A comparative analysis of air-jet yarn properties with the properties of ring spun yarns

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REZUMAT – ABSTRACT

Analiză comparativă între proprietățile firelor filate cu jet de aer și proprietățile firelor filate cu inele

Filarea cu inele este cea mai obișnuită metodă utilizată dintre metodele de filare a fibrelor scurte. Din cauza limitărilor vitezei de producție a filării cu inele, noile metode de filare devin din ce în ce mai populare. Dintre noile metode de filare, sistemele de filare cu jet de aer au atras atenția prin cota lor de piață. În acest studiu, proprietățile firelor filate cu jet de aer au fost analizate comparativ cu proprietățile firelor filate cu inele echivalente, atât pentru firele unice, cât și pentru cele cu fire răsucite. S-a constatat că firele filate cu jet de aer pe mașinile de filat Rieter și Murata nu prezintă diferențe semnificative în ceea ce privește proprietățile fizice. Datorită structuriilor speciale, firele filate cu jet de aer prezintă valori mai mici ale pilozității și ale tenacității în comparație cu firele filate cu inele, echivalente.

Cuvinte-cheie: fir filat cu jet de aer, mașină de filat Murata Vortex, filare cu jet de aer Rieter, fir filat cu inele, proprietățile firului

A comparative analysis of air-jet yarn properties with the properties of ring spun yarns

Ring spinning is the most common method used among the short staple fibers spinning methods. Due to limitations of the production speed in the ring spinning, new spinning methods become more popular with each passing day. Air-jet spinning systems gathered attention with their market share in the new spinning methods. In this study, the properties of the air-jet yarns were comparatively analyzed with the properties of the equivalent Ring yarns, for both single and ply-twisted forms. It was found that the Rieter and Murata air-jet yarns do not show significant differences in terms of physical properties of yarns. Due to their special structure, air-jet yarns show lower hairiness and tenacity values when compared to the equivalent Ring yarns.

Keywords: air-jet yarn, Murata Vortex Spinner, Rieter air-jet spinning, Ring yarn, yarn properties

INTRODUCTION

The textile industry is under a continuous and unplanned obligation to meet the diverse array of customer demands. This obligation inevitably finds its reflections, which require the yarn industry to produce diverse, novel and creative yarns with high production speed. Consequently, new spinning techniques such as open-end rotor, open-end friction, air-jet have been introduced into the textile market, which offer improved properties, quality and/or reduced costs for yarn production. Among them, air-jet spinning system has obvious advantages like very high spinning and delivery speed [1–2].

Air-jet spinning technology was firstly introduced by DuPont in 1956, though at that time it was not commercially successful for 100% short staple spinning. By this system, the so-called fascinated yarns are produced, having outside binding fibers wrapped around a core of parallel fibers. Fascinated yarn production system is based on false twist principle, where the twist is imparted pneumatically in air-jet spinning [3–6].

Murata Machinery Ltd. from Japan has developed the most commercially successful air-jet spinning machines to date and continues to dominate globally the air-jet spinning technology. The company introduced its first air-jet spinning machine, Murata Jet Spinner, MJS 801, in 1982. The machine contains a three-roll drafting system and is equipped with two air-jet nozzles that create air vortices rotating in opposite directions. The system had some restriction on producing yarns of 100% cotton or rich blends of cotton fibers [7].

Subsequently, Murata has modified its air-jet spinning system. The latest concept in air-jet spinning developed by Murata Machinery Ltd. is known as the MVS – Murata Vortex Spinner, in 1997. Rieter Machine Works Ltd. has introduced similar air-jet spinning machine at the 2009 International Textile Machinery Exhibition in Istanbul [7–8].

These two systems use a modified single air nozzle which resulted in higher number of wrapping fibers when compared with the previous air-jet spinning systems. In both systems, the fiber bundles are firstly fed to a four-line drafting unit, and then the drafted fiber bundles are passed through the modified spinning nozzle and hallow spindle to make them into a strand of yarn. The air stream in spinning nozzle focuses the leading ends of the fiber bundles at the yarn center and directs the trailing ends to form the outer layer that wraps the yarn. This action results in a fascinated yarn structure that consists of a core of parallel fibers held together by wrapper fibers. The formed yarn passes through the yarn cleaner, where defects are removed, and is wound on a package [3, 6–7, 9–10].

Even though both MVS and Rieter air-jet spinning (RAJ) machines are based on a similar principle; the air-jet nozzles used in Murata and Rieter are different in design and construction. Due to the air stream in spinning nozzle, a certain torque is generated in the yarn being formed. This torque has the tendency to propagate to the front roller of drafting unit. This kind of the twist propagation must be avoided to prevent interferences with the generation of the necessary free fiber ends. Therefore, the two companies adopted two different solutions, where Murata used a needle in the nozzle block, as illustrated in figure 1, *a*, and Rieter used a special curved path of the fibers at the nozzle tip with an arc shape, as shown in figure 1, *b*. Occurring a bending action at the tip of the needle (for MVS) and curved path (for RAJ) prevents the twist propagation [11].

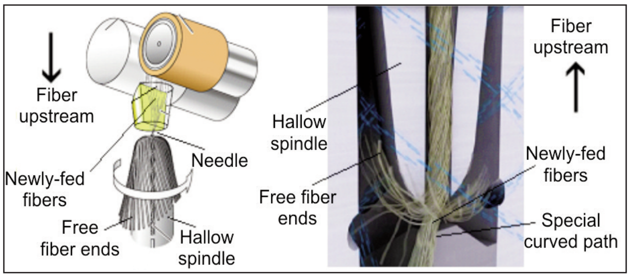

Fig. 1. Illustrations of yarn formation zones in MVS (*a*) and RAJ (*b*) [11, 15]

The fiber upstream is another difference in the design of the two systems (figure 1). In the Murata system, the drafting system is located above the spinning nozzle and yarns are delivered at the bottom. Rieter preferred to reverse the setup and the sliver is fed from the bottom and delivered yarn is wound up at the top. By the reverse set up, Rieter provides space efficiency and also additional support for the generation of free fiber ends.

The properties of spun yarns have significant influence on the performance of subsequent manufacturing operations as well as the quality of the textile end-products [1]. Yarn properties are mainly affected by the yarn structure, which is primarily determined by the spinning process [12–13]. In the literature, the studies related to air-jet spinning systems, especially RAJ, have been limited. In addition, the majority of the available literature constitutes of the information provided by the machine manufacturer companies [14–17]. In this paper, the properties of the MVS and RAJ yarns were comparatively analyzed with the properties of the equivalent Ring yarns both single and ply-twisted form.

MATERIALS AND METHODS

The paper analyses various properties of air-jet yarns (MVS and RAJ) compared to the equivalent Ring yarns. Initially, 100% viscose Ne 30/1 yarns were produced with three different systems. Viscose fibers with 38 mm average staple length and 1.2 dtex fineness were used. Viscose fibers were processed on the traditional short staple system using standard mill procedures, adjustments and practices. The major spinning parameters and count-twist details of the yarns were summarized respectively in table 1 and table 2.

Table 1

SPINNING PARAMETERS

	MVS	RAJ	Ring
Delivery Speed (m/min)	400	400	18.2
Total Draft	160	160	30.6
Sliver Weight (kTex)	3.58	3.58	0.58
Spindle Speed (rpm)	-	-	16500
Ring Diameter (mm)	-	-	40
Spindle Inner Diameter (mm)	1.2	1.2	-
Air Pressure (MPa)	0.55	0.55	-

Table 2

COUNT AND TWIST DETAILS OF YARNS

Yarn type	Nominal count (Ne)	Actual count (Ne)	Nominal twist (T/m)	Actual twist (T/m)
MVS	Ne 30/1	29.50	-	-
	Ne 30/2	14.56	645	648
RAJ	Ne 30/1	29.65	-	-
	Ne 30/2	14.74	645	650
Ring	Ne 30/1	28.50	800	785
	Ne 30/2	14.54	645	642

The MVS yarn was produced on the MVS 861 while the RAJ yarn was produced on the Rieter J10 machine. In order to produce ply-twisted yarn samples, some yardage of single MVS, RAJ and Ring yarns were passed to the two-for-one twisting machine (Leewha 560 SA).

All yarn samples were conditioned at least for 24 hours in an atmosphere of 20 ± 2°C and 65 ± 2 % relative humidity. All tests were performed at the same conditions. Yarn tensile properties were investigated by Premier Tensomaxx 7000 testing machine. Tensile test was conducted at the specimen test length of 500 mm and yarn speed of 5 m/min. Yarns unevenness and hairiness tests were performed by Premier Tester 7000 with yarn speed of 400 m/min at 2.5 minutes testing time. Visual comparisons of all yarn types were examined with Olympus SZ61 stereo microscope. Test results were analyzed by using one-way replicated ANOVA, and the means were compared by DUNCAN tests at 0.05 level using the SPSS 13.0 statistical package.

RESULTS AND DISCUSSION

In this section, various physical properties of single and ply-twisted air-jet yarns were discussed comparatively with Ring counterparts. The longitudinal views of single and ply-twisted yarns were examined under the stereomicroscope as seen in figure 2. The MVS and RAJ single yarns show a structure where the strand of the input fibers is divided into two groups of relatively parallel fibers in the core and wrapping fibers at the sheath. From figure 2, it is easy to see that air-jet yarns have less hairiness when compared with Ring yarns. Moreover, air-jet yarns have much more bulk and loose structure for both single and ply-twisted forms. RAJ single yarns have a more ring-like appearance as well as a higher number of wrapper fibers compared to MVS yarns.Additionally, the number of fibers of RAJ single yarns hooked in both ends is relatively higher than that of MVS yarns. It is thought that the amount of hooked fibers is affected by the yarn forming process and direction of fiber upstream.

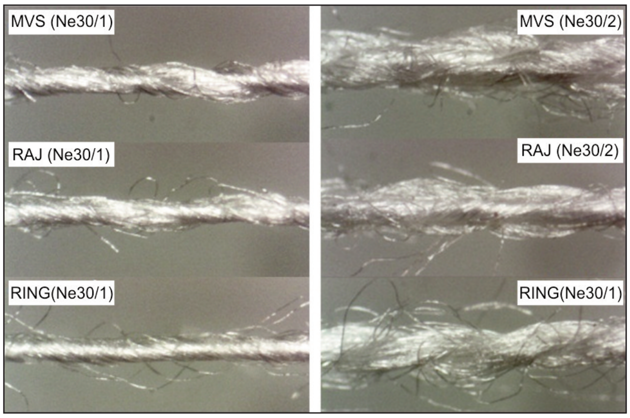

Fig. 2. Longitudinal views of MVS, RAJ and Ring yarns at the magnification of 40×

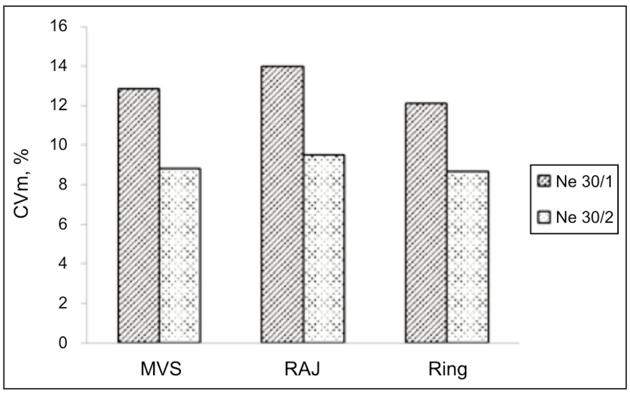

Fig. 3. Average unevenness values of yarn samples

Unevenness values of yarn samples were given in figure 3. Based on the ANOVA results, the spinning system has a significant influence on the unevenness values of yarns (p_{single} = 0.000, $p_{ply\text{-}twisted}$ = 0.000). The Duncan test results of unevenness, tenacity, breaking elongation and hairiness of yarns produced in this study were given respectively in tables 3–6. According to Duncan test results, there are significant differences between unevenness values of all yarn samples, for both single and ply-twisted forms (table 3). The lowest unevenness values were obtained from the Ring yarns whereas the highest unevenness values were seen in RAJ yarns, for single and ply-twisted form.

Table 3

DUNCAN TEST RESULTS FOR UNEVENNESS

Process	Single form			Ply-twisted form		
Unevenness	1	2	3	1	2	3
MVS		12.85			8.814	
RAJ			13.91			9.51
Ring	12.102			8.65		
Sign.	1.000	1.000	1.000	1.000	1.000	1.000

The unevenness values of Ring yarns are better than that of air-jet yarns. In yarn production, the mechanism of twist insertion is a major factor that affects the structure and ultimately the properties of the produced yarn. The lower unevenness of Ring yarns may be a result of almost constant twist distribution in the yarn structure when compared to air-jet yarns. As expected, the unevenness values of single-ply yarns are higher than that of the ply-twisted yarns. This result reflects the positive influence of plying process on the unevenness values.

Tenacity values of yarn samples were given in figure 4. Based on the ANOVA results, the spinning system has a significant influence on the tenacity values of yarns (p_{single}= 0.018, $p_{ply\text{-}twisted}$ = 0.000). Duncan test results show that there isn't a significant difference between tenacity values of yarns produced by air-jet systems for both single and ply-twisted forms (table 4). It was observed that the tenacity values of air-jet yarns are lower than that of Ring counterparts. In the case of MVS yarn, Soe et al. reported that the twisted

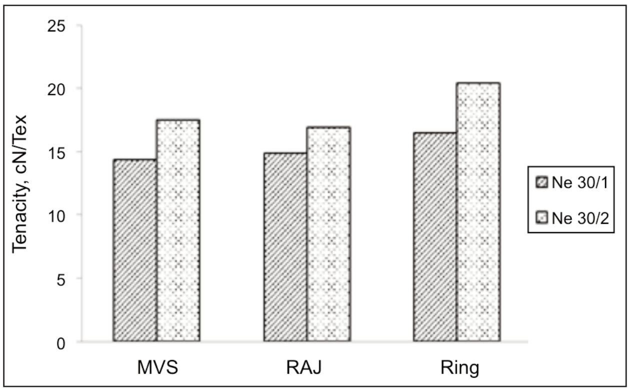

Fig. 4. Average tenacity values of yarn samples

Table 4				
DUNCAN TEST RESULTS FOR TENACITY				
Process	**Single form**		**Ply-twisted form**	
Tenacity	1	2	1	2
MVS	14.37		17.87	
RAJ	14.86		17.284	
Ring		16.48		20.80
Sign.	0.461	1.000	0.184	1.000

fiber core of Ring yarn as opposed to the nontwisted core of the MVS yarn, creates a stronger bond between the fibers and these fundamental structural effects cause the higher tenacity value of Ring yarn compared with MVS yarn [18].

In addition, it was seen that the increase in the tenacity values of yarns after ply-twisting process varies according to spinning systems. The ratios of increase were founded as 23.80%, 22%, and 14% for Ring, MVS, and RAJ yarns respectively.

Breaking elongation values of yarn samples were given in figure 5. Based on the ANOVA results, the spinning system has a significant influence on the breaking elongation values of yarns (p_{single} = 0.000, $p_{ply\text{-}twisted}$ = 0.000). Duncan test results show that there isn't a significant difference between breaking elongation values of air-jet yarns for both single and ply-twisted form. Conversely, the differences between breaking elongation values of air-jet and Ring yarns

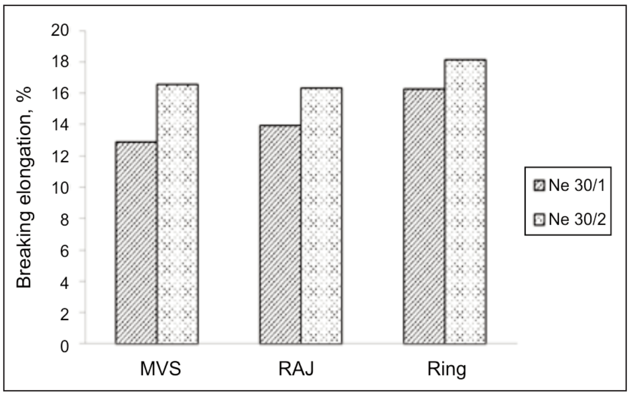

Fig. 5. Average breaking elongation values of yarn samples

Table 5				
DUNCAN TEST RESULTS FOR BREAKING ELONGATION				
Process	**Single form**		**Ply-twisted form**	
Breaking elongation	1	2	1	2
MVS	12.89		16.558	
RAJ	14.02		16.30	
Ring		16.24		18.11
Sign.	0.076	1.000	0.212	1.000

were found to be statistically significant for both single and ply-twisted form (table 5).

The highest breaking elongation value was obtained with Ring yarns for single and ply-twisted form. The lowest breaking elongation value was obtained with MVS yarns for single form whereas the lowest one was obtained with RAJ yarns for ply-twisted form (figure 5). As known, the breaking elongation values of single yarns increase with ply-twisting process. The maximum increase was observed in MVS yarns; conversely, the minimum increase was observed in Ring yarns.

Yarn hairiness is characterized by the amount of freely moving fiber ends or fiber loops protruding from a yarn. The hairiness properties of yarn samples were measured using Premier Tester. Premier Tester works through a light source incident on the yarn core, and the amount of light scattered by the protruding fibers is used to work out a Hairiness Index (H) value for the yarn. The H value corresponds to the total length of protruding fibers in centimeters within the measurement field of 1 cm length of the yarn [19]. In figure 6, the average Hairiness Index values of yarn samples were shown.

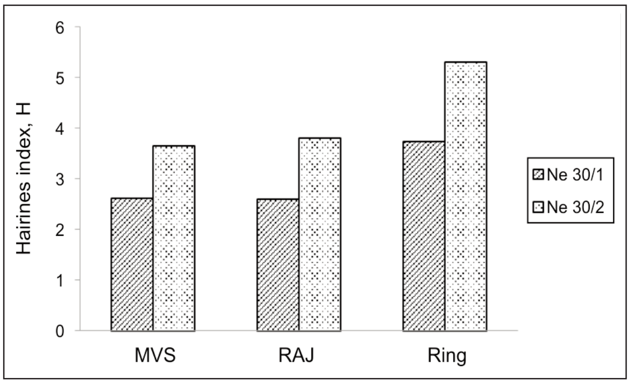

Fig. 6. Average hairiness values of yarn samples

According to ANOVA test result, the spinning system has a significant influence on the H values of yarns (p_{single} = 0.000, $p_{ply\text{-}twisted}$ = 0.000). When Duncan test results are evaluated, it was seen that H values of air-jet yarns are lower than that of Ring yarns for both single and ply-twisted form. More than half of the surface area of air-jet yarns is covered by the layer of wrapper fibers. The lower H value of air-jet yarns could be explained by the layer of wrapper fibers. In the literature, there are a lot of studies related with MVS yarns which confirm these findings [2, 20]. As seen in table 6, there is not a significant difference between H values of air-jet single yarns. Conversely, the differences between H values of MVS and RAJ yarns were found to be statistically significant for ply-twisted form. When a general evaluation was made in terms of single and ply-twisted yarns, results show that the increase of H values after

Table 6

DUNCAN TEST RESULTS FOR HAIRINESS					
Process	**Single form**		**Ply-twisted form**		
Hairiness	1	2	1	2	3
MVS	2.61		3.64		
RAJ	2.6			3.8	
Ring		3.73			5.31
Sign.	0.868	1.000	1.000	1.000	1.000

ply-twisting process by about 39.5%, 46.2% and 42.4% for MVS, RAJ and Ring yarns, respectively.

CONCLUSIONS

In this study, we investigated the various properties of single and ply-twisted air-jet yarns in comparison with Ring counterpart. The yarn samples were produced by MVS, RAJ and Ring spinning systems and 100% viscose fibers were chosen as the raw material for this work.

Taking unevenness results into consideration, it is seen that the unevenness values of yarns vary for each spinning system, for both single and ply-twisted form. Results imply that the unevenness values of Ring yarns are better than that of air-jet yarns. Also, the worst unevenness value is seen in RAJ yarn, for both single and ply-twisted form.

The test results reveal that air-jet yarns demonstrate worse tenacity and breaking elongation properties than Ring counterparts for both single and ply-twisted form. The possible reason for comparatively lower tenacityvalues of air-jet yarns is the non-uniform load distribution related with the disoriented air-jet yarn structure forming two groups of relatively parallel fibers in the core and wrapping fibers at the sheath.

Analysis of test results also shows that hairiness values of air-jet yarns are lower than that of Ring yarns. Specific structure of air-jet yarns having wrapper fibers could be said to be responsible for the considerably low amount of hairs. Furthermore, the difference between hairiness values of air-jet yarns is found statistically insignificant for single form.

BIBLIOGRAPHY

[1] Örtlek, H.G., Önal, L. *The comparative study on the characteristic of knitted fabric made of vortex-spun viscose yarns*, In: Fiber and Polymer Science, 2008, vol. 9, pp. 194–199.

[2] Örtlek, H.G., Ülkü, S. *The comparison of the properties of murata vortex-ring-and rotor spun cotton yarns*, In: 5th International Istanbul Textile Conference Papers, İstanbul, 2005.

[3] Basu, A., *Progress in air-jet spinning*, In: Textile Progress, 1999, vol. 29, no. 3, The Textile Institute, Manchester.

[4] Erdumlu, N., *An approach to investigate the spinnability of fine count yarns on vortex spinning system*, In: İstanbul Technical University, Institute of Science and Technology, Phd Thesis, İstanbul, 2011, 154 p.

[5] Basal, G., Oxenham, W. *Vortex spun yarn vs. air-jet spun yarn*, In: AUTEX Research Journal, 2003, vol. 3. no.3, pp. 96–101.

[6] Örtlek, H.G., Nair, F., Kılık, R., Güven, K. *Effect of spindle diameter and spindle working period on the properties of 100% viscose MVS yarns*, In: Fibers&Textiles in Eastern Europe, 2008, vol. 16, no. 3, pp. 17–20.

[7] Erdumlu, N., Özipek, B., Oxenham, B. *Vortex spinning technology*, In: Textile Progress, 2012, vol. 44:3-4, pp.141–174.

[8] Erdumlu, N., Özipek, B., Öztuna, A.S., Çetinkaya, S. *Investigation of vortex spun yarns properties in comparison with conventional ring and open-end rotor spun yarns*, In: Textile Research Journal, 2009, vol 79(7) pp. 585–595.

[9] Eldessouki, M., Ibrahim, S., Farag, R. *Dynamic properties of air-jet yarns compared to rotor spinning*, In: Textile Research Journal, 2015, vol. 85, no. 17, pp. 1827–1837.

[10] Kireçci, A., Erdal, P. P., İçoğlu, H. İ. *Comparison of the fastness properties and color values of cotton fabrics knitted from air-vortex and ring spun yarns*, In: TekstilveKonfeksiyon, 2009, vol. 4, pp. 304–311.

[11] Yaşar, T. *Evaluation of yarns performances produced with air-jet spinning systems*, In: Erciyes University, Institute of Science, Master Thesis, Kayseri, p. 102, 2015.

[12] Kilic, G. B., Okur, A. *A comparison for the physical properties of cotton, modal and acrylic yarns spun in ring and OE-rotor spinning systems,* In: Industria Textila, 2016, vol. 67, no. 2, pp. 80–89.

[13] Karakan, G., Palamutçu, S., Erdem, R., Abdulla, G. *The influence of nozzle pressure and yarn count on vortex spun yarn properties produced by MVS machine,* In: Industria Textila, 2016, vol. 66, no.1, pp. 11–18.

[14] Anonymous, *Roller jet spinner*, In: Customer Information Brochure, Murata Machinery Limited, No. 804, 4 p, 1995.

[15] Murata Vortex Spinner, Instruction Manuel, Murata Machinery Limited, pp. 1–348.

[16] Rieter J 20, Air-jet spinning machine brochure, 2714-v1 tr 1407.

[17] Muratec, Vortex yarn guide book, Cat No.171P4C2- 05-9-3 (NS), 2005.

[18] Soe, K. A., Takahashi, M., Nakajima, M., Matsuo, T., Matsumoto, T. *Structure and properties of MVS yarns in comparison with ring yarns and open-end rotor spun yarns*, In: Textile Research Journal, 2004, vol. 74 (9), pp. 819–829.

[19] Haleem, N., Wang, X. *Recent research and developments on yarn hairiness*, In: Textile Research Journal, Vol. 85(2), pp. 211–224, 2014.

[20] Kilic, M., Okur, A., *The properties of cotton-Tencel and cotton-Promodal blended yarns spun in different spinning systems*, In: Textile Research Journal, 2011, vol. 81(2), pp. 156–172.

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