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EFFECT OF FILAMENT FINENESS ON COMPOSITE YARN RESIDUAL TORQUE

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Abstract:

Yarn residual torque or twist liveliness occurs when the twist is imparted to spin the fibers during yarn formation. It causes yarn snarling, which is an undesirable property and can lead the problems for further processes such as weaving and knitting. It affects the spirality of knitted fabrics and skewness of woven fabrics. Generally, yarn residual torque depends on yarn twist, yarn linear density, and fiber properties used. Composite yarns are widely produced to exploit two yarns with different properties such on optimum way at the same time and these yarns can be produced by wrapping sheath fibers around filament core fiber with a certain twist. In this study, the effect of filament fineness used as core component of composite yarn on residual torque was analyzed. Thus, the false twist textured polyester filament yarns with different filament fineness were used to produce composite yarns with different yarn count. The variance analysis was performed to determine the significance of twist liveliness of filament yarns and yarn count on yarn twist liveliness. Results showed that there is a statistically significant differences at significance level of α=0.05 between filament fineness and yarn residual torque of composite yarns.

Keywords:

microfilament; composite yarn; yarn residual torque

1. Introduction

Composite yarns, regular in appearance along their length, have both staple fiber and filament components. These yarns can be produced by several processes, such as conventional covering, core spinning, twisting, wrapping, and air covering. Core spinning is one of production techniques for the composite-covered yarns that has a core part, which can be elastomeric or any kind of multifilament yarn is completely covered by sheath especially staple fiber [1]. If elastomeric fiber is used as the core part, this yarn is named as elastic core-spun yarn. When the filament yarns are used as the core part, this yarn will be named as hard core-spun yarn. There are various production systems available such as friction spinning, air vortex, open-end spinning, ring spinning etc. to produce core spun-yarn. Modified ring spinning system is the most commonly used to produce elastic and hard core-spun yarns and there are also so many researches about the properties of core-spun yarns produced with this system [2-11].

During yarn production, stress gets accumulated in the yarn as residual torque because of the helical deformation of fibers, which causes a tendency to snarl. Yarn snarling occurs when a twist lively yarn is given sufficient slack and reduced tension [12]. Yarn snarling is illustrated in Figure 1. When the yarn is hanged as a loop and allowed to rotate freely, direction of snarl (S or Z) arises spontaneously in the opposite twist direction. A twist lively yarn always shows a tendency to get relieved of the stress induced during torque application [13]. Twist factor is one of the most important parameters that affects yarn residual torque by itself [14].

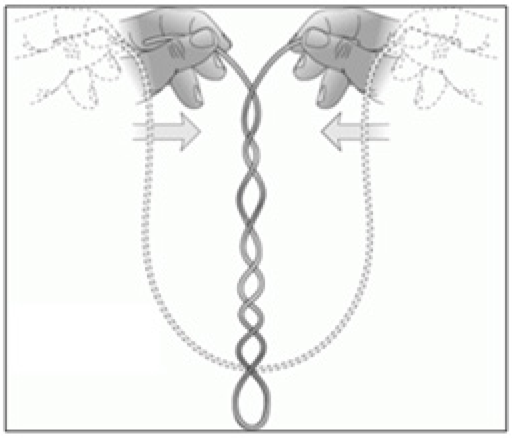

Figure 1. Snarling in a twist lively yarn [15]

Although there are three types of measurement techniques (direct, semidirect and indirect methods) to determine the yarn twist liveliness, there is no standard method available [16,17]. So, a subjective assessment was adopted. The most widely used method for detection of the yarn residual torque, as a commercial practice by yarn producers for quick estimation, is the indirect method; it is measured by hanging of a certain weight in the middle of the determined length of the yarn and bringing two ends of the yarn together slowly and allowing yarn to snarl freely. The number of turns in the snarl yarn is expressed as turns per meter and is taken as the residual torque of the yarn [18-23].

Although various studies are available about methods to determine yarn residual torque property and its effects on knitted fabric spirality and woven fabric skewness, a study on the effect of core part in hard core-spun yarn on yarn residual torque is not available.

Core part contributes to some physical properties of the core-spun yarn such as elongation, strength, unevenness etc. The present study is undertaken to examine the effects of core part residual torque properties determined on hard core-spun composite yarn torque property. Therefore, modified ring spinning method, which is most commercially used in practice, is used to manufacture core-spun yarn, which consists of introducing drawn (false twist) textured polyester filament yarns with different filament fineness (medium, fine and micro) to the spinning process. When microfilaments are textured, special characteristics such as softness, high bulk etc. will be imparted [24]. False twist texturing process is the most applicable texturing process for microfilaments [24-26]. So, the commonly used false twist textured polyester filaments with medium, fine, and microfineness were selected. Moreover, hard core-spun yarn samples were produced at different yarn counts to investigate the effect of core/sheath ratio on yarn residual torque, as well.

2. Experimental

2.1. Materials

In order to compare the influence of filament fineness and yarn residual torque on composite yarn twist liveliness, medium, fine, and microfalse-twist textured polyester filament yarns with different fineness at the same linear density were used to produce combed cotton-covered hard core-spun yarn. The commonly used false-twist textured filament yarns in the production line were selected and provided from Korteks Company in Bursa, Turkey and specifications of these filament yarns are illustrated in Table 1. As a sheath fiber cotton had 30 mm staple length, 4.5 micronaire fineness and 34 g/tex strength.

Among core-spun yarn production systems, modified ring spinning system is most commercially used and can be easily adapted to produce core-spun yarn, so this system was chosen for this study. In this system, filaments are fed at the creel. It is introduced into the center of the drafted sheath fiber, at the nip of the front drafting rollers or it was fed in with cotton fibers just behind the front roller of the drafting zone. Typical modified ring spinning system to produce hard core-spun yarn is shown in Figure 2.

Hard core-spun yarns were produced on modified ring spinning system with four different yarn counts (37 tex (Ne 16/1), 30 tex(Ne 20/1), 25 tex (Ne 24/1) and 21 tex (Ne 28/1)). The production line of hard core-spun yarn samples is shown in Table 2.

In this study, Ne 0.6 combed cotton roving was used as sheath fiber for the production of all different yarn counts. The hard core-spun yarn samples were manufactured at the same twist factor. The production parameters of hard core-spun yarn samples are shown in Table 3. For all yarn counts, the twist factor was kept constant, so the twist value, which is turns per meter, increased from Ne 16/1 to Ne 28/1 yarn samples. All yarn tests were carried out after conditioning the specimens in a standard atmosphere at 20 ± 2°C temperature and 65 ± 4% relative humidity for 24 hours.

2.2. Method

The measurement method for residual torque of yarns was adopted according to the method presented by Basu and Çelik [18,20]. The twist liveliness of false-twist textured polyester filament yarns with different filament fineness and hard core-spun yarn samples were measured by indirect method. One-meter-long yarn was taken out from the package in such a way that no untwisting occurs before making loop. Then a load equivalent to 10mg/tex is suspended in the middle of the yarn. Two free ends were taken together to allow the snarl freely or to make loop. During the test, tendency to snarl of both filaments and core-spun yarns were noted. Then, number of turns in the snarl yarn was measured by using Prowhite twist tester. In this case, 10 measurements were carried out for each yarn samples.

Table 1. Specifications of false-twist textured filament yarns [27]

Specifications	Fiber Classification				
	Medium	Fine	Micro		
Filament Yarn Linear Density, dtex (ISO 2060)	110	110	110	110	110
Filament Number	36	96	144	196	333
Filament Fineness, dtex	3.05	1.15	0.76	0.57	0.33
Tenacity, cN/dtex (ISO 2062)	4.11	3.77	3.69	3.77	4.17
Elongation, % (ISO 2062)	20.97	21.04	18.85	17.16	19.44
Crimp Contraction, % (DIN 53840-1)	37.39	14.84	9.62	8.7	5.31
Crimp Module, % (DIN 53840-1)	22.58	7.59	4.55	4.12	2.46
Crimp Stability, % (DIN 53840-1)	86.04	81.1	76.97	78.33	75.36

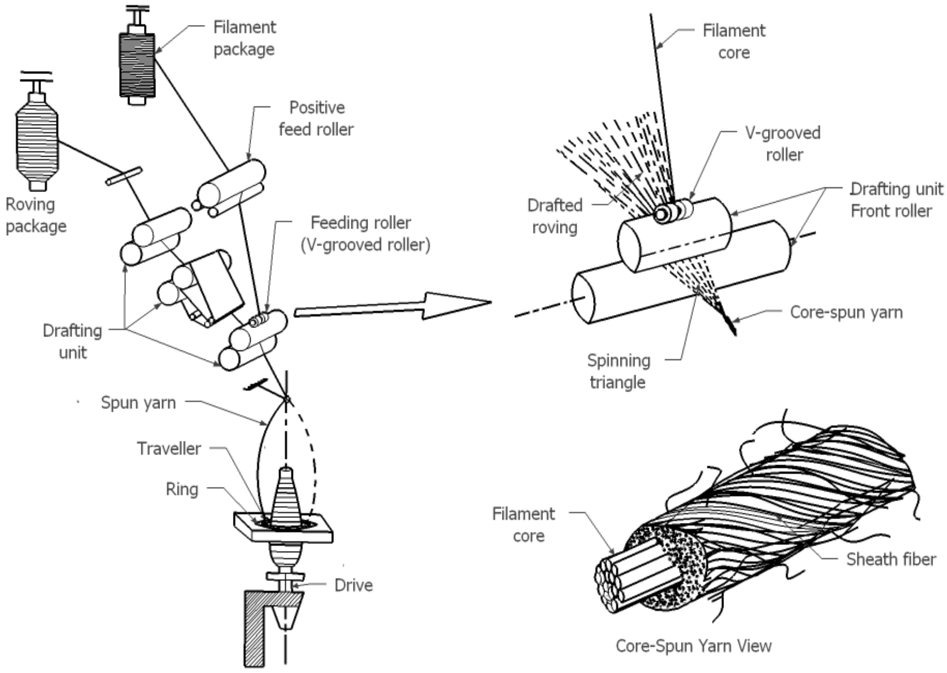

Figure 2. Modified ring spinning system, positioning the filament core at the nip point of the front roller, core-spun yarn view (It may not be reproduced without permission)

Table 2. Production line of hard core-spun yarn samples

Machine Order	Manufacturer
Blowroom	Trützschler (2006)
Carding Machine	Trützschler (2006)
Drawframe (1)	Rieter RSB 35(2005)
Combing Preparation (Unilap)	Rieter 600 (2003)
Combing	Rieter E62 (2003)
Drawframe (2)	Rieter RSB 40(2005)
Roving Frame	Zinser 668 (2003) 120 flyers
Ring Frame	Zinser 351 (2003) 240 spindles
Bobbin Machine	Shlafhorst 338 Autoconer (2005)

Table 3. Production parameters of hard core-spun yarn samples

Yarn Count (Ne)	**16/1**	**20/1**	**24/1**	**28/1**
Core/Sheath Ratio (%)	30/70	37/63	45/55	52/48
Draft Ratio	27	33	40	47
Twist Factor (αe)	3.9	3.9	3.9	3.9
Twist (t.p.m)	614	687	752	812
Twist Direction	Z	Z	Z	Z
Spindle Speed (rpm)	8000	8000	8000	8000

2.3. Statistical analysis

In order to establish an equation (model) that could better correlate the residual torque of polyester filament yarns with different filament finenesses at 95% confidence interval, SPSS statistical package program was used. Regression analysis curve estimation was used to choose the best model.

Hard core-spun yarn residual torque results and testing of the varying independent parameters, i.e. filament fineness and yarn count for their significance at 95% confidence interval using ANOVA (Analysis of Variance) technique by Design Expert 6.0.1 package software were performed to calculate the percentage contribution of the independent parameters and their interactions on twist liveliness. Regression models that explain the relationship between independent parameters and hard core-spun yarn twist liveliness properties were established. In this regard, general factorial design was applied to establish regression models. The analysis of variance was performed to select the proper model for yarn residual torque.

3. Results and discussion

3.1.Polyester filament yarn residual torque

When the direction of snarl was examined, the tendency of false-twist textured polyester filament yarns was found to be in the S direction, i.e. counterclockwise direction. Histograms for yarn residual torque of these yarns with different filament finenesses, with error bar graphs, were drawn and is shown in Figure 3. It is clearly seen that twist liveliness decreases with increasing filament number. This situation can be due to the higher filament number that withstands stress along the length of filament during false-twist texturing processes. It can be concluded that better twist development, leading to a higher detorque, is required to open the twisted structure of the false-twist textured yarn from higher to lower filament number in the cross-section.

According to the statistical analysis, to determine the relationship between filament fineness parameters and residual torque, quadratic model was chosen. In quadratic model, higher R^2 value was obtained with simple relationship between dependent and independent parameters. The model summary and parameter estimate of regression analysis is shown in Table 4. In Table 4, the quadratic model explains about 93.9% of the variability in yarn residual torque at α = 0.05 significance level. Adjusted R-Square for quadratic model ($R^2_{adj.}$=93.6 %) also shows a true goodness of fit for quadratic model. Regression quadratic model equation of false-twist textured polyester filament yarn residual torque is presented in equation (1) illustrated in Table 4.

3.2. Hard core-spun yarn residual torque

During composite yarn production, twist was applied in Z direction. During the test, the snarl tendency of yarns was analyzed and direction of snarl was observed as freely rotating of yarn in the opposite twist direction of the twist applied, that is, S direction. Residual torque graphs of hard core-spun yarns were drawn with respect to the yarn count to evaluate the differences and changes of filament fineness effects separately and these graphs with error bars were shown in Figure 4. As seen in Figure 4, yarn residual torque value decreases for all hard core-spun yarns from medium to micro false-twist polyester filament yarns. This situation can prove that filament residual torque, which is used as core part, influences yarn residual torque. To produce all hard core-spun yarns, twist factor was kept constant, which resulted in increasing twist per meter from Ne 16/1 to Ne 28/1 yarn count. Yarns with higher twist have more compact structure but exhibit higher residual torque at the same time [28].

As the number of fibers (cotton and filament) in the cross-section of the yarn samples increase, the yarn residual torque also exhibits a positive influence [29]. On the other hand, higher number of the filaments or fibers withstand the torque. As a result, core-spun yarns with microfilament core part have an advantage with low-yarn residual torque than the others.

The results of ANOVA and the regression model were obtained by using general factorial design. Variance analysis result for yarn residual torque is given in Table 5. The table shows that the effects of the independent factors A (filament fineness) and B (yarn count) are statistically significant at α = 0.05. In addition, the interaction terms of AB has a statistically significant effect on the twist liveliness at α = 0.05. The coefficient of variation R-Square (R^2) value is a “goodness of fit” measure and ranges in value from 0 to 1.The model explains about 91.67% of

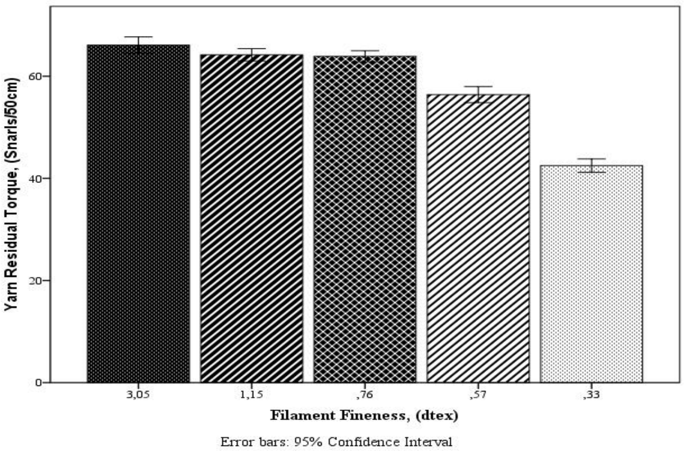

Figure 3. Polyester filament yarn residual torque

Table 4. Model summary and parameter estimates of false twist textured polyester filament yarns

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	Filament fineness	Filament fineness^2	Filament fineness^3
Linear	0.763	154.669	1	48	0.000	75.120	-5.500	--	--
Logarithmic	0.585	67.640	1	48	0.000	70.091	-11.980	--	--
Quadratic	**0.939**	**359.095**	**2**	**47**	**0.000**	**59.520**	**7.871**	**-2.229**	--
Cubic	0.955	323.327	3	46	0.000	70.720	-7.862	3.771	-0.667
Yarn residual torque=59.520+7.871*Filament fineness-2.229*Filament fineness^2 (1)									

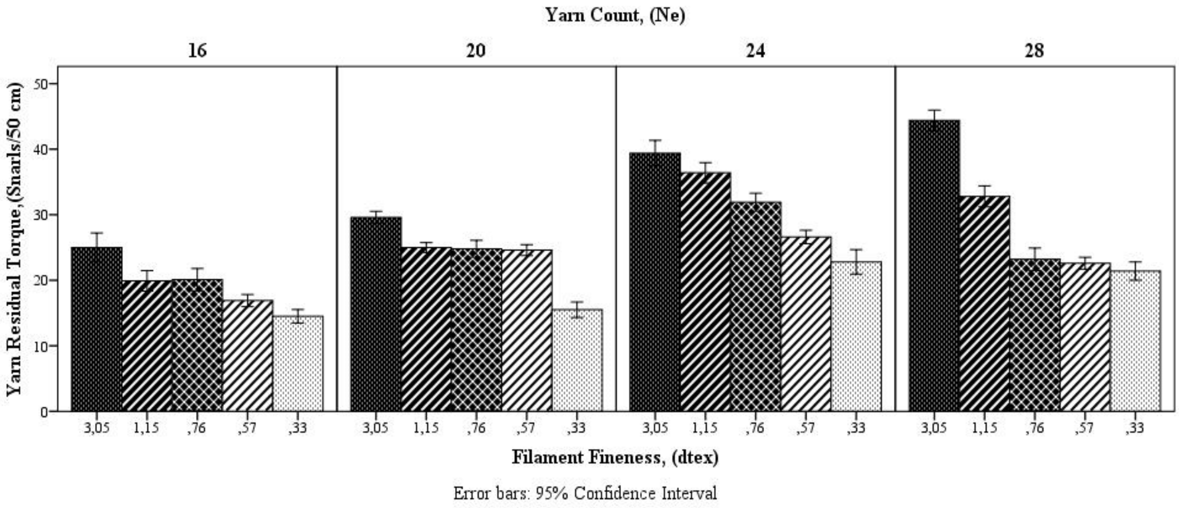

Figure 4. Composite yarn residual torque of samples

Table 5. ANOVA results of yarn residual torque

Source	Sum of Squares	DF	Mean Square	F Value	Prob>F	Significant at 95%
Model	2078.75	5	415.75	39.64	< 0.0001	Significant
A-Filament Fineness	1499.68	1	1499.68	142.99	< 0.0001	Significant
B-Yarn Count	385.09	1	385.09	36.72	< 0.0001	Significant
A^2	421.08	1	421.08	40.15	< 0.0001	Significant
B^2	48.73	1	48.73	4.65	0.0449	Significant
AB	135.30	1	135.30	12.90	0.0021	Significant
Residual	188.79	18	10.49	--	--	--
Corrected Total	2267.54	23	--	--	--	--
Yarn residual torque ==-36.43435+12.27054*A+4.12643*B-5.19570*A^2-0.089063*B^2 +0.53480*A*B (2)						

the variability in yarn twist liveliness of hard core-spun yarn samples for all observations. The adjusted *R*-Square for model ($R^2_{adj.}$=89.4 %) is close to the ordinary R^2, which indicates a true goodness of fit. Regression model equation for hard core-spun yarn twist liveliness using design expert software is presented in equation (2) as shown in Table 5.

4. Conclusions

In this paper, the effects of filament fineness and yarn count on hard core-spun yarn residual torque were investigated. To this aim, false-twist textured polyester filament yarns were used as the core part to produce hard core-spun yarns with different yarn counts at the same spinning production parameter. In terms of yarn residual torque of hard core-spun yarns, filament fineness is important and it has been indicated that there are statistically significant differences for the significance level of α=0.05 between different filament finenesses.

False-twist textured microfilament polyester yarns have an advantage to obtain lower yarn residual torque, which is an undesirable property. For the further study, the effect of the filament fineness on knitted fabric spirality properties can be examined. Thus, the advantages of using of microfilament as core part of core-spun yarn can be put forward.

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