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Influence of Spinning Parameters on Polyester/Polyester and Polyester/Viscose DREF-3 Yarns Tensile Properties

Abstract
In this study, polyester staple fiber core/polyester sheath and polyester staple fiber core/viscose sheath DREF-3 core yarns were produced using different spinning parameters in order to understand their effect on yarn tensile properties. Yarns of 65 tex linear density were produced using three different core/sheath ratio levels × four different spinning drum speeds × three different air suction pressures at a constant opening roller speed of 4200 r.p.m and constant production speed of 100 m/min. The tensile properties of the yarns were tested, and the results obtained were evaluated by regression analysis using an SPSS statistical program at a 0.05 significance level. The effect of the core/sheath ratio on yarn tenacity and yarn elongation at break properties are significant. With an increase in the core/sheath ratio, yarn tenacity decreases due to insufficient wrapper fibers in the yarn. An increase in the core ratio decreases yarn elongation because sheath fibers are in a buckling form, helically wound in the yarn structure, in which there is more chance for yarn extension. An increase in the spinning drum speed damages fiber in the sheath and increases the number of hooks at the end of fibers, as a result of which the core yarn tenacity decreases. However, an increase in the spinning drum speed does not have a significant effect on the yarn elongation at elongation at breakratio. At a higher air suction pressure, Polyester/viscose yarn tenacity and the elongation at break ratio increase. On the other hand, the air suction pressure does not have a significant effect on the tensile properties of polyester/polyester yarns. It appears that the effect of air suction pressure changes according to the physical properties of fiber in the sheath. The air suction pressure may only have a significant effect on yarn tensile properties when short and coarse fibers are used in the sheath.

Key words: *DREF-3 friction spinning, core yarn, spinning parameters, yarn tensile properties.*

Introduction

Core spinning is a technique used to produce core sheath composite yarn. The main aim of using core yarns is to take advantage of the different properties of components. Core yarns have a structure consisting of two components - one is the center axis or core of the yarn and the other is the covering. The core can be a continuous filament or staple fibre, while staple fibre is used for the outer covering or sheath of the yarn. The core of the yarn improves yarn tenacity and also permits the use of lower twist levels, while the sheath provides the staple fibre yarn appearance and physical properties of the surface [1, 2].

The DREF-3 friction spinning system (***Figure 1***) has two drafting units: The first unit provides core fibres along the yam axis, and the second unit supplies wrapper fibres at right angles to the spinning drum. In the second unit, fibres are fed in sliver form and opened by a carding roller. The fibres opened are held on the surface of the perforated spinning drum by air suction. The perforated spinning drums move in opposite directions in contact with the yarn surface and create torque, thus sheath fibres wrap around the core, and the core yarn structure is formed. The core parts of the yarn are almost parallel to each other and have an untwisted form along the yarn axis. Only wrapper fibres hold the core tightly [3 - 5].

The spinning drum speed and air suction pressure have an important role in friction spinning. The spinning drum alters the torque of wrapper fibres, while the air suction pressure transports fibres in the duct of the second unit to the yarn formation zone and also holds fibres on the surface of the perforated spinning drum [6].

The main aim of this study was to determine the effect of the spinning drum

Table 1. *Yarn properties.*

Yarn linear density	Core material	Sheath material	Core/sheath ratio	Spinning drum speed, r.p.m.	Air suction pressure, Pa
65 tex	Polyester sliver	Viscose sliver	40/60, 50/50, 60/40	2500, 3000, 3500, 4000	2000, 2800, 3700
	Polyester sliver	Polyester sliver	50/50, 60/40, 70/30	2500, 3000, 3500, 4000	1300, 1400, 1500

speed and air suction pressure on DREF-3 yarn tensile properties produced at three different core/sheath ratios.

Experimental

In this study, polyester staple fibre core/polyester sheath and polyester staple fibre core/viscose sheath yarns were produced using different spinning parameters in order to understand their effect on DREF-3 yarn tensile properties. Friction spun 65 tex yarns were produced at three different core/sheath ratios × four different spinning drum speeds × three different air suction pressures, at a constant opening roller speed of 4200 r.p.m and constant production speed of 100 m/min. An experimental table of the study is given in ***Table 1***.

Table 2. Strength properties of the yarns

Spinning drum, r.p.m.	Average values of core yarn strengths, cN/tex							
	Polyester/polyester				Polyester/viscose			
	Core/sheath ratio	Air auction, Pa			Core/sheath ratio	Air suction, Pa		
		1300	1400	1500		2000	2800	3700
2500	50/50	19.78	23.30	22.41	40/60	15.72	15.61	15.50
	60/40	21.13	21.83	19.38	50/50	16.04	17.21	17.51
	70/30	19.72	17.40	19.12	60/40	12.76	13.72	14.20
3000	50/50	20.25	23.96	22.52	40/60	14.90	15.38	15.14
	60/40	20.93	19.60	20.37	50/50	15.26	17.70	18.49
	70/30	15.82	16.57	20.25	60/40	14.31	14.52	14.50
3500	50/50	20.60	19.39	19.00	40/60	13.38	17.85	17.54
	60/40	20.05	19.85	20.87	50/50	14.20	18.41	18.67
	70/30	15.73	10.91	15.37	60/40	12.61	13.86	13.69
4000	50/50	15.68	19.19	17.40	40/60	12.43	12.63	14.89
	60/40	18.07	15.33	17.45	50/50	12.88	13.85	15.34
	70/30	13.31	16.87	13.37	60/40	9.04	10.34	11.83

Table 3. Elongation properties of the yarns

Spinning drum, r.p.m.	Average values of core yarn elongation at break ratio, %							
	Polyester/polyester				Polyester/viscose			
	Core/sheath ratio	Air auction, Pa			Core/sheath ratio	Air suction, Pa		
		1300	1400	1500		2000	2800	3700
2500	50/50	14.68	14.95	15.61	40/60	13.27	13.05	12.91
	60/40	14.56	14.36	13.78	50/50	12.30	12.79	12.51
	70/30	12.84	11.29	12.50	60/40	10.58	10.50	10.86
3000	50/50	14.93	15.12	15.55	40/60	12.67	12.87	12.78
	60/40	13.58	13.93	14.85	50/50	12.09	13.19	13.43
	70/30	12.93	11.30	13.35	60/40	10.84	11.19	11.11
3500	50/50	14.87	13.98	13.93	40/60	12.05	12.38	12.26
	60/40	13.67	14.21	14.25	50/50	11.42	13.50	13.80
	70/30	10.80	9.14	11.59	60/40	10.32	12.23	11.92
4000	50/50	14.11	15.02	13.96	40/60	12.03	11.85	12.03
	60/40	13.38	13.26	13.69	50/50	11.34	12.76	13.87
	70/30	11.42	12.65	12.70	60/40	10.17	11.25	11.76

*Table 4. Result of regression analysis for yarn tenacity; *Statistically significant.*

Spinning parameters	Polyester/Polyester		Polyester/Viscose	
	Coefficient	Significance	Coefficient	Significance
Core/Sheath ratio	-0.2043	0.0001*	-0.1066	0.005*
Spinning drum speed	-0.0029	0.0001*	-0.0016	0.003*
Air suction pressure	0.2683	0.4720	0.1152	0.009*

*Table 5. Result of regression analysis for the yarn elongation at break ratio; *Statistically significant.*

Spinning Parameters	Polyester/Polyester		Polyester/Viscose	
	Coefficient	Significance	Coefficient	Significance
Core/Sheath ratio	-0.1425	0.0001*	-0.0725	0.0001*
Spinning drum speed	-0.0004	0.055	-0.0001	0.059
Air suction pressure	0.1662	0.335	0.0490	0.011*

In the DREF-3 core spinning process, the transporting of fibres from the first drafting unit to the spinning zone is very important. With a decrease in the core/sheath ratio, the time for fibres to travel the distance between the front rollers and the spinning zone increases at a lower speed. The fibre bundle might be weaker and affected by air suction and gravitational forces [4], hence core fibres cannot reach the spinning drums and wind around the front rollers, as a result of which the yarn finally breaks. A picture of fibre transportation from unit 1 through the yarn formation zone is given in ***Figure 1***.

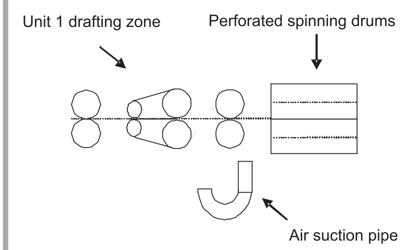

Figure 1. *Fibre transportation from unit 1 through yarn formation zone.*

The core/sheath ratio and air suction pressure for polyester/polyester and polyester/viscose yarns could not be the same in this study due to the different types of sheath material in the yarn spinning. At lower spinning drum speeds, it is impossible to produce polyester staple fibre core/polyester sheath core yarns with a 40/60 core/sheath ratio and 2.0 kPa, 2.8 kPa and 3.7 kPa air suction pressures due to yarn breakage. This result may be explained by the various fibre surface frictional forces between polyester/viscose and polyester/polyester fibres. The fibre surface frictional force helps to hold fibres together while transporting them from the unit 1 drafting system to the spinning zone [4], as well as in the spinning zone. It seems that the surface friction between polyester and viscose fibres is higher than that between polyester fibres. For this reason polyester/viscose yarns run well with lower core/sheath ratios like 40/60 and at higher air suction pressures, such as 2.0 kPa, 2.8 kPa and 3.7 kPa.

Polyester slivers (38 mm fibre staple length, 1.2 denye fibre fineness) and viscose slivers (fibre staple length – 35.4, denye fibre fineness – 1.42) were used as wrapper sheaths in the core yarn production. In this study, polyester and viscose were second draw frame slivers of 2.65 g/m and 4.85 g/m size, respectively.

Experimental yarns were produced on a DREF-3 friction spinning machine at the Textile Technique Institute of RWTH University. The sliver feeding position influences the core yarn twist structure [7]. Owing to this, the feeding position of three polyester slivers and two viscose slivers were the same and fixed during the yarn spinning processes.

The strength-elongation characteristics of the yarns were measured according to ISO 2062 using a Llyod constant rate elongation tester. For this tester, the rate of extension was 500 mm/min, and the specimen length was 500 mm for the yarns.

Results and discussion

The tenacity and elongation at breakelongation at break values of polyester staple fibre core/polyester sheath and polyester staple fibre core/viscose sheath DREF-3 yarns are given in ***Table 2***, respectively.

In order to understand the effect of spinning parameters on yarn tensile properties, the experimental results were evaluated by regression analysis using an SPSS statistical program at a 0.05 significance level. In the regression analysis, the core/sheath ratio, spinning drum speed and air suction pressure are independent parameters, whereas the yarn tenacity and elongation at break ratio are dependent parameters.

In all the regression variance analysis, significance levels were found to be less than 0.05, which prove that the relations between the independent and dependent parameters are statistically significant. The coefficients and significance levels of independent parameters found by regression analysis are given in ***Tables 4*** and ***5***.

The effect of the core/sheath ratio

Based on the yarn tenacity results, it is clear that an increase in the core ratio firstly increases the yarn tenacity then evidently decreases it. It seems that the core contributes directly to the yarn strength in the presence of sufficient wrapper fibres to maintain yam integrity. However, exceeding the optimum core ratio probably provides too few wrapper fibres to prevent core slippage, reducing yarn strength thereafter [8]. Based on the regression analysis, the effect of the core/sheath ratio has a significant effect on yarn tenacity. An increase in the core/sheath ratio decreases yarn tenacity due to insufficient wrapper fibres in the yarn. The core/sheath ratio has a significant effect on yarn elongation at break - a lower core/sheath ratio had a higher elongation. This result is in agreement with previous researches [4, 9]. In core yarns, most wrapper fibres are in a buckling and helically wound position due to the wrapper fibre feeding system, which may cause more yarn extension. If there are more wrapper fibres, the extension becomes higher and core yarn elongation increases.

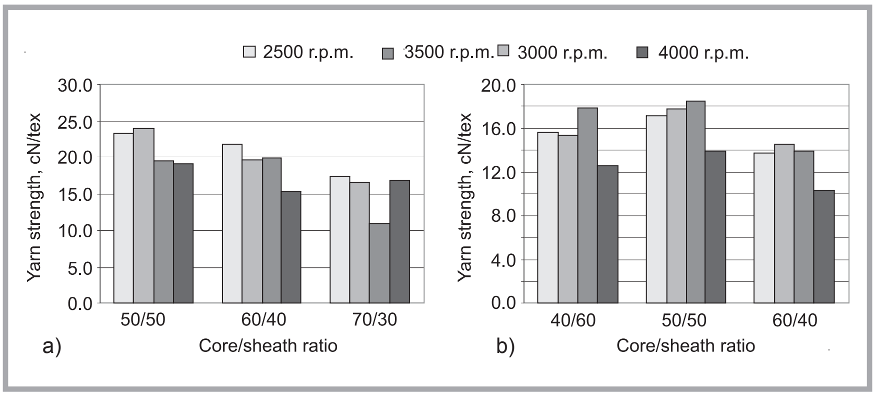

Figure 2. *The effect of core/sheath ratio on: a) Polyester/Polyester and b) Polyester/Viscose yarn strength at four spinning drum speeds and 1400 (a) and 2800 (b) Pa air suction pressure.*

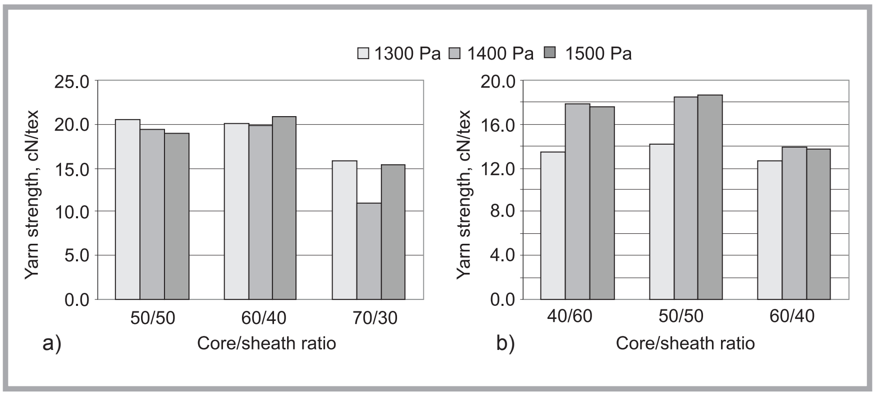

Figure 3. *The effect of core/sheath ratio on: a) Polyester/Polyester and b) Polyester/Viscose yarn strength at three air suction pressures and 3000 rpm spinning drum speed.*

The effect of the core/sheath ratio on yarn strength at a constant air suction pressure (1.4 kPa for Polyester/Polyester and 2.8 kPa for Polyester/Viscose yarns) and four different spinning drum speeds is given in ***Figures 2*** and ***3***. The effect of the core/sheath ratio on yarn strength at a constant spinning drum speed (3000 r.p.m), with four different air suction pressures is given in ***Figure 3***.

The effect of the spinning drum speed

The spinning drum speed is a highly significant factor for yarn tenacity because it provides the radial force to wrap sheath fibres around the core.

Based on the statistical analysis, it can be stated that the spinning drum speed has a significant effect on yarn tenacity,- at higher spinning drum speeds yarn tenacity decreases. This could be due to the wrapper fibres as at higher spinning drum speeds hooked wrapper fibres in the yarn may increase. As a result, wrapper fibres may not be wound around the core and will not efficiently contribute to the tenacity due to their decreased length.

On the other hand, the spinning drum speed does not have a significant effect on core yarn elongation, which is in agreement with previous researches [4, 9].

The effect of the spinning drum speed on yarn strength at a constant core/sheath

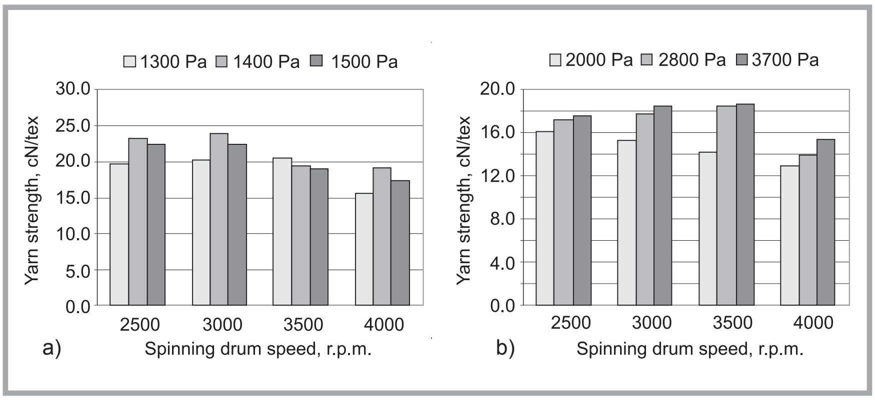

Figure 4. *The effect of spinning drum speed on: a) Polyester/Polyester and b) Polyester/Viscose yarn strength at three air suction pressures and 50/50 core sheath ratio.*

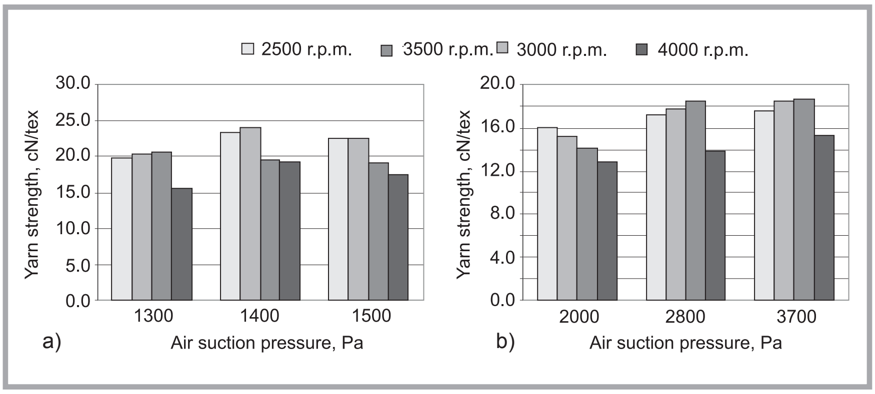

Figure 8. *The effect of air suction pressure on: a) Polyester/Polyester and b) Polyester/Viscose yarn strength at four spinning drum speeds and 50/50 core sheath ratio.*

ratio (50/50), with three different air suction pressures, is given in ***Figure 4***.

The effect of air suction pressure

With an increase in air suction pressure, wrapper fibres may be wound better around the core, hence the production of core yarns with a high core/sheath ratio is possible.

The air suction pressure has a significant effect on polyester/viscose yarn tenacity - at a higher air suction pressure, yarn tenacity increases. It seems that at higher air suction pressures, slippage between the fibres and spinning drum decreases, and wrapper fibres may be wound better around the core, as a result of which yarn tenacity increases. The effect of the air suction pressure on yarn strength at a constant core/sheath ratio (50/50) and four different spinning drum speeds is given in ***Figure 5***.

The air suction pressure has a significant effect on polyester/viscose yarn elongation at break. The yarn elongation ratio increases with an increase in air suction pressure owing to an increase in the buckling form of wrapper fibres, which may create more chances of yarn extension. On the other hand, the air suction pressure does not have a significant effect on polyester/polyester core yarn tenacity and elongation ratio properties. In all probability the effect of the air suction pressure varies according to the physical properties of fibres in the sheath. The air suction pressure may only have a significant effect on core yarn tensile properties when short and coarse fibres are used in the sheath.

Conclusion

The core/sheath ratio has a significant effect on yarn tenacity and the elongation ratio. An increase in the core/sheath ratio decreases the tenacity and elongation ratio due to a decrease in the wrapper fibre ratio in the core yarn.

The spinning drum speed has an important effect on yarn tenacity - at higher spinning drum speeds, yarn tenacity decreases. This could be because of the wrapper fibres - at higher spinning drum speeds, hooked wrapper fibres in the yarn may increase. However, the spinning drum speed does not have a significant effect on the core yarn elongation ratio.

The air suction pressure has a significant effect on PES/viscose yarn tenacity and elongation ratio properties. At higher air suction pressures, the yarn tenacity and elongation ratio increase. However, the effect of air suction pressure does not have a significant effect on PES/PES yarn properties. The air suction pressure may only have a significant effect on core yarn tensile properties when short and coarse fibres are used in the sheath.

The surface frictional force is perhaps one of the most important parameters. If the friction force between the core and sheath material is high, the production of core yarns with a high core ratio at a high air suction pressure is possible.

Acknowledgment

This work was supported and sponsored by a TUBITAK Abroad Research Scholarship from TUBITAK Textile Research Centre.

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Received 02.11.2007 Reviewed 12.11.2009