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Comparative Study on Carded Cotton Yarn Properties Produced by the Conventional Ring and New Modified Ring Spinning System

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Abstract

In this paper, the properties of yarns which were produced by using a modified ring spinning system (ProSPIN®) and conventional ring spinning system were comparatively investigated. The modified spinning system which was used in yarn production has basically the characteristic of compact spinning system and is at present used especially in the production of mid-count yarns. In this study, conventional ring yarns and equivalent modified ring spun yarns were produced with different yarn counts and twists using 100% carded cotton raw material. Tests were conducted to determine the tensile, unevenness, imperfection and hairiness properties of the yarns. It was found that the modified ring spun yarns showed considerable positive differences in some yarn properties compared with conventional ring yarns. The differences in tenacity values were more evident especially in yarns with lower twist coefficients, while differences in hairiness values were more so in finer yarns. Also the unification of two separate and compacted fibre strands during yarn formation ensures better values for both mass irregularity and IPI because of the doubling effect.

Key words: *carded cotton, ring spinning, modified ring spinning, tensile, unevenness, hairiness.*

Introduction

Staple yarn spinning systems can be divided into three groups: ring spinning, new spinning systems and modified ring spinning systems.

Ring spinning, which has a history of 200 years, is the oldest and most common production system in all staple yarn spinning. Because of the yarn strength, availability of fibre raw materials and flexibility of yarn count range that can be produced in particular, ring spinning is still clearly ahead of all staple yarn spinning systems [1-7].

Since about 50 years of experience, there have been systems such as open end rotor spinning, friction spinning, air jet spinning, which are known as new spinning methods, as an alternative to ring spinning, especially due to its limited production speed [3]. These systems can be characterized by high production speed, fewer processing steps and high automation capabilities. The general disadvantages of the new spinning systems are; partial weaknesses with respect to yarn strength, limitations on usable fibre raw materials and yarn count range that can be produced [8].

Modified ring spinning systems are the ones which include modifications either on the drafting systems of ring spinning frames or at the exit of the drafting zones. Compact, Sirospun®, compact-siro, Solospun®, nozzle-ring and core-sheath spinning can be given as examples of these spinning systems. If the restrictive effect of the traveller on production speed is taken into consideration, the target of modified ring spinning systems is to improve the yarn properties obtained, especially strength and hairiness, rather than to increase the production speed [3, 4, 6, 9-11].

In conventional ring spinning (***Figure 1***), the zone between the nip line (N-N^1) of the pair of delivery rollers and the twisted end of the yarn is called the ‘spinning triangle’. The width of the spinning triangle (B) depends mainly on the spinning tension, which varies inversely with the tension. Also it is always narrower than the width of the fibres fed (A), which represents the critical weak spot of the ring spinning process [1, 9, 10, 12]. In this zone, the fibre assembly contains no twist. The edge fibres splay out from this zone and make little or no contribution to the yarn strength. Furthermore the edge fibres lead to the familiar problem of yarn hairiness. Additionally the fibres in the spinning triangle are twisted into yarn under unequal tension (maximum at the edge and minimum at the centre of the spinning triangle) [1, 9, 10, 13]. This also causes a decrease in yarn strength. In this manner; the elimination or minimisation of the spinning triangle has become the most important solution for the improvement of yarn properties. The effects of Sirospun and Solospun systems, especially for compact spinning, are realised through the spinning triangle [6, 13-16].

The compact spinning principle is based on the compacting of the fibre strand at the exit of the drafting system of the ring spinning machine. In compact spinning, which was introduced at the end of the 1990’s, the spinning triangle is nearly or completely eliminated, and almost all fibres are incorporated into the yarn structure under the same tension. This leads to significant advantages such as increasing yarn tenacity and yarn abrasion resistance and reducing yarn hairiness [1, 9, 10, 17, 18, 30]. There are different

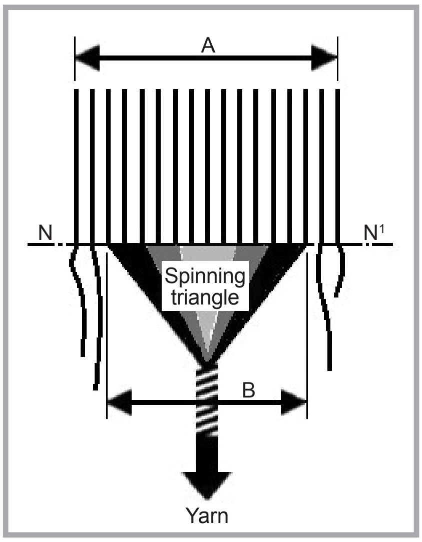

Figure 1. *Spinning triangle formation in conventional ring spinning.*

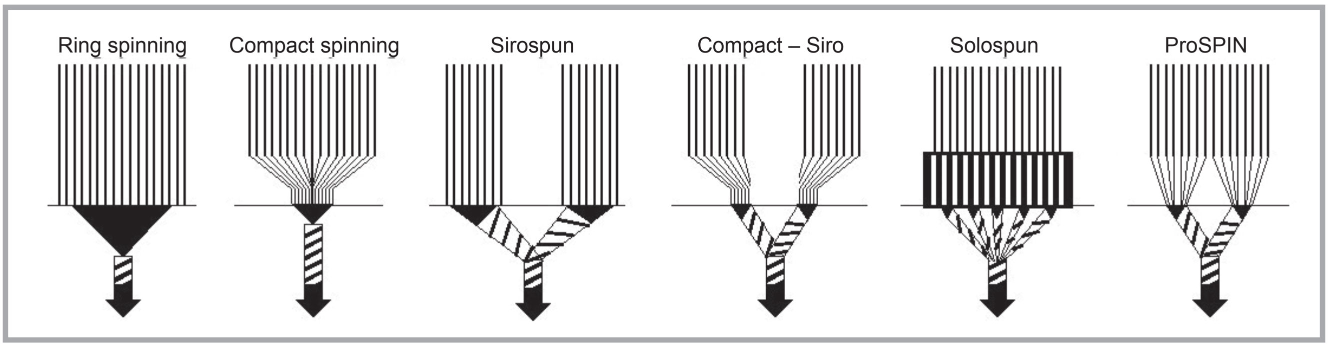

Figure 2. *Spinning triangle formations in different spinning systems.*

Table 1. *Fibre properties.*

Quality parameters	Mean
Micronaire	4.60
Fibre length, UHML in mm	30.11
Uniformity index	84.30
Short fibre, %	4.90
Tenacity, cN/tex	30.05
Elongation at break, %	7.10

compact spinning systems produced by different spinning machine manufacturers. The main differences among these systems are the condensing principle and condensing unit design. At present, most of the compact spinning systems use the pneumatic principle; however, the system using the mechanic-magnetic principle is an important alternative. The system is cheaper, less complicated than using pneumatic systems, and does not need additional energy (pressurized air) consumption [19].

Sirospun, which was introduced at the beginning of the 1980's, is a ring spinning system modified by dividing the original one-ring spinning triangle into three, including two primary spinning triangles and one final triangle. In this system; two rovings are fed into the apron zone at a predetermined separation simultaneously, and two fibre strands come from the draft zone and enter the nip of the front roller. Then a primary twist is imposed on those two fibre strands, where two smaller primary triangles are produced. Finally two strands are twisted into a Sirospun yarn by a final twist, and the corresponding final triangle is produced [15]. The twist direction of the final yarn obtained in this system is the same as that of the substrands. The Sirospun yarn structure more closely resembles that of a single yarn than that of a two-fold yarn, with the additional features of increased abrasion resistance and reduced yarn hairiness [20]. At the beginning of the 2000's, a new spinning system emerged which would be called 'compact-siro', in which compact and Sirospun spinning were combined [21].

Solospun, introduced in 1998, was greatly facilitated by the experience gained during the development and implementation of the previous Sirospun spinning technology [22]. In Solospun, the drafted ribbon, instead of being compacted, is divided into substrands that form the spinning triangle. At the apex of the triangle(s), the strands are twisted together, similar to the plying of several yarns. This confers better integration of the edge fibres as fibres are trapped within and between strands [7]. As a result, Solospun is a less hairy and stronger yarn than conventional ring spun yarn [11].

In this paper, a newly developed modified ring spinning system was used in yarn production together with a conventional ring spinning system. The modified ring spinning system considered in this study, called "ProSPIN$^{®}$", was developed, patented [23-25] and commercialised in 2016 by Ozdilek Inc. in Turkey. In ProSPIN, the roving which is fed into the drafting system of the ring spinning frame is separated into two strands by the use of a specially designed compactor. Later the two separate and compacted fibre strands are unified by the twist to form a yarn. In this respect, the ProSPIN system can be regarded as a combination of the compact, Sirospun and Solospun systems. When the yarn formation zone, which has the greatest effect on yarn properties, is considered, it can be concluded that the ProSPIN system has a primarily compact-siro spun character. Thus the principle of the ProSPIN system also depends on changing the formation of the spinning triangle in conventional ring spinning. ***Figure 2*** schematically presents spinning triangle formations in the above-mentioned different spinning systems. Due to the restriction of roving traverse movement, cots quickly abrade in all compact spinning systems. The ProSPIN system has cot protection equipment for the elimination of abrasion of the front top cot of the drafting system. This paper presents comparative data on yarn properties derived from conventional ring spinning and the ProSPIN system.

Experimental

Yarn production

Rovings made from 100% carded cotton fibres of Greek origin were used in the experimental part. Rovings were of 809 tex count and had a twist coefficient of $\alpha_m = 36$. Mean values of cotton fibre (taken from bales) properties measured with an Uster HVI 900A testing machine (Uster Technologies AG, Switzerland) are presented in ***Table 1***.

Yarns were produced at 4 different yarn counts (49.2 tex, 36.9 tex, 29.5 tex and 21.1 tex) and at 2 different twist levels ($\alpha_m = 106$ and $\alpha_m = 124$). Conventional ring yarns were produced on a Rieter G33 ring spinning machine, and equivalent ProSPIN yarns were produced on the same machine after modification. ***Figure 3*** presents a ring spinning machine modified with ProSPIN, and ***Figure 4*** shows the ceramic compactor used in this study and a view of the yarn forming zone. The compactor was designed for the production of yarns coarser than 20 tex. During yarn production, the same rovings and spindles were used in order to eliminate any possible effect originating from the rovings and spindles on yarn quality properties. The codes and some important production parameters of the yarns are presented in ***Table 2***.

Tests applied to yarns

Tests were performed on the yarns of 16 different types produced to assign

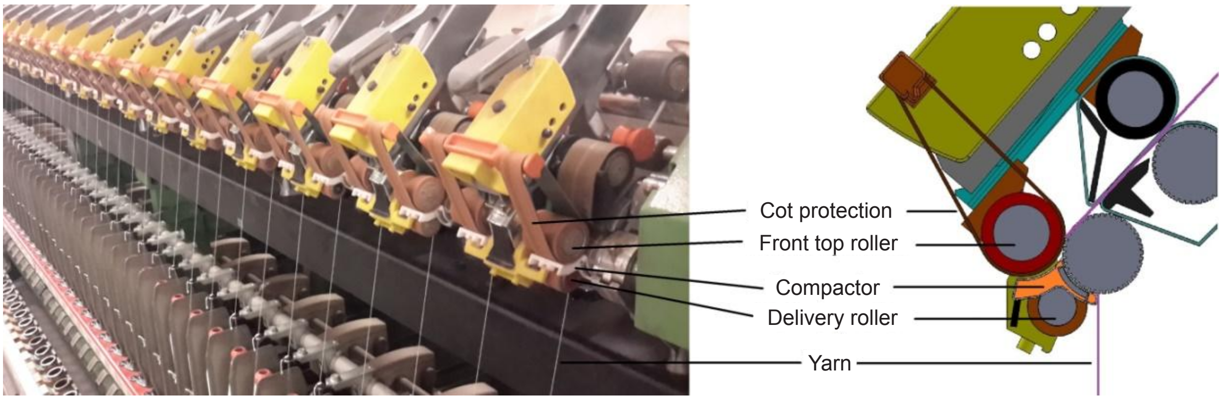

Figure 3. *Ring spinning machine modified with ProSPIN.*

their properties. Tensile properties of the yarns were measured using an Uster Tensojet 3 (Uster Technologies AG, Switzerland) (for each yarn type, a total of 12 tests from 6 bobbins were performed at a 200 m/min test speed and 2 min test intervals). Mass irregularity, yarn imperfections and hairiness (Uster H) properties were measured using an Uster Tester 3 (Uster Technologies AG, Switzerland) (for each yarn type, a total of 12 test from 6 bobbins were performed at a 400 m/min test speed and 1 min test intervals). Zweigle S3 hairiness values were obtained with a Zweigle G567 (Zweigle, Switzerland) (for each yarn type, a total of 6 test were performed from 3 bobbins at a 100 m/min test speed and 2 min test intervals). To obtain images of the yarns produced, a TESCAN MAIA3 XMU model Scanning Electron Microscope (SEM) (Tescan, Czech Republic) was used at a magnification ratio of 100X. Before the tests, the yarn samples were preconditioned at standard conditions (20 ± 2 °C temperature, 65% ± 2 relative humidity) for 24 hours. Test results of the yarns in the same yarn group (ProSPIN and conventional ring) were evaluated statistically by applying the t-test, which is an analysis method used for the comparison of two means.

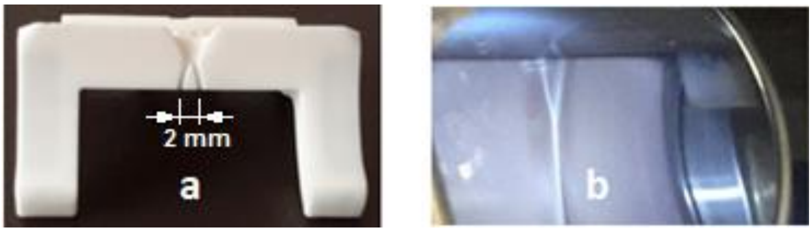

Figure 4. *Compactor (a) and yarn forming zone, (b) at the exit of the compactor.*

Results and discussion

Differences between the structures of ProSPIN and ring yarns and their corresponding hairiness could be observed from the SEM images in ***Figure 5*** (for 49.2 and 36.9 tex) and in ***Figure 6*** (for 29.5 and 21.1 tex). When the photographs were examined visually, it was observed that ProSPIN yarns had a more compact and even fibre alignment when compared with the corresponding conventional ring yarns.

Test results (mean values and error bars) of the yarns are given in ***Figures 7-12***. Results of the statistical analysis performed on the properties of conventional ring and ProSPIN yarns are presented in ***Table 3***.

Tensile properties

The tenacity and elongation at break values of the yarns were compared in graphical form in ***Figures 7*** and ***8,*** respectively. When a comparison was made between ProSPIN and conventional ring spun yarns in the same group, it was observed that ProSPIN yarns had breaking tenacity values of up to 6.0-14.6% higher than for conventional ring spun yarns,

Table 2. *Codes and some important production parameters of the yarns.*

Yarn group	Yarn code	Spinning system	Nominal yarn count, tex	Nominal twist coeff., α_m	Spindle speed, rpm	Traveller type	Ring diameter, mm
12L	R12L	Ring	49.2	106	10671	C1 HRMT 125	45
	P12L	ProSPIN					
12H	R12H	Ring	49.2	124	12500	C1 HRMT 125	45
	P12H	ProSPIN					
16L	R16L	Ring	36.9	106	12378	C1 HRTW 85	45
	P16L	ProSPIN					
16H	R16H	Ring	36.9	124	14500	C1 HRTW 85	45
	P16H	ProSPIN					
20L	R20L	Ring	29.5	106	12805	C1 HRTW 60	45
	P20L	ProSPIN					
20H	R20H	Ring	29.5	124	15000	C1 HRTW 60	45
	P20H	ProSPIN					
28L	R28L	Ring	21.1	106	13232	EL1 HDW 50	45
	P28L	ProSPIN					
28H	R28H	Ring	21.1	124	15500	EL1 HDW 50	45
	P28H	ProSPIN					

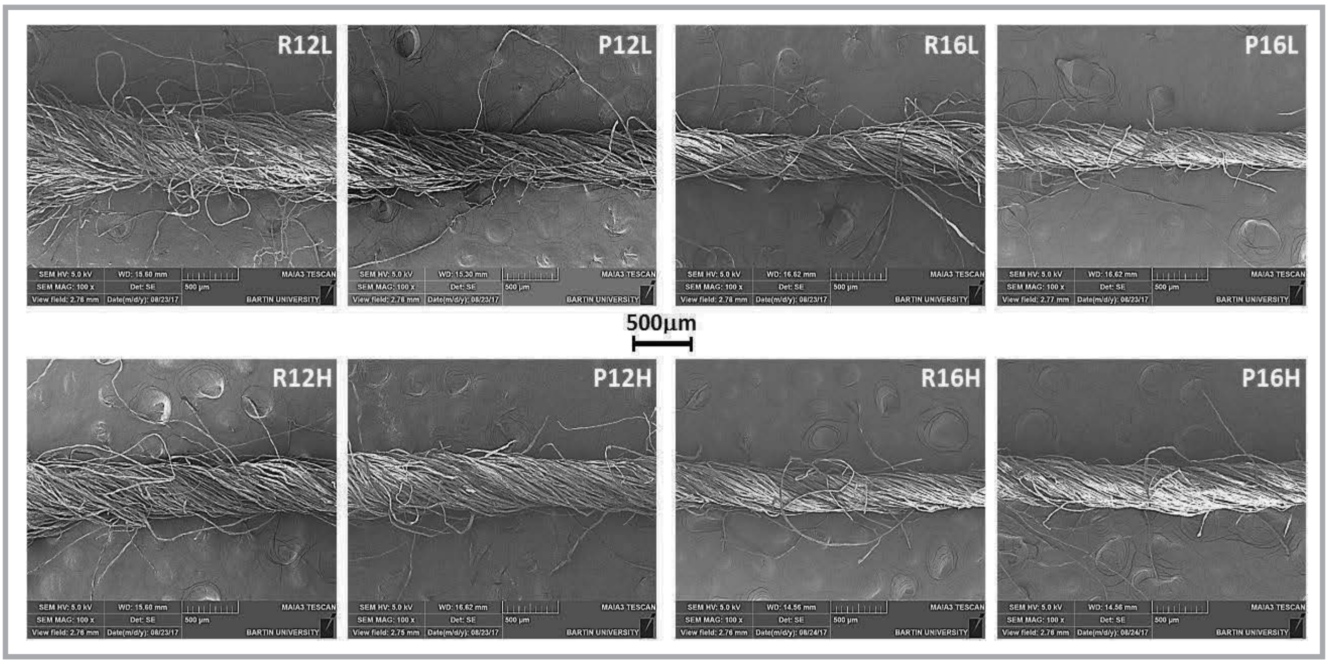

Figure 5. SEM images of 49.2 tex and 36.9 tex yarns.

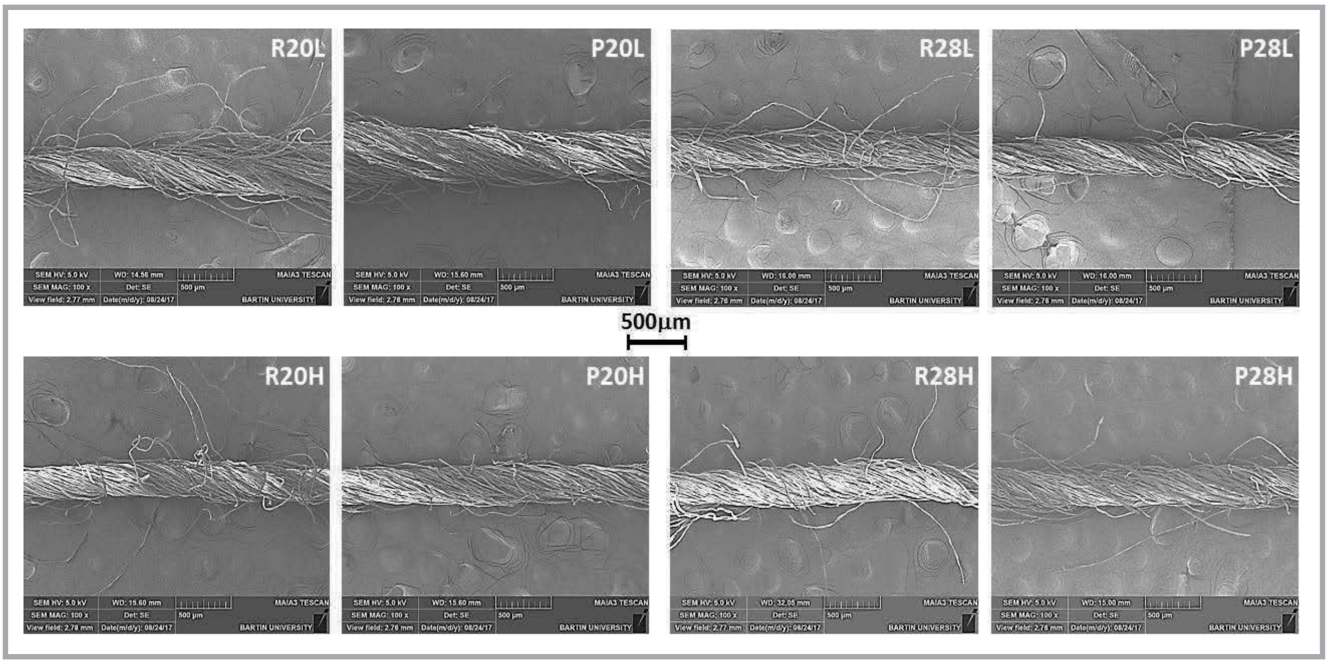

Figure 6. SEM images of 29.5 tex and 21.1 tex yarns.

Table 3. *Test results (p values) of t-test analysis.* ***Note:*** *^{ns} non significant, * there is a statistically significant difference at $\alpha = 0.05$.*

	Yarn group, *tex/a_m*							
	12L *(49.2/106)*	**12H** *(49.2/124)*	**16L** *(36.9/106)*	**16H** *(36.9/124)*	**20L** *(29.5/106)*	**20H** *(29.5/124)*	**28L** *(21.1/106)*	**28H** *(21.1/124)*
Tenacity, cN/tex	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*
Elongation at break, %	0.266^{ns}	0.121^{ns}	0.876^{ns}	0.136^{ns}	0.000*	0.645^{ns}	0.000*	0.000*
%CV$_m$	0.000*	0.000*	0.001*	0.000*	0.000*	0.000*	0.002*	0.000*
IPI	0.000*	0.000*	0.053^{ns}	0.000*	0.001*	0.000*	0.020*	0.000*
Uster H	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*
Zweigle S3	0.000*	0.000*	0.001*	0.000*	0.002*	0.001*	0.002*	0.000*

and the differences observed in tenacity were statistically significant.

In the ProSPIN system, the delivery of two fibre strands through a narrow exit in a condensed form minimises the formation of the spinning triangle. Thus a more even fibre integration and more uniform fibre tension in the yarn structure is obtained. This is an expected and known result of the minimised spinning triangle, ensuring a higher tenacity of ProSPIN yarns than that of conventional ring yarns. Another finding with respect to the tenacity results implied that the tenacity differences between ProSPIN and ring yarns became higher especially for yarns which had lower twist coefficients. This result is compatible with some other researches in which the compact and compact-siro systems were compared with the conventional ring spinning system [9, 26, 27]. The reason for this situation may be explained as follows: The fibres that constitute the yarn structure align in the direction of the fibre length and altogether in the form of a rope in the spinning of compact yarns. Because of this behaviour, the twist-tenacity curve of compact yarns loses its slope at lower twist levels as compared with ring spun yarns. According to this, the tenacity increasing effect of twist in compact yarns begins at lower twist coefficient levels than for ring yarns. Some researchers have pointed out that compact yarns attain a maximum breaking tenacity approximately 20 α_m lower than for ring spun yarns. This situation also ensures that compact yarns are spun at lower twist coefficients, which cannot be achieved for ring spun yarns [12, 28].

When a comparison was made among the elongation at break values of the yarns, ProSPIN yarns showed differences between -1.7% and 9.5% when compared to ring yarns. These differences were not statistically significant in many yarn groups. Regarding the elongation at break values, obvious and statistically significant differences were observed only at 21.1 tex count yarns.

Yarn irregularities and yarn faults

The mass irregularity and fault IPI values of the yarns were compared in graphical form in ***Figures 9*** and ***10,*** respectively. When the unevenness test results were considered, it was observed that ProSPIN yarns had better mass irregularity results up to 11.8% than ring spun yarns in the

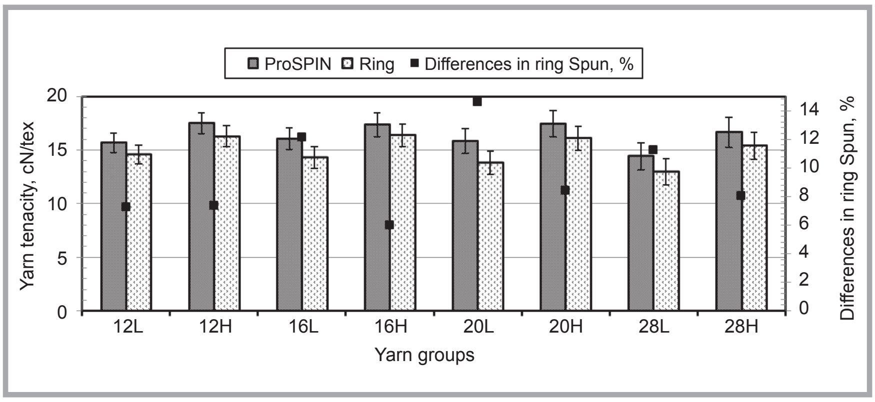

Figure 7. *Tenacity values of yarns.*

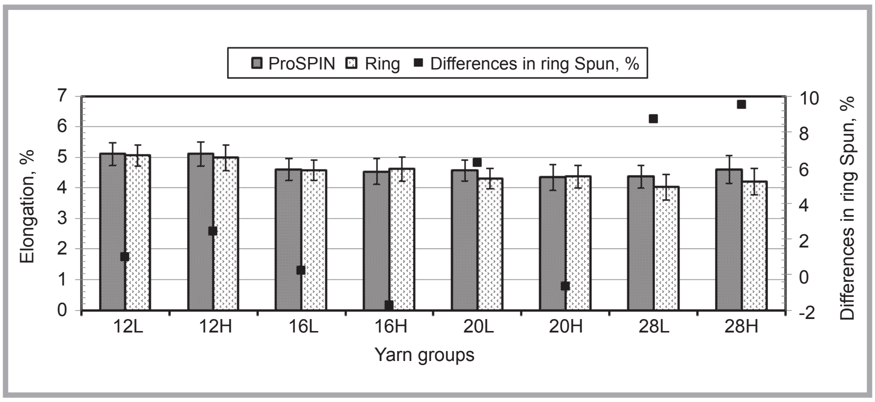

Figure 8. *Elongation at break values of yarns.*

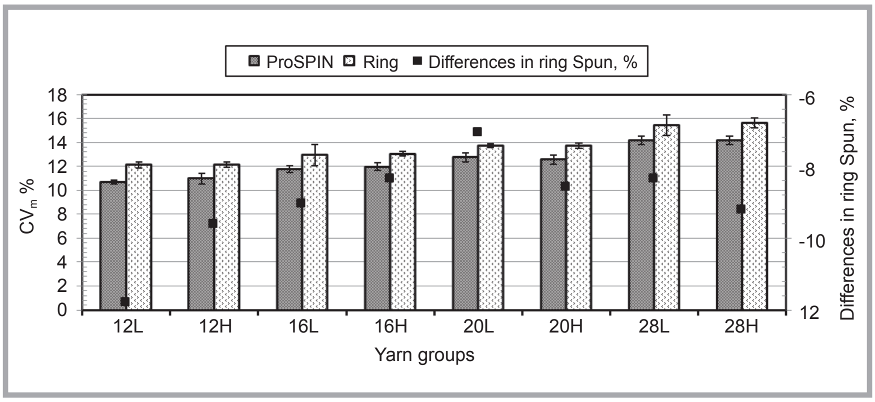

Figure 9. *CV_m % values of yarns.*

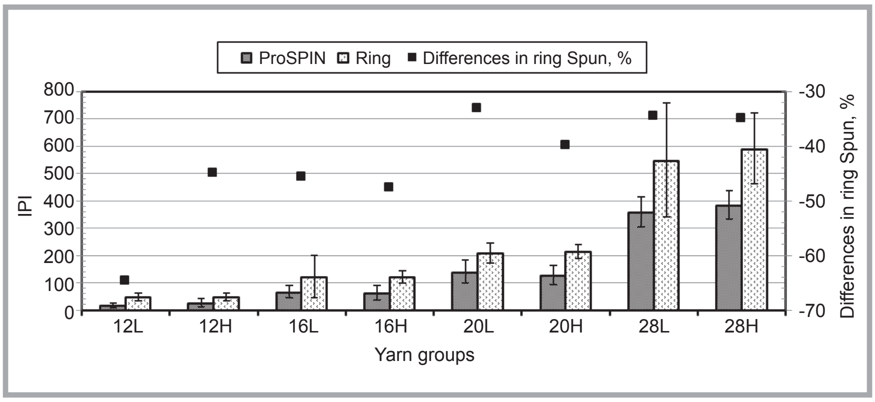

Figure 10. *IPI values of yarns.*

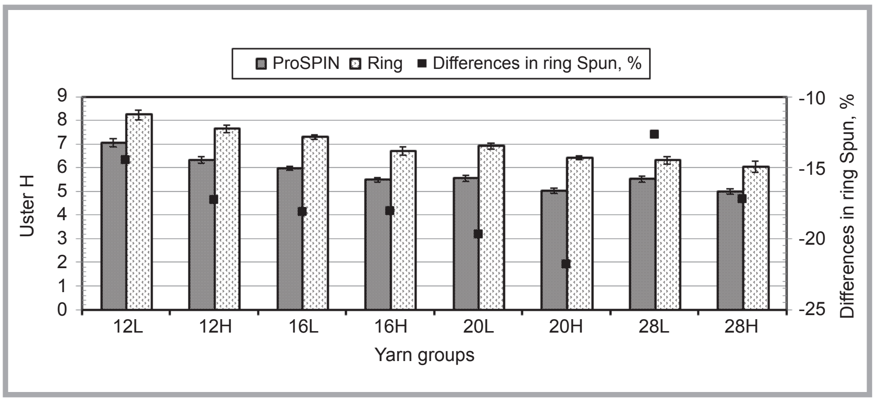

***Figure 11.** Hairiness (Uster H) values of yarns.*

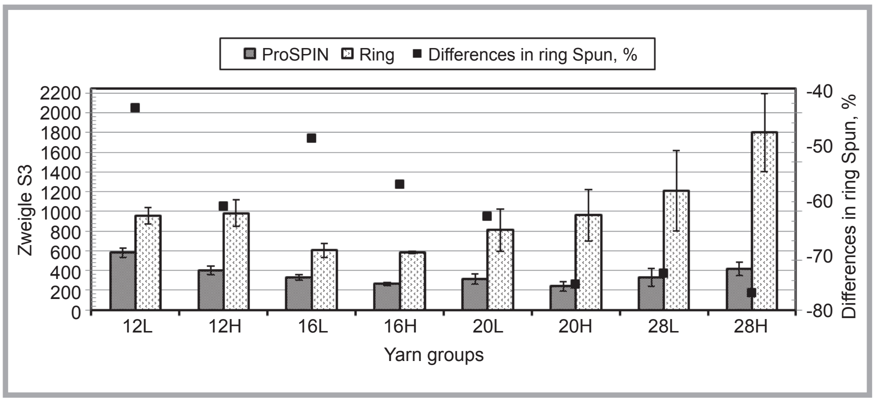

***Figure 12.** Hairiness (Zweigle S3) values of yarns.*

same yarn group. The differences observed in the mass irregularity values of ProSPIN and ring yarns were statistically significant. The lower mass irregularity of ProSPIN yarns than that of conventional ring yarns could be the result of the unification of two separate and compacted fibre strands during yarn formation (doubling effect) [29].

IPI values are the cumulative number of thin places (-50%), thick places (+50%) and neps (+200%) present per 1000 meters of yarn. When the IPI values were taken into consideration, it was observed that ProSPIN yarns had between 33.0% and 64.6% lower IPI values than ring yarns. Except for only one yarn group (36.9 tex, α_m = 106), the differences observed in IPI values between the two different yarn types were statistically significant. Regarding this result, it could be stated that the differences between ProSPIN and ring yarns became slightly more evident as yarn counts decrease (as yarns became coarser). Considering the IPI values, the lower imperfection values of ProSPIN yarns than those of conventional ring yarns could be related to the doubling effect.

Hairiness properties

The Uster Hairiness Index (Uster H) and Zweigle S3 (total number of 3 mm and longer hairs) hairiness values of the yarns are shown in ***Figures 11*** and ***12*** respectively. When both H and S3 values of the yarns produced were taken into account, it was observed that ProSPIN yarns have lower hairiness than ring spun yarns. It could be seen from ***Figures 11*** and ***12*** that the differences between H values of ProSPIN and ring yarns were up to 21.8%, almost lying in a similar numerical range. However, the differences in S3 values were up to 76.8%, being more evident for thin yarns. According to the statistical values obtained for both H and S3, the hairiness differences between ProSPIN yarns and ring spun yarns showed statistically significant differences. The lower Uster H and Zweigle S3 hairiness values of ProSPIN yarns than those of conventional ring yarns could stem from the higher fibre integration of compacted fibre strands in yarn formation. Besides this, the Siro effect could be another factor which ensures that fibres are better integrated in the yarn structure, causing the hairiness to decrease [31].

The hairiness results also showed that the more effective and easier compactibility of finer fibre strands ensured higher differences in Zweigle S3 values between ProSPIN and conventional ring yarns.

Conclusions

In the ProSPIN system, the roving which is fed into the drafting system is separated into two branches by the use of a special compactor which is placed at the end of the drafting system. Then the two separate and compacted fibre strands are unified by the twist to form the yarn. Thus it can be stated that the system is a combination of the compact, Sirospun and Solospun systems. It can also be concluded that the ProSPIN system combines the advantageous aspects of these three systems.

The system has a similar function to the compacting principle of Rotorcraft RoCoS®, and there is no additional energy cost during the operation. Also, similar to the RoCoS, the installation of ProSPIN is simpler than for other compact spinning systems. Additionally it can be said that the cot protection equipment of ProSPIN would ensure low maintenance costs.

In the ProSPIN system, the separation of the drafted fibre strand into two equal substrands is of utmost importance for spinning breaks and yarn properties. In this system, there is a fine adjustment mechanism which determines the position of the compactor. However, difficulties will be encountered in the separation of the drafted fibre strand when finer yarns are going to be produced. Regarding this, the ProSPIN system can be used in the production of mid- and mid-coarse count yarns, which are not commonly produced with conventional compact spinning systems. In this study, 49.2-21.1 tex count conventional and ProSPIN yarns were produced, and during production, although detailed data were not collected, no negative effect on spinning breakages was observed in spinning with ProSPIN. Moreover it could be said that fewer breakages were observed during yarn production with ProSPIN.

When all the yarn properties investigated in the paper were taken into account, it was observed that ProSPIN yarns had better values than ring yarns, especially for breaking tenacity and hairiness. Differences in the tenacity values were more evident especially in yarns with lower twist coefficients, while differences in hairiness values were more evident in finer yarns. It was feasible to predict that the compactor which divides the strand into two substrands may disturb the fibre flow and order before unification prior to twist, which would cause a negative effect on yarn faults. However, the better mass irregularity and IPI values of ProSPIN yarns ensured that such a negative effect did not occur. On the contrary, the unification of two separate and compacted fibre strands during yarn formation ensures better values for both mass irregularity and IPI because of the doubling effect.

As a result, obvious improvements were obtained in yarn properties with ProSPIN when compared with conventional ring spinning. In further studies, the effects of the differences in yarn properties on weaving, knitting and finishing processes together with fabric performance characteristics will be researched. ❑

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References

1. Stalder H. New spinning process ComforSpin®. *Melliand International* 2000; 6, 2: 22-25.
2. Biermann I., Knick A. Rieter Com4® yarns. *Rieter Documentation* 2016; pp. 36.
3. Cheng KPS, Yu C. A study of compact spun yarns. *Textile Research Journal* 2003; 73, 4: 345-349.
4. Xia Z, Xu W. A review of ring staple yarn spinning method development and its trend prediction. *Journal of Natural Fibers* 2013; 10,1: 62-81.
5. Stalder H. Compact spinning-a new generation of ring spun yarns. *Melliand English* 1995; 3: 29-33.
6. Lawrence CA. *Advances in Yarn Spinning Technology.* Woodhead Publishing. Cambridge, UK, 2010, pp. 463.
7. Lawrence CA. *Fundamentals of Spun Yarn Technology*. CRC Press, Boca Raton, USA, 2003, pp. 509.
8. Stalder H. *Alternative Spinning Systems*. The Rieter Manual of Spinning, 2011, pp. 60.
9. Kadoglu H. Quality aspects of compact spinning. *Melliand International* 2001; 7, 1, 23-25.
10. Olbrich A. The Air-Com-Tex 700 condenser ring spinning machine. *Melliand International* 2000; 6, 26-29.
11. Prins M W, Lamb P R, Finn N. Solospun-the long-staple weavable singles yarn. *In: Proc Textile Institute 81st World Conference* April, 2001, Melbourne, Australia.
12. Artzt P. Possibilities of improving the efficiency of compact spinning. *Melliand English* 2002; 3: 19-21.
13. Hechtl R. Compact spinning system-an opportunity for improving the ring spinning process. *Melliand English* 1996; 77, 4: 37-38.
14. Beceren Y, Nergis B U. Comparison of the effects of cotton yarns produced by new, modified and conventional spinning systems on yarn and knitted fabric performance. *Textile Research Journal* 2008; 78, 4: 297-303.
15. Liu X, Liu N, Su X. Research on mechanical properties of the siro-spinning triangle using the finite element method. *Textile Research Journal* 2015; 85, 4: 416-431.
16. Soltani P, Johari M S. A Study on siro, solo, compact, and conventional ring spun yarns. Part I: Structural and migratory properties of the yarns. *Journal of the Textile Institute* 2012; 103, 6: 622-628.
17. Omeroglu S, Ulku S. An investigation about tensile strength, pilling and abrasion properties of woven fabrics made from conventional and compact ring-spun yarns. *FIBRES & TEXTILES in Eastern Europe 2007;* 15, 1: 39-42.
18. Goktepe F, Yilmaz D, Goktepe O. A comparison of compact yarn properties produced on different systems. *Textile Research Journal* 2006; 76, 3: 226-234.
19. Altas S, Kadoglu H. Comparison of conventional ring, mechanical compact and pneumatic compact yarn spinning systems. *Journal of Engineered Fibers and Fabrics* 2012; 7, 1: 87-100.
20. Najar SS, Khan ZA, Wang XG. The new solo-siro spun process for worsted yarns. *Journal of the Textile Institute* 2006; 97, 3: 205-210.
21. Su X, Gao W, Liu X, Xie C, Bojun Xu. Research on the compact-siro yarn structure. *FIBRES & TEXTILES in Eastern Europe* 2015; 23, 3, 111: 54-57.
22. https://csiropedia.csiro.au/solospun/, access date: October 2017.
23. WO 2010114503. In yarn production, apron cladding mechanism and method to the rollers coated with elastic material and found in the drafting and guiding zone, having shift structure and pre-tensioning mechanism.
24. WO 2011084113. Spinn twist yarn production system.
25. www.prospin.com.tr, access date: October 2017.
26. Hossoy, I. *Comparison of compact and conventional ring spinning systems.* MSc Thesis, Unpublished, Istanbul Technical University, 2001, pp. 58.
27. Omeroglu, S. An investigation about the comparison of compact and ring yarn properties. *Proc. International Scientific Conference* 2004, Gabrovo, Bulgaria.
28. Brunk K N. *Three years of practical experience with the EliTe^{a} CompactSet in short-staple spinning*. Spinnovation 2002, 3, 3, 11.
29. Brunk K N. EliTe compact set-the versatile method of yarn compaction. *Melliand International* 2004; 10, 1: 24-26.
30. Bedez Ute, T. A comparative study between the dynamic friction characteristics of compact and siro yarns. *Tekstil ve Konfeksiyon 2016;* 26, 1: 55-63.
31. Soltani P, Johari M S. Effect of strand spacing and twist multiplier on structural and mechanical properties of siro-spun yarns. *Fibers And Polymers 2012;* 13, 1: 110-117.

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