setting provides man-made fiber with good thermal conductivity, steaming processes under vacuum make it possible for bobbins to shrink homogenously in every section. The yarns of such a bobbin are dyed homogenously without causing stripe effects or colour differences between the inner and outer sections of the bobbin [5].

The blend consisting of PES and viscose is used widely in the textile industry. This type of blend benefits from the high strength of PET fiber and from the natu-

ral qualities, brightness and comfortable wearing property of viscose fiber. In addition, viscose fiber has a high elasticity when compared with cotton fibres. When used together with PES fibers, viscose fiber gives a more harmonious blend as regards elongation at break [8].

Since the tenacity of the wet cotton yarn is higher than that of dry ones, cotton yarns have a higher tenacity under high moisture [9]. Studies concerning heat-setting are limited in literature and nearly all of these studies are related to cotton because of its positive reactions against moisture. For this reason, the current study which has been performed on the heat-setting of yarns consisting of PES/viscose is expected to make a contribution to textile literature.

## Experimental

In this study, 30 tex and 20 tex carded yarns consisting of 67% PES and 33% viscose were used - the linear density and staple length of PES fibres were 1,6 dtex and 38 mm respectively, and the linear density and staple length of viscose fibres were 1.7 dtex and 39 mm, respectively. Yarns were wound onto bobbins with a Schlafhorst Autoconer 238 machine. These yarns were subjected to heat-setting under 630 mmHg pressure and at temperatures of 90 °C and 110 °C with a machine working in compliance with the direct vacuum steaming system of the Welker Company. The cycles below were followed:

- Pre-heating : 45 °C
- Vacuum : 630 mmHg
- Heating : 90 °C (10 min),  
110 °C (20 min)
- Vacuum balance : 500 mmHg

Yarn bobbins were dyed in a Mini-HT laboratory-type bobbin dyeing machine produced by Dilmenler Machinery Industry. The dyeing process was carried out according to the conventional two-step dyeing method. PES fibres were first dyed with disperse dyes at 130 °C, and they were then subjected to reductive clearing at 75 °C. In the second step, viscose fibres in the blend were dyed with reactive dyes at 80 °C, and then after-treatments (washings) for reactive dyeing were performed. Finally, the bobbins were dried on a radio frequency drier.

Yarn count, twist and tenacity measurements of the yarns were taken before and after heat-setting and after dyeing. Before the measurements were taken, all the yarns were kept under standard conditions. (at 20 °C ± 2 °C and 65% ± 2% relative humidity) Yarn count measurements were carried out in compliance with ISO 2060. Yarn twist measurements were taken in accordance with ISO 2061 on a James H. Heal twisting meter. Tenacity measurement of all the yarns was performed in accordance with ISO 2062 on Uster Tensorapid 3.

A spectrophotometer was used to find out whether inner, middle and outer sections of the bobbins had any differences in colour. Measurement was made with an observational angle of 10° and with D65 illuminant, using the CMC 2:1 equation [10]. To investigate the effects of heat-setting and dyeing properties on the yarn tenacity and elongation at break, t tests were performed at 5% (0.05) and 10% (0.1) level of significance.

## Results and discussion

The effects of heat-setting at 90 °C and 110 °C, and of the following dyeing process on the tenacity and elasticity properties of 20 tex and 30 tex yarns are given in Table 1.

**Table 1.** Changes in yarn tensile strength properties after heat-setting and dyeing process.

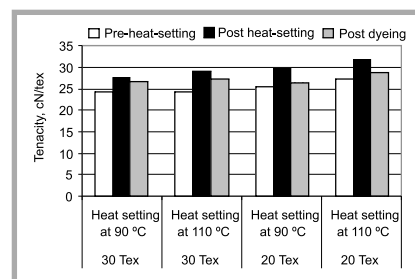
Parameters		Yarn properties							
		After heat-setting (Changes as %)				After dyeing (Changes as %)			
		30 tex		20 tex		30 tex		20 tex	
		90 °C	110 °C	90 °C	110 °C	90 °C	110 °C	90 °C	110 °C
Tenacity, cN/tex	X	15.0	19.9	16.9	15.7	-4.4	-4.8	-11.3	-9.5
	CV %	-14.3	-15.8	13.6	12.3	9.3	16.7	-6.9	-5.5
Elongation at break, %	X	8.9	8.7	8.7	5.4	-3.0	-5.7	-6.0	-3.7
	CV %	-20.7	-25.5	11.8	8.8	3.2	11.4	-7.7	-6.5
Work of rupture, cN	X	15.0	12.4	13.6	12.9	-4.3	-5.5	-4.8	-4.5
	CV %	-13.9	-14.1	18.7	16.9	4.3	8.9	-8.8	-8.0

As can be seen in Figure 1, the heat-set process brought about a considerable improvement in the tenacity of yarn. The rate of increase varied between 15% and 19.9%, depending on the yarn count and temperature of the process (Table 1). The tenacity of yarns, subjected to heat-set showed a decrease of 4.4 – 11.3% after the dyeing process; however, their yarn tenacity was still higher than the tenacity of unset yarns.

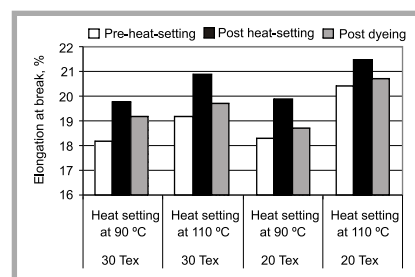
In textile material science, a classic and fundamental problem is the connection between the tensile properties of fibers and yarns. A yarn is a complex system made by a fibrous structure, i.e., a bundle consisting of a given number of single fibers; this bundle, after twisting, becomes a yarn. [11] The improvements observed in the tenacity of PES/viscose yarns after heat-setting can be attributed to the effects of this thermal process on PES fibers, which constituted 67% of the blend. The physical and chemical properties of fibers such as dye absorption, strength etc. are close related to the structure of non-crystalline sections. Due to the temperature of the heat-setting applied, the rate of crystalline sections, the average distance between crystalline centers and the number of bonds between macromolecules in fibres increased, as a consequence of which the degree of orientation in fibres increased, causing an improvement in the yarn tenacity [12].

The slight decrease in the yarn tenacity after the dyeing process was something expected. This fall arose from the fact that especially viscose fibers and partly PES fibres get slightly damaged during reductive washing with NaOH. The t-tests we performed show that heat-setting and dyeing process affect the tenacity of yarns.

The effects of heat-setting at 90 °C and 110 °C and of dyeing on the elongation % of yarn are given in Figure 2.



**Figure 1.** The effect of the heat-setting process on tenacity of yarn.



**Figure 2.** The effect of the heat-setting process on elongation at break of yarn.

The heat-setting processes increased the values of yarn elongation within the range of 5.4% and 8.7%. Since cellulose macromolecules, which form regenerated cellulose fibres, are short, the attraction between these macromolecules was not very strong. Therefore, when a force parallel to the fiber axis was applied to the regenerated cellulose fibers, bonds between the macromolecules weakened, causing the fibers to break. Breakages of wet regenerated fibres took place more easily because of the swelling and sliding effects of water [12, 13]. Consequently, the elongation values of the wet regenerated cellulose fibers were noticeably higher than those of dry ones. Generally, the tenacity values decreased, but elongation values (%) increased, while these fibres were wet [9 - 13]. The increase observed after the application of heat-setting in the elongation (%) values of the yarn fell a little after the dyeing process. However, the elongation values (%) obtained after the dyeing process are still higher than those of the unset yarns. The heat-setting process improved both the tenacity and elongation (%) of these yarns. The t tests performed indicate that heat-setting and dyeing processes affected the elongation (%) of the yarns.

After heat-setting, the work of rupture values of the yarns increase by 12 - 15%, and, as a result of this, these yarns were expected to show a higher performance in the following process. These values

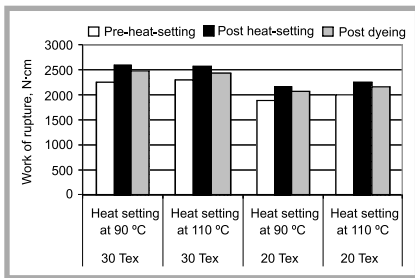


Figure 3. The effect of the heat-setting process on work of rupture of yarn.

decreased by 4 - 6% after the dyeing process (Figure 3). Increases obtained after heat-setting at 110 °C were lower than those obtained after heat setting at 90 °C. The increase observed in the work rupture value of the yarns decreased a little because of reductive washing in the dyeing process but this value was still higher than that of the unset yarns.

Work of rupture can be considered to be the working capacity of the yarn. Working capacity is the most important value which showed the yarn performance in the following processes. The work capacity of a yarn corresponds to the area below the stress-strain curve and expresses the behavior of the yarn during subsequent treatment. Therefore, it is suggested that increases in the tenacity and elasticity of the yarn should not be assessed individually, but together with its work capacity [3].

The CV % values which belong to tenacity, elongation and work of rupture of 30 tex and 20 tex yarns are given in Table 1. While 30 tex yarn showed decreases in tenacity, elongation at break (%) and work of rupture, CV % values after heat-setting at 90 °C and 110 °C, 20 tex yarns showed increases in these CV% values. The tenacity of the yarn decreased and tenacity CV% values increased as the yarn got thinner. Tenacity CV% values of 30 tex yarn were increased after dyeing, however they were lower than those of the unset yarns. The tenacity CV% values of 20 tex yarn were decreased after the dyeing process, but they were high when compared with the values obtained before heat-setting.

Twisted yarns tend to untwist. When twisted yarn tension is slackened (which occurs at their unwinding from packages), the yarns usually get coupled as loops and twisted in reverse direction forming snarls which lead to breakages during further yarn processing. When wo-

ven into fabrics, snarlings cause faulty and lower grade fabrics. Therefore, yarns needs heat setting in order to prevent untwisting and snarling [14].

Twisted yarns which were subjected to the setting processes underwent some changes in their interior structure, as a result of which resilient and elastic deformations were able to take place and the macromolecules of the yarn able to change from a curved to a straight shape. At the same time, the monofilaments could have become somewhat elongated and come to occupy a position in which they would follow a helical path without stresses, as the elastic forces would be suppressed.

The straightening of macromolecules led to yarn elongation, but elastic forces tended to shorten them. As a result, there was the possibility that yarn length might remain unchanged, but due to the suppression of elastic forces, the stresses in yarns could have almost disappeared [14].

Viscose yarns featured high hygroscopicity, good adsorbency, and swelling. Swelling of viscose yarns was accompanied by an increase in yarn cross section by 25 - 65% and an insignificant increase by 3-5% in fibre length [9, 14]. The cause of this change is that cellulose macromolecules which form viscose fibres shorten and the rate of the amorphous part of fibre is high [13]. The

weakening of intermolecular ties facilitate an easier shift of molecules. In this case, the moisture acted as a lubricant. Heat intensified the motion of molecules, reduced the forces of intermolecular effect and their shift became easier. As twisted yarns were heated in swelled state (i.e. stressed state) the macromolecule shift occurred quicker.

If twisted yarn swelled in a free state, its cross section increased and the orientation of yarns remained unchanged, a shrinkage of yarn could be observed with a certain reduction in its strength. The yarns were stretched in a swelled state to increase their strength [14].

The setting of twist in case of polyester yarns was accomplished only by heating but without swelling of yarns. By moistening the twisted yarns, having a stabilised twist in the free state, the reverse process of deformation relaxation took place which imparted the capacity of spontaneous untwisting to the yarn [14].

Changes in the yarn's linear density and twist as a result of heat-setting are given in Table 2.

As it can be seen in Table 2 slight changes took place in the twisting values of the yarn after heat-setting. This process fixed yarn twisting and eliminated yarn liveliness, thus preventing snarling. Thus, we were able to enhance the performance

Table 2. Linear density and twist measurements of 30 tex and 20 tex PES/viscose yarns after heat-setting.

Parameters		Yarn properties			
		30 tex		20 tex	
		Heat-set at 90 °C	Heat-set at 110 °C	Heat-set at 90 °C	Heat-set at 110 °C
Pre-heat setting	tex	29.4	29.4	19.6	19.6
	t.p.m.	963	959	960	964
Post-heatsetting	tex	30.1	30.4	20.0	20.2
	t.p.m.	940	930	934	935
Changes as %	tex	2.4	3.4	2.1	3.1
	t.p.m.	-2.4	-3.0	-2.7	-3.0
Post dyeing	tex	31.2	31.6	20.6	20.8
	t.p.m.	919	915	920	922
Changes as %	tex	3.7	3.9	3.0	3.0
	t.p.m.	-2.2	-1.6	-1.5	-1.4

Table 3. The results of color measurements made on 30 Tex and 20 Tex PES/Viscose yarns.

Yarn count	Unset, ΔE			Heat-set at 90 °C, ΔE			Heat-set at 110 °C, ΔE		
	inner-outer	middle-outer	middle-inner	inner-outer	middle-outer	middle-inner	inner-outer	middle-outer	middle-inner
30 tex	0.18	0.19	0.18	0.14	0.15	0.17	0.19	0.19	0.17
20 tex	0.16	0.18	0.18	0.16	0.16	0.17	0.15	0.20	0.21

of the yarn in the following production processes by means of twist setting.

The heat-setting of man-made yarns under vacuum with saturated steam, besides reducing the residual shrinkage, resulted in no dye variations in the fabric, no tube buckling and no quality changes between the inner and outer sections of the bobbin [5]. The measurements performed, as given in Table 3, show that no considerable differences in colour among the inner, middle and outer sections of the bobbins existed.

The spectrophotometer gave a PASS value in each of the measurements, indicating that the bobbins did not have an unacceptable difference in color among the inner, middle and outer sections. The color difference value which came out after the dyeing of the yarns subjected to heat-setting at 90 °C was lower than the values which came out when the yarns were subjected to heat-setting at 110 °C, and those not subjected to heat-setting and dyed. However, the values of colour differences which exist among the inner, middle and outer sections of the fixed and non-fixed bobbins are very close to each other and, therefore, they can be considered insignificant.

## Conclusions

In this study, tenacity, elongation at break (in per cent), and work of rupture of 30 tex and 20 tex yarns were found to be enhanced due to heat-setting. The tenacity and elongation at break values of the yarns decreased after dyeing; however, these values are still high when compared with those of the pre-heat setting.

The increase of temperature from 90 °C to 110 °C caused a decrease in the strength values of the yarns. For this reason, heat-setting at 90 °C can be considered to be sufficient to enhance the strength properties of PES/viscose yarns – consisting of 67% PES and 33% viscose.

After heat-setting, slight changes were observed in the twist values of the yarn. Yarn twist was fixed via heat-setting, thus preventing yarn snarling. As a result of these, the yarn is likely to show better performance in the following production steps. Besides, colour differences among the inner, middle and outer sections of bobbins were found to be insignificant after the measurements.

For further studies it will be useful to investigate yarn liveliness and the relationship between yarn liveliness and heat-setting.



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## References

1. Ozdemir O., Şardağ S., *Yarn Conditioning and New Methods, Textile&Technique, Turkey, June 2004, pp. 248-260.*
2. [www.welker.de/html/englisch/heatsetting.html](http://www.welker.de/html/englisch/heatsetting.html), 2004.
3. Toggweiler P., Gleich S., Wanger F., *Improved Quality With The Contexxor Conditioned Yarn, Meiland English No. 9 (1995) pp. 154-155.*
4. *Xorella catalogue, 2003.*
5. *Xorella Contexxor, The Innovative Conditioning and Steming System, 2003 catalogue.*
6. Yazdi A. A., *Woven Fabric Skewness and Yarn Twist, Proceedings of 2nd International Istanbul Textile Congress, pp.1-7. [CD-ROM] April, 2004.*
7. Artzt P., *The Influence of Different Spinning Processes on The Structure and Properties of Yarns, Proceedings of 2nd International Istanbul Textile Congress, pp.1-8. [CD-ROM] April, 2004.*
8. Enhos S.A., *An Investigation About the Factors Affecting the Strength Properties of Blended Yarns, Master thesis, University of Uludag, Bursa 2001., pp.73.*
9. Adanur S., *Wellington Sears Handbook of Industrial Textiles, Technomic Publishing Co. Inc. Lancaster.-Basel., 1995, pp. 593-594.*
10. Kara I., *An Investigation About the Effects of the Twist Setting Conditions, Final Year Project, University of Uludag, Bursa, 2002.*
11. Ahumada O., Cocca M., Gentile G., Martuscelli E., D'orazio L., *Uniaxial Tensile Properties of Yarns: Effect of Moisture Level on the Shape of Stress-Strain Curves, Textile Research Journal 174 (11) 2004, 1001-1006.*
12. Tarakcıoğlu I., *Textile Finishing and Machines –Production and Finishing of Polyester Fibres; Aracılar Publishing Co. Izmir, 1986, pp. 414-416.*
13. Morton W.E., Hearle J.W.S., *Physical Properties of Textile Fibres; Heineman, 1975, pp.290.*
14. Usenko V., *Processing of Man-made Fibres, 1979, Moscow, pp. 178-189.*

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