Mohsen Shanbeh, Behnaz Baghaei, Samira Alidadi, Abbas Tabibi

Textile Engineering Department, Isfahan University of Technology
Isfahan 84156-83111, Iran
E-mail: mshanbeh@cc.iut.ac.ir

Coating of Core Yarn. An Alternative Method of Decreasing the Strip-back Phenomenon of Core-spun Yarns

Abstract
This paper describes a new and simple method of decreasing the strip-back phenomenon of core-spun yarns. In the method proposed, before the production of these yarns, the core part was coated with a Methyl Methacrylate (MMA) binder using a purpose-built method based on the conventional pad-dry-cure (PDC) system. Two counts of polyester filament yarn, namely 111 and 44 dtex, were used as the core part, and the nip pressure of the padding system was changed on two levels to evaluate the effect of the pick-up percentage. The core-spun yarns were produced on a modified ring spinning frame. The tensile properties of the core-spun yarns, their cover factor after abrasion, and the abrasion resistance and pilling of the fabrics woven were studied. The results obtained showed the effectiveness of the method proposed for the improvement of the strip resistance of core-spun yarns after the abrasion process, as well as of the abrasion resistance and pilling of woven fabrics. The statistical evaluation, based on one-way analysis of variance, revealed a significant difference between the properties of conventional and modified core-spun yarns in most cases.

Key words: *core-spun yarn, coating of core part, strip-back, abrasion resistance, pilling.*

Introduction

Core yarns are structures consisting of two component fibres, one of which forms the centre axis or core of the yarn, and the other the covering. Generally, the core is a continuous monofilament or multifilament yarn, while staple fibres are used for the outer covering or sheath of the yarn. The production of these yarns has been done successfully on many spinning systems such as ring, rotor, friction, and air jet. Among these methods, the modified ring spinning frame was the first method used to produce these yarns based on the simple modification of a ring spinning frame. Core yarns have been used to improve the strength, durability, aesthetic and functional properties of fabrics. Theses yarns are commonly used as industrial and household sewing thread, in special military and industrial textile products, in light-weight apparel fabrics, industrial clothing, tents, underwear, sportswear and outerwear [1 - 5]. Many studies have managed to optimise and enhance the physical and mechanical properties of core spun yarns and fabrics. The properties of fabrics produced with cotton covered nylon-core yarns and greige fabrics were studied by Sawhney *et al.* [6]. Ruppenicker *et al.* [7] compared the properties of cotton/polyester core and staple blend yarns and fabrics. Balasubramanian and Bhatnagar [8] studied the effect of different production parameters on the tensile properties of core spun yarns containing nylon multifilament yarns as core and cotton fibre in a sheath. Tarafder and Chatterjee [9] compared the hairiness of core yarns with that of 100% cotton single yarns. The core yarns showed fewer protruding ends and loops than equivalent cotton single yarns, because the number of staple fibres present in the core yarns was lower than that in the equivalent cotton single yarns. Jeddi et al. [10] evaluated the effect of the production parameters of cotton-covered nylon filament core-spun yarns, namely the twist factor and pretension on the filament path in the yarn structure, the yarn diameter, evenness, and tensile properties.

A common problem associated with core-spun yarns is the slippage of staple fibres relative to the filament core part because of the abrasive action of further textile processes [11]. This phenomenon is called 'strip-back' or 'skinning back'. Miao and et al. in 1996 [11] evaluated the effect of filament pre-tension, filament twist using ring and the DREF-2 production method on the sheath slippage of core-spun yarns. Filament pre-tension and the twisting of filament had a significant effect on sheath slippage. Several attempts have been made to minimise this problem. Sawhney et al. proposed a new design for the ring frame. In their system, the consolidated core fibres are coaxially held in a sandwich form before they are twisted to produce a core-spun yarn [12, 13]. In another method proposed by Louis et al. in 1989 [14], the three roving guides keep the roving separated as they pass through the drafting zone of the ring frame. In another system suggested by Jou et al. [15], a filament–charging device was designed based on the principle of a two-electrode system. This was employed to separate a multi-filament yarn. The filaments separated were then mixed with the staple fibres of a roving at the roller. Although many researches have been carried out on core-spun yarns, the problem of sheath-fibre slippage has not been completely solved. Therefore, the purpose of this study was to evaluate and suggest a new method of decreasing the slippage of sheath fibre from the core part. Hence a simple method was created based on changing the surface properties of the core part by coating it with a Methyl Methacrylate (MMA) binder before using it to produce core-spun yarns. We believe that changing the surface of the core part to get better integrity and contact between it and the sheath fibre could improve the sheath slippage resistance of these yarns as well as the abrasion resistance and pilling of woven fabrics.

Materials

We used cotton fibre with a 28 mm effective length and fineness with a micronair value of 4.3 as sheath fibre, as well as 111 dtex/36 f polyester filament yarn with a tenacity of 36.36 cN/tex, and elongation at break of 37.14%, and 44 dtex/13 f nylon filament yarn with a tenacity of 34.91 cN/tex, and elongation at break of 37.74% as cores to produce cotton covered polyester core-spun yarns (23:77 and 11:89 polyester - to - cotton ratio) on a modified ring spinning frame.

Test methods

Method proposed for coating the core part

As mentioned earlier, the main aim of this study was the surface modification of the core part based on its coating using a Methyl methacrylate (MMA) binder to investigate the effect of this process on the slippage of sheath fibre from the core part. The coating process of yarns is shown schematically in ***Figure 1***. As can be seen, the standard pad-dry-cure (PDC) method using a two-roller laboratory padder (Mathis, Switzerland) was used. The nip pressure was set at 1×10^5 and 2×10^5 Pa (1 and 2 bar, respectively) to investigate the effect of the pick-up percentage. After padding, the sample was dried by passing a specially designed heating chamber along a padder of 120 °C and winding it on a bobbin using a special winding system equipped with an inverter to compromise the speed of the padder and winding system. The pad solution contained 200 cc of methyl methacrylate (MMA) binder, 800 cc of distilled water and 30g of di-ammonium phosphate. Finally, the heat setting of the coated yarns was performed for 3 minutes at 170 °C in an oven.

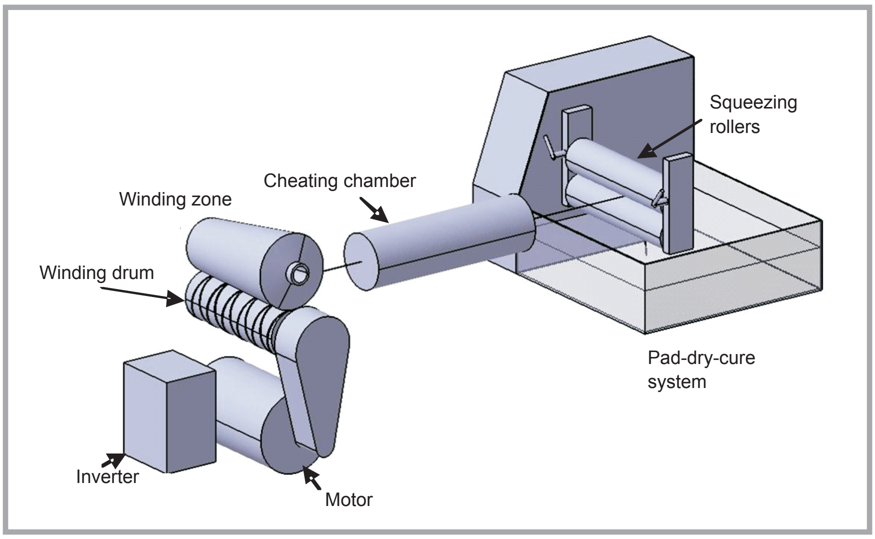

Figure 1. *Schematic diagram of the coating method.*

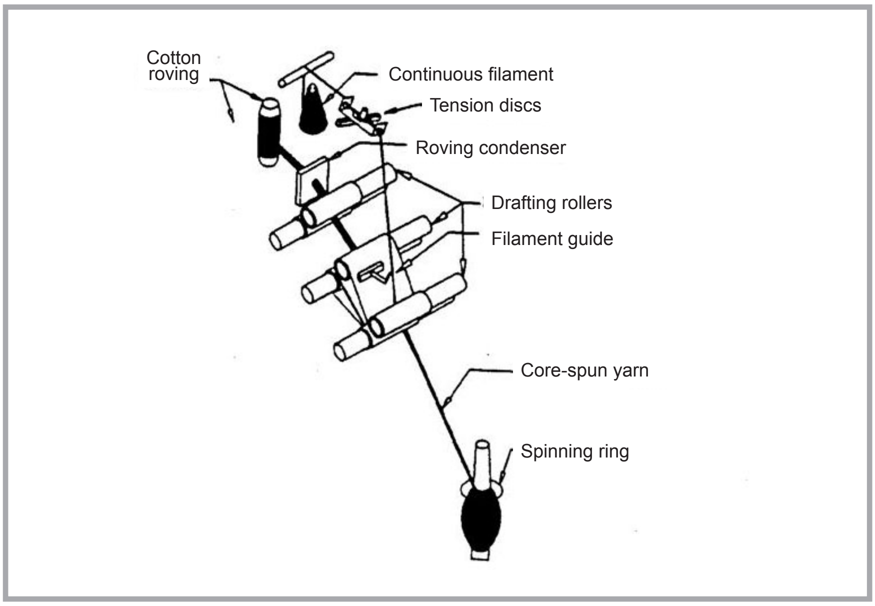

Figure 2. *Spinning process of core-spun yarn [7].*

Core-spun yarn and fabric manufacturing

Ruppenicker *et al.* [7] and Balasubramanian & Bhatnagar [8] proposed a conventional method to produce core-spun yarns. A diagram of the spinning process used to produce samples is shown in ***Figure 2***. A conventional ring spinning frame with a double apron drafting system was modified to accommodate cones of polyester filament yarns. The core yarns were fed from the cone through an adjustable tensioning device to the front rolls of the drafting system. During test, the pre-tension of the core part was modified to 29.42 and 14.71 cN for 111 and 44 dtex polyester yarns, respectively. A porcelain guide, located near the top front roll, was used to place the core part in the centre of the strand of drafted cotton fibres. Overall 6 yarn samples, coded 2/44, 1/44, 0/44, 2/111, 1/111 and 0/111, were produced. In each code the left number represents the nip pressure on the pad system, and the right one shows the count of the core yarn. 0/44 and 0/111 shows samples produced without any preprocessing of the core part. ***Table 1*** shows some settings of the ring spinning frame. According to ***Table 1*,** the nominal count of the sheath part was 34.52 tex, and the metric twist factor (α_m) was set at 108.9. The production speed was 13.27 m/min.

Table 1. *Some settings of the ring spinning frame used to produce samples.*

Roving count, hank	Break draft	Total draft	Twist, t.p.m.	Spindle speed, r.p.m.	Ring diameter, mm
0.8	1.56	21.37	588	7800	46

The yarns were used as the weft, and 6 fabrics with F/2/44, F/1/44, F/0/44, F/2/111, F/1/111 and F/0/111 were produced with a Twill 2/1 structure using a rapier weaving machine (G6100, Sulzer). The parameters of the woven fabrics were as follows: warp yarns - 29.53 tex (65/35, P/C), weft density in 1/cm - 20, warp density in 1/cm - 33, and reeded width in cm - 220.

Yarn testing

All tests were carried out after the specimens were conditioned in standard atmospheric conditions (temperature 20 ± 2 °C, 65 ± 2% relative humidity). Tensile tests of the yarns were done according to ASTM D-2256 standard test method [16] using a Zwick tensile testing machine, which is based on the Constant Rate of Elongation method (CRE). Each yarn sample was tested 30 times.

SEM images have proved to be very useful for studying the surface characteristic

Table 2. *Tensile properties of core parts before and after coating;* ***Note****: Data in parenthesis are CV% values.*

Code	Count, dtex	Pick-up, %	Elongation at break, %	Tenacity, cN/tex
0/44	44.44	-	18.87 (7.80)	34.91 (5.05)
1/44	45.78	2.65	15.38 (9.17)	35.54 (3.98)
2/44	46.61	4.98	14.57 (15.66)	35.17 (8.80)
0/111	111.11	-	18.57 (9.68)	36.36 (6.20)
1/111	118.79	7.02	17.42 (5.97)	36.63 (2.88)
2/111	123.20	10.99	17.02 (5.38)	37.01 (3.35)

Table 3*. Tensile properties of core-spun yarns;* ***Note****: Values in parenthesis are CV% values.*

Code	Count, tex	Elongation at break, %	Tenacity, cN/tex	Work up to break, N·mm
0/44	39.48	4.66 (8.33)	13.47 (8.15)	69.99 (13.96)
1/44	39.78	4.43 (13.01)	13.68 (8.32)	72.68 (17.49)
2/44	39.88	4.96 (10.22)	14.57 (8.50)	79.10 (15.68)
0/111	46.39	4.22 (7.79)	9.68 (29.69)	61.29 (7.73)
1/111	47.17	4.32 (12.15)	11.28 (9.57)	67.35 (17.64)
2/111	47.59	4.23 (21.61)	11.12 (21.49)	66.36 (26.06)

Table 4*. Significant values (p-values) of the analysis of variance (ANOVA) at 95% significance level; *statistically significant for α = 0.05.*

Tenacity		
Core part	44 dtex polyester	0.052
	111 dtex polyester	0.315
Yarns	With 44 dtex polyester core part	0.000*
	With 111 dtex polyester core part	0.001*

Table 5. *Mass loss of woven samples after 1000, 3000, 6000 and 9000 abrasion cycles.*

Fabric code	Mass loss in g after X abrasion cycles			
	X = 1000	X = 3000	X = 6000	X = 9000
F/0/44	0.67	0.79	2.08	5.04
F/1/44	0.61	0.73	1.95	4.15
F/2/44	0.36	0.46	1.84	3.51
F/0/111	0.51	0.76	2.96	5.87
F/1/111	0.47	0.68	2.73	5.03
F/2/111	0.42	0.53	2.60	4.60

Table 6*. Pilling of woven samples after 125, 500 and 2000 abrasion cycles.*

Abrasion cycles	Fabric code					
	F/0/44	F/1/44	F/2/44	F/0/111	F/1/111	F/2/111
125	1 - 2	1 - 2	1 - 2	1 - 2	1 - 2	1 - 2
500	2 - 3	2 - 3	1 - 2	2 - 3	1 - 2	1 - 2
2000	3 - 4	2 - 3	2 - 3	3 - 4	2 - 3	2 - 3

and structural changes of textile materials, including fibres, yarns and fabrics. To assess the effect of the coating process on the surface structure of core-parts, the coated samples were studied using a Philips scanning electron microscope, and some micrographs are presented herein.

By considering the method proposed by Sawheny et al. [12], the strip resistance of the core-spun yarns was assessed by subjecting the yarn to a limited degree of abrasion using a a purpose-built method in which a knitting needle was mounted in the path of the yarn. In this method, a loop of the yarn was circulated using a rotating drum. The rotation of the yarn was set at 300 cycles taking into consideration yarn slippage on the drum. Therefore, the rotating time and drum speed were 15 minutes and 165 r.p.m, respectively. The abraded and unabraded yarns were wound onto a black frame of 2 × 2 cm dimension to examine and compute its cover factor. A scanner with a 1200 dpi resolution was used as the image taking device. It is worth mentioning that the optical differentiate between the core part and wrap fibres was obtained by dying only the sheath component of the yarn with direct blue dye, with the core parts remaining white. The cover factor and strip resistance of the core part were assessed by an especially objective method involving the use of an image processing technique to evaluate the percentage of the core part that is visible.

Fabric Testing

The abrasion resistances of the fabrics were tested according to ASTM D-4966 [17] standard test method for the abrasion resistance of textile fabrics - the Martindale abrasion tester method. The abrasion resistance was determined using the mass loss as the difference between the masses before and after abrasion cycles of 1,000, 3,000, 6,000 and 9,000.

The pilling resistance of the fabrics was tested according to ASTM D-4970 [18] standard test method for pilling resistance and other related surface changes of textile fabrics: the Martindale tester. We rated the samples after 125, 500 and 2000 revolutions, respectively, for six pairs of the test sample in each trial. The abraded samples were compared with standard specimens, and then they were given the following scale: 5 - no pilling, 4 - light pilling, 3 - moderate pilling, 2 - severe pilling, 1 - very severe pilling.

Results and discussions

Properties of the core parts after padding are presented in ***Table 2***. As is shown, the pick-up percent was from 2.65% to 4.98% and from 7.02% to 10.99% for 44 dtex and 111 dtex polyester filament yarns, respectively. The results revealed that the coating process for filament yarns did not have negative effects on their tensile properties. The coating of the core part caused a decrease in the elongation at break and a marginal increase in the tenacity. Physical properties of the core-spun yarns are shown in ***Table 3***. An increase in the tenacity of core-spun yarns produced from coated core parts was observed. For 44 dtex polyester core yarns, this difference was obvious when coated at a nip pressure of 2×10^5 Pa, and for 111 dtex polyester core yarns the difference was observed after padding at a nip pressure of 1×10^5 Pa. The maximum difference between the tenacity of 111 dtex and 44 dtex polyester core-spun yarns before and after coating the core part was 16.59% and 8.17%, respectively. This was an expected result because the coating of core parts might cause a better entanglement of sheath fibres with the core part, which would lead to an increase in friction between the core and sheath parts and, consequently, to a rise in yarn strength. The elongation at break of core-spun yarns did not show a specific trend. All of the outcomes related to physical and mechanical properties were also tested for significant differences in means by one-way analysis of variance (ANOVA) using Minitab software. To deduce whether the parameters were significant ($p < 0.05$) or not, p values were examined. Significant values from the analysis of variance are given in ***Table 4***. Statistical evaluation showed that the difference in means for tenacity values of the core parts were not significant, whereas the tenacity of the core-spun yarns was of great significance. However, the elongation at break of the core parts and core-spun yarns did not show significant variation before and after the coating process at a 95% significance level.

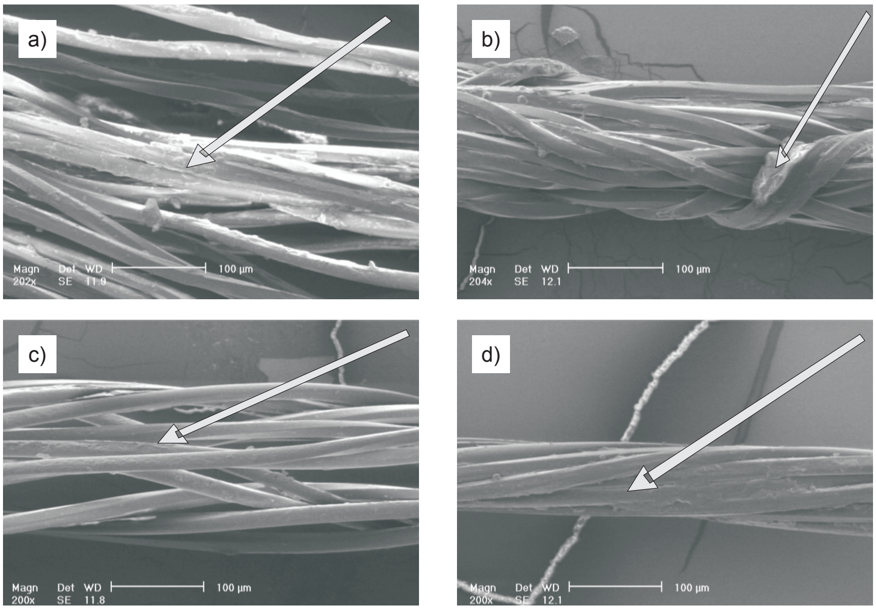

Figure 3. *Surface structure of samples: a) 1/111, b) 2/111, c) 1/44 and d) 2/44; magnified 200×.*

SEM images of different core samples at a magnitude of 200× are presented in ***Figures 3.a - 3.d***. The effect of coating on the yarn structure and surface changes of the core parts is clear in these figures when samples 2/100 and 2/40 (***Figures 3.b*** and ***3.d***) were compared with samples 1/40 and 1/100 (***Figures 3.a*** and ***3.c***). The cohesion of the binder on the surface of fibre strands is shown in the figures by arrows. These differences in the structure could be confirmed by the pick-up percentage of the samples, presented in ***Table 2,*** because the pick-up of samples 2/100 and 1/100 were 10.99% and 7.02%, respectively. However, the results presented in ***Table 2*** revealed that the pick-up value of sample 1/40 was not significant, i.e. 2.65%, confirmed by SEM images of this sample, which are shown in ***Figure 3.c***. This shows the effect of the count of core yarns on the pick-up percentage and, consequently, the coating performance.

Figure 4 shows the cover factor of core-spun yarns after conducting the method proposed for simulating the abrasion process. The results revealed that the coating of the core-part by the PCD method could improve the cover factor of core-spun yarns in the simulated mechanical abrasion process as compared to conventional core yarns. Moreover, by increasing the nip pressure in PCD, there is more pick-up of core parts, causing an increase in the abrasion resistance of the core-spun yarns. It was also noticeable that the increase in the abrasion resistances of 111 dtex polyester/cotton core-spun yarns was more than those of 44 dtex polyester/cotton core-spun yarns. The difference between the cover factors of yarns 0/111 and 2/111 after abrasion was 5.25%, compared to 4.34% for yarns 0/44 and 2/44. The statistical evaluation at a 95% significance level showed that there is a significant difference between the cover factor of core-spun yarns before and after the abrasion process.

Table 5 shows the mean mass loss values of the fabrics after four different abrasion cycles. The results showed the better abrasion resistance of the fabrics with coated samples. The difference between the mass loss of samples F/0/111 and F/2/111 after 9000 abrasion cycles was 1.14 g, and for samples F/0/44 and F/2/44 it was 1.53 g. The surface change

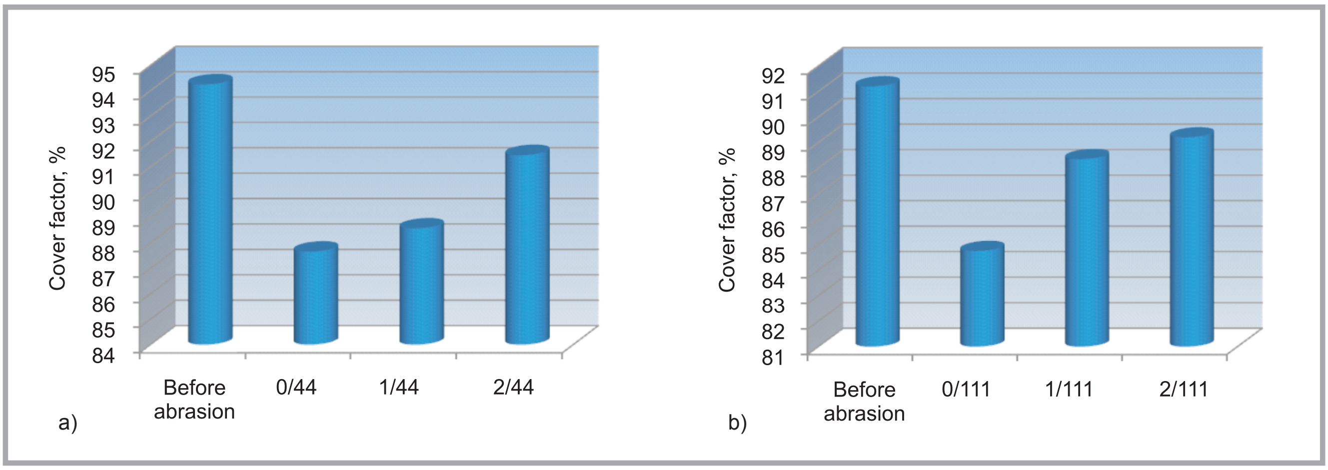

Figure 4. *Cover factor of core-spun yarns after the abrasion process: a) 44 dtex polyester core-spun yarn samples and b) 111 dtex polyester core-spun yarn samples.*

of the core part and more entanglement of fibre of the core part with sheath fibre, which might decrease sheath fibre separation from the yarn structure during the abrasion process, could be the main factors that might improve the abrasion resistance of woven fabric using modified yarns.

The pilling ranking of the fabric samples is given in ***Table 6*** (see page 30). The results obtained demonstrated that the coating process had a positive effect on the pilling resistances of the samples. This effect was dominant in 2000 abrasion cycles, and there was no difference in the pilling of samples after 125 abrasion cycles. Once again this phenomenon could be attributed to the more entanglement of core and sheath fibres in the yarn structure as a result of changes in the surface properties of core fibres, as shown in the SEM images. It seems that in sample F/1/44, the coating of the core part did not have a clear effect on the pilling of woven fabrics.

Conclusions

In this preliminary work, a simple method of increasing the sheath slipping resistance of core-spun yarns by surface modification of the core part is proposed. The results obtained did not show the negative effect of coating the core part on the tensile properties of core-spun yarns. Although the cover factor of samples increased marginally after simulation of the abrasion process, the pilling and abrasion resistance of woven samples showed the effectiveness of this method. It seems that the nip pressure of the pad method has to be considered carefully to get the optimum condition of coating, especially when fine core yarns are used. In the future, we aim to work on the effect of the kind of core part, the interaction between core and sheath materials, the kind of binder, and nip pressure of the PDC method in detail, and we will use statistical and artificial intelligence algorithms to get the optimum condition for yarn production. Finally, designing an on-line system containing a padding system and a heating chamber on a ring spinning frame will be a useful method to produce these yarns with modified properties.

References

1. *Pourahmad A., Johari M. S.; Production of Core-Spun Yarn by the Three Strand Modified Method, The Journal of the Textile Institute, 2009, Vol. 100, No. 3, pp. 275-281.*
2. *Ruppenicker G. F., Harper R. J., Sawhney A. P., Robert K. Q.; Comparison of Cotton/Polyester Core and Staple Blend Yarns and Fabrics, Textile Research Journal, 1989, Vol. 59, No. 1, pp. 12-17.*
3. *Harper R. J., Ruppenicker G. F., Donaldson D.; Cotton Blend Fabrics from Polyester Core Yarns, Textile Research Journal, 1986,February, 1986, pp. 80-86.*
4. *Sawhney A. P. S., Ruppenicker G. F.; Special Purpose Fabrics Made with Core-Spun Yarns, Indian Journal of Fibre and Textile Researches,1997, Vol. 22, December, pp. 246-254.*
5. *Pramanik P., Patil V. M.; Physical Characteristics of Cotton/Polyester Core Spun Yarn Made Using Ring and Air-jet Systems, AUTEX Research Journal, 2009, Vol. 9, No. 1, pp. 14-19.*
6. *Sawhney A. P. S., Ruppenicker G. F., Robert K. Q.; Cotton Covered Nylon-Core and Greige Fabrics, Textile Research Journal, 1989, April, pp. 185-190.*
7. *Ruppnicker G. F., Harper R. J., Sawhney A. P., Robert K. Q.; Comparison of Cotton/Polyester Core and Staple Blend Yarns and Fabrics, Textile Research Journal, 1999, January, pp.12-17.*
8. *Balasubramanian N., Bhatnagar V. K.; The Effect of Spinning Condition on the Tensile Properties of Core –Spun Yarns, The Journal of The Textile Institute, 1970, Vol. 61, No. 11, pp. 534-554.*
9. *Tarafder N., Chatterjee S. M.; Influence of Controlled Pretension of the Core on the Hairiness of Cotton Nylon Core Spun Yarns, Indian Journal of Textile Research, 1989, Vol. 14, No. 12, pp. 155-159.*
10. *Jeddi A. A. A., Johari M. S., Merati A.; A Study of the Structural and Physical Properties of Cotton-Covered Nylon Filament Core-Spun Yarns, 1997, Vol. 88, part. 1, No.1, pp. 12-20.*
11. *Miao M., How Y. L., Ho S. Y.; Influence of Spinning Parameters on Core Yarn Sheath Slippage and other Properties, Textile Research Journal, 1996, Vol. 66, No. 11, pp. 676-684.*
12. *Sawhney A. P. S., Ruppenicker G. F., Kimmel L. B., Robert K. Q.; Comparison of Filament-Core Spun Yarns Produced by New and Conventional Methods, Textile Research Journal, 1992, Vol. 62, No. 2, pp. 67-73.*
13. *Sawheny A. P. S., Robert K. Q., Ruppenicker G. F., Kimmel K. B.; Improved Method of Producing a Cotton/Polyester Staple-Core Yarn on a Ring Spinning Frame, Textile Research Journal, 1992, Vol. 62, No. 1, pp. 21-25.*
14. *Louis G. L., Salaun H., Kimmel L. B.; Ring Spun all Staple Core-Warp Yarn – a Progress, Textile Research Journal, 1989, Vol. 59, No. 4, pp. 244-246.*
15. *Jou G. T., East G. C., Lawrence C. A., Oxenham W.; The Physical Properties of Composite Yarns Produced by an Electrostatic Filament-Charging Method, The Journal of the Textile Institute,1996, Vol. 87, No. 1, part 1, pp. 78-96.*
16. *American Society for Testing Materials, ASTM-D2256, Standard Test Method for Tensile Properties of Yarns by the Single-Strand Method.*
17. *American Society for Testing Materials, ASTM-D4966, Standard Test Method for Abrasion Resistance of Textile Fabrics (Martindale Abrasion Tester Method).*
18. *American Society for Testing Materials, ASTM-D4970, Standard Test Method for Pilling Resistance and Other Related Surface Changes of Textile Fabrics: Martindale Tester.*

Received 29.06.2010 Reviewed 20.04.2011