(REFEREED RESEARCH)

COMPARATIVE STUDY ON VISCOSE YARN AND KNITTED FABRIC MADE FROM OPEN END AND RIETER AIRJET SPINNING SYSTEM

Shoaib IQBAL[1], Moaz ELDEEB[1], Zuhaib AHMAD[1], Adnan MAZARİ[2]

[1]Department of Textile Technology, Faculty of Textiles, Technical University of Liberec, Liberec, Czech Republic
[2]Department of Clothing, Faculty of Textiles, Technical University of Liberec, Liberec, Czech Republic

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ABSTRACT

In this paper, yarn and fabric properties made from Rieter air jet and rotor open end spun yarns have been investigated. For each spinning system, three different yarn count were spun, also a single Jersey plain knitted fabric was produced from each yarn count. Statistical analysis clarified that both spinning system and yarn linear density affects most of the yarn and fabric tested properties significantly. Results showed that air jet yarns are stronger, regular and have fewer neps than rotor yarn. Furthermore, yarn properties were reflected in fabric properties as well, i.e. air jet fabrics were found to have a higher value of bursting strength, abrasion resistance and they are smoother than rotor fabrics.

Keywords: Airjet yarn, Rotor yarn, Rieter airjet yarn, Knitted fabric, Yarn properties, Fabric properties

Corresponding Author: Shoaib Iqbal, iqbal_shoaib@hotmail.com

1. INTRODUCTION

It is known that the characteristics of yarn structure depend mainly on the spinning technique. During open-end rotor yarn formation, the fibers in the core of the yarn become twisted and some surface fibres are wrapped around the core, this is unique for the open-end technique which makes it easy to identify it from other yarns [1]. While in air-jet yarns the core fibers are wrapped around by some wrapper fibers but the difference is that unlike open-end rotor yarn, air-jet yarns have a core in which the fibers are parallel to the yarn axis without any twist, and this wrapping of the core by the surface fibers is periodic in nature over the length of the yarn [2]. Due to this difference, there is bound to be some differences between the physical and mechanical properties of both yarns.

There have been numerous studies that compare rotor and air jet yarn properties. The comparative studies between vortex and rotor yarns showed that yarns spun on vortex spinning system exhibit lower hairiness, less irregularity due to the uniformly distributed layer of wrapper fibres. However, there was contradiction between the results of imperfections. Vortex yarn tenacity was claimed to be higher than rotor yarns. On the other hand, the breaking elongation of vortex yarns is expected to be lower than rotor yarns due to the existence of wrapper fibers which in turn prevent fibres slippage during loading process. However, there was also contradiction between the results in literature about vortex yarn elongation being superior to the other spinning systems [3,4,5,6,7,8,9,10,11]. Since yarn characteristics affect fabric properties, numerous studies have been performed to compare the characteristics of knitted fabrics manufactured from rotor and air jet yarns. As far as knitted fabric from both systems is concerned, previous studies reported that the bursting strength of fabrics knitted using vortex yarns is higher than that fabrics knitted from rotor yarns. Fabrics knitted from vortex yarns are higher abrasion resistant which results from the existence of wrapper fibres, which resist the movement of tightly packed parallel core fibres and restrict the fiber migration in yarn structure during abrasion process [5,7,8,10]. Furthermore, Ortlek et al [12] studied the color values for both systems before and after abrasion. And they concluded that the fabrics knitted from vortex yarns showed higher reflectance (R%) values. While color decrement with abrasion cycles is higher for fabrics knitted from vortex yarns. In 2009, Rieter presented the latest method in air jet yarn production called Com4Jet. Both Rieter and Murata systems are based on a similar principle but the nozzle block in Rieter system does not contain the needle holder that works as a twisting guide. In this system, the drafting zone consists of four over four roller drafting arrangement. As shown in Figure 1, the drafted fibre strand is fed to the vortex chamber and the channel where the yarn is withdrawn lies above the fibre feed channel. Therefore, during fibre transportation process some fibres are separated from the main stream which is approximately straight from the drafting zone to the spindle tube entrance point. Due to the air vortices inside the spindle, these fibres are twisted to wrap around the main fibre strand which forms the core of the yarn. The resultant yarn is wound by a winding device. The yarn structure consists of core fibres which are parallel and consolidated by wrapper fibres that are inclined to yarn axis by different angles [13].

All previous comparisons were carried out on Murata jet spun (MJS) yarn or Murata vortex spun (MVS) yarn [14,15].

A comparison using Rieter air jet spun yarn is not reported yet. The slight difference in nozzle design for both Rieter and Murata systems may lead to different trends, therefore this study aims to give a better understanding of this new technique. In this article, an experimental investigation was carried out on the comparison of the properties of Rieter air-jet yarns with open-end rotor yarn. Furthermore, studying the influence of above mentioned spinning systems on the mechanical and surface characteristics of knitted fabrics.

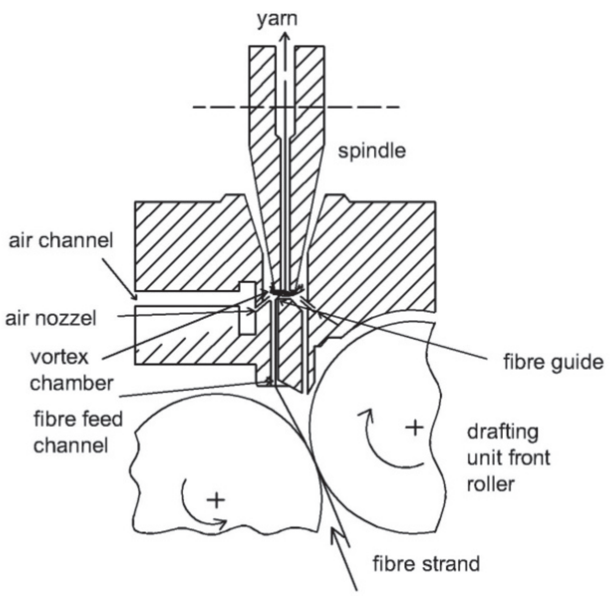


Figure 1. Schematic diagram of the yarn formation zone in Rieter air jet spinning machine [13].

2. MATERIAL AND METHOD

100% viscose fibres of 1.3 dtex and 38mm length were spun to produce air jet spun yarns. After carding process, the sliver was drawn using three consecutive drawing passages in order to enhance fibre orientation and sliver evenness. The drawn sliver with 3.5 ktex was spun using Rieter air jet spinning machine J20 to produce yarns with different counts. For the open-end rotor spun yarn, the same raw material was used but two passages of draw frame were used instead of three. Rieter R60 open end rotor spinning machine was used to spin the yarns with different counts. Table 1 shows the parameters of the spinning machines used to spin yarns with16, 23 and 30 Tex.

Table 1. Air jet and rotor spun yarns production parameters.

Air Jet			
Yarn count	16	23	30
Nozzle pressure (bar)	6	5	6
Delivery speed (m/min)	400	400	400
Rotor			
Yarn count	16	23	30
Twist (T/M)	562	422	334
Rotor speed (rpm)	95,000	100,000	130,000
Delivery speed (m/min)	95	116	128

Yarn samples were conditioned prior to testing under standard conditions 20±2^{0}C and 65±2% relative humidity for 24 hours. Yarns longitudinal view was checked using Nikon optical projection microscope. While their cross sections were checked using Nikon microscope and following the standard test method [16]. Uster 4 was used to measure yarn irregularity, imperfections and hairiness according to ASTM 1423, recording 10 observations from each yarn sample. Instron 4411 was used to measure yarn tensile properties according to ASTM D2256. The yarns were then used to produce single Jersey knitted fabric. The fabric was knitted on a 25 gauge and 5 inch diameter circular knitting machine with the specifications shown in Table 2. Afterward, fabric samples were conditioned in the same standard conditions mentioned earlier.

Fabric thickness was measured using Mesdan Lab 1880 instrument according to EN ISO5084 test method. Martindale pilling and abrasion tester were used according to ASTM 4966 to measure fabric abrasion resistance. For each fabric type, eight readings were recorded and percentage of fabric weight loss was calculated after 10,000 rubbing cycles. Also, Testometric M350-10CT instrument was used to measure fabric bursting strength according to ISO 13938-2. To study fabric surface characteristics, KES-FB4 Surface Tester was used to measure fabric friction coefficient and surface roughness. To compare the color characteristics for both systems, knitted fabric samples were dyed in a winch using reactive bifunctional dye 2%, Pink colour (Ryvalon, Czech Republic), NaCl 40 g/l, Na_2CO_3 20 g/l and temperature 80^{0}C for 1 hour. Colour measurements were carried out with a spectrophotometer (Data color 100). Afterwards, a colour fastness test was performed using ISO 105-C06 test method and Grey Scale value (GSc) was obtained. The effect of spinning system, yarn count and their interaction effect on yarn and fabric properties were studied using Two-Way ANOVA test at the confidence level of 95%. In addition, a Tukey post hoc test was performed for yarn count only (as it has more than 2 levels) to determine which yarn count differed. There was a non-significant variation noticed in yarn thick places and fabric coefficient of friction, therefore Tukey post hoc test was not applied.

Table 2. Knitted fabric geometrical characteristics.

Spinning system	Yarn count (tex)	Loop length (mm)	Stitches density (stitches/cm^2)	Tightness factor (tex$^{1/2}$/cm)	Fabric weight (g/m^2)	Thickness (mm) at 1 KPa
Air jet yarn	16	3.2	194.4	12.5	96	0.49
	23	3.8	153.8	12.5	124	0.58
	30	4.3	112.8	12.6	140	0.70
Rotor yarn	16	3.3	184.1	12.5	99	0.48
	23	3.8	163.7	12.5	127	0.52
	30	4.3	112.8	12.6	140	0.61

3. RESULT AND DISCUSSIONS

3.1. Yarn properties

3.1.1. Yarn tensile properties

As it can be seen in Figure 2, comparing both yarns longitudinal view, the air jet yarn has a better covering of the wrapper fibers which contribute to the strength of the yarn as compared to the rotor yarn where the wrapper fibers are poorly oriented and twisted. Also observing the cross sectional view, It can be observed that in rotor yarns, wrapper fiber are irregularly wrapped around the core fibers with varying angles and some of them can be seen forming an angle of 90^o taking the belt shape, while in airjet yarns, wrapping effect is much regular and wrapper fibers are identifiable forming a cap-like shape.

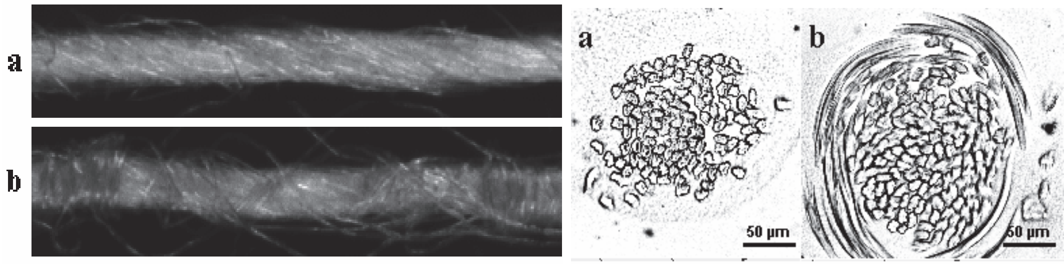


Figure 2. Longitudinal and cross sectional view of yarns; (a) air jet, (b) rotor.

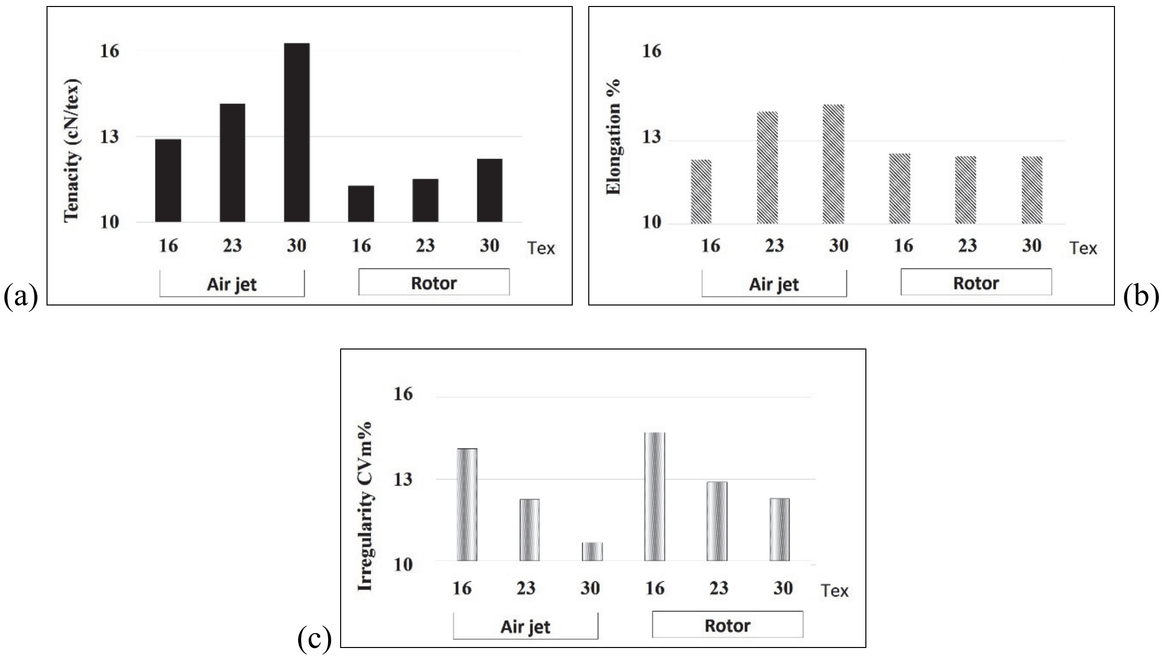


Figure 3. Air jet and rotor yarn (a) tenacity, (b) breaking elongation and (c) irregularity.

Table 3 and 5 shows the statistical significance of spinning type, yarn linear density and their interaction effect on yarn and fabric properties at 95% confidence level. While Figure 3 shows air jet and rotor yarn irregularity, tenacity and breaking elongation at different linear densities. Results reveal that coarse yarns with 30 Tex have higher tenacity than finer yarns with 16 Tex. For rotor and air jet yarn, the increase in the tenacity due to increase in yarn linear density from 16 Tex to 30 Tex is 8.2% and 26.2% respectively. This increase is due to the increased number of fibres in the yarn cross section and higher number of fibres contributes to the composition of the yarn and load bearing. Rotor yarn has considerably lower tenacity as compared to air jet yarn by about 23.5% and differences are found to be statistically significant as shown in Table 3. This is due to the difference in the yarns structure produced by the varying spinning techniques.

It is obvious that yarn elongation trend is almost similar to its relevant tenacity trend. Coarser rotor yarns exhibit almost the same elongation for the finer yarns. While coarser air jet yarns with 30 tex have higher elongation than finer yarns with 16 tex by about 15.9% which is due to the fact that the number of fibers in the core of the air jet yarn increase as yarn becomes coarser thus increasing the fiber to fiber friction, which in result increases the breaking elongation of the yarn. The rotor yarn has considerably lower breaking elongation as compared to Rieter air jet yarns because wrapping effect in rotor yarns is irregular which increases the incidence of premature failure. However, in MVS, there was a contradiction about yarn breaking elongation where some researchers claimed that rotor yarn breaking elongation is higher than MVS yarn while others claimed the contrary [5,3,7].

Table 3. Statistical significance of spinning system and yarn count on yarn properties.

Form	Property	System type	Yarn count	System type*yarn count
Yarn	Irregularity	0.000*	0.000*	0.000*
	Thin places	0.032*	0.000*	0.010*
	Thick places	0.163	0.000*	0.350
	Neps	0.000*	0.000*	0.000*
	Total imperfections	0.000*	0.000*	0.000*
	Hairiness	0.004*	0.000*	0.000*
	Tenacity	0.000*	0.000*	0.000*
	Elongation	0.000*	0.000*	0.000*

*: Significant at 95% confidence level

3.1.2. Yarn irregularity and imperfections

Observing results of yarn irregularity shown in Figure 3 and average air jet and rotor yarn imperfections shown in Table 4, it is clear that yarn count has a greater effect on yarn irregularity, neps, thin and thick places than the spinning system. Generally, coarser yarns (30Tex) have lower irregularity and total imperfections than finer yarns (16 Tex). Irregularity change when the yarn linear density changes in air jet system is 32.3% and for rotor system is 19.8%. In agreement with other reported findings regarding MVS yarn, the trend is clear from Table 4 that the yarn spun using the rotor technique has more irregularity than the air jet spun yarn by approximately 8% and differences are found to be statistically significant as shown in Table 3 [9]. The total yarn imperfections reduced remarkably by 88% and 73% for air jet and rotor system, respectively when the count changes from 16 to 30 Tex. For both spinning systems, as yarn gets finer, yarn irregularity and imperfections deteriorate as the number of fibers in yarn cross section decreases. This deterioration is more obvious in rotor yarns particularly in 16 Tex and this is due to the fact that the rotor spinning technique is not suitable for spinning finer yarns. The average difference between the two spinning systems is found to be statistically significant. Air jet yarn has fewer imperfections than the rotor yarn. As for the spinning systems are concerned the difference in thick and thin places is very slight but for the neps, the difference is very obvious.

Table 4. Average air jet and rotor yarn imperfections at different linear densities.

Spinning system	Air jet			Rotor		
Yarn count (tex)	16	23	30	16	23	30
Thin places (-50%)	35.6	4	1	18.4	4	0.8
Thick places (+50%)	29.2	5.6	3.2	29.6	6.4	14
Neps (+200%)	12.8	10.5	4.8	50	10	11.6
IPI/km	77.6	20.1	9	98	20.4	26.4

3.1.3. Yarn hairiness

As shown in Figure 4, air jet yarn exhibits lower hairiness than corresponding rotor yarn for 23 tex and 30 tex, this is attributed to the uniform layer of wrapper fibres in yarn sheath which reduces the hairiness along yarn length. However, there is insignificant difference between 16 and 23 Tex yarn hairiness according to the results of the statistical analysis between groups. This result agrees with the findings of Erdumlu,N [10], where it was found that MVS yarn is more even than rotor spun yarn. Nevertheless, for 16 Tex, hairiness of air jet yarn is more than rotor yarns.

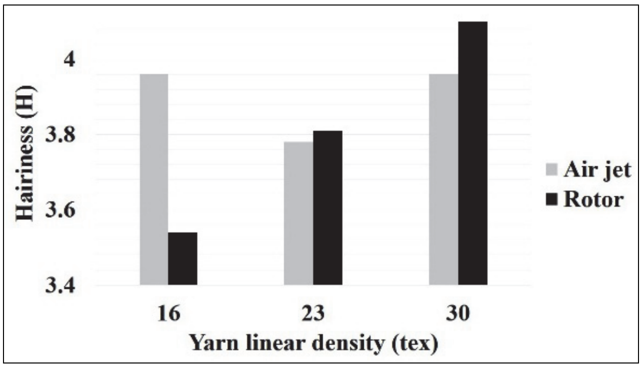


Figure 4. Air jet and rotor yarn hairiness.

3.2. Fabric properties

3.2.1. Fabric bursting strength

Table 5. Statistical significance of spinning system and yarn count on fabric properties.

Form	Property	Syste m type	Yarn count	System type*yarn count
Fabric	Bursting strength	0.000*	0.000*	0.475
	Abrasion resistance	0.000*	0.015*	0.000*
	Coefficient of friction	0.065	0.900	0.497
	Geometric roughness	0.000*	0.019*	0.151
	Colour lightness value (L)	0.000*	0.000*	0.000*
	Colour difference after washing (ΔE_f)	0.000*	0.000*	0.000*

*: Significant at 95% confidence level.

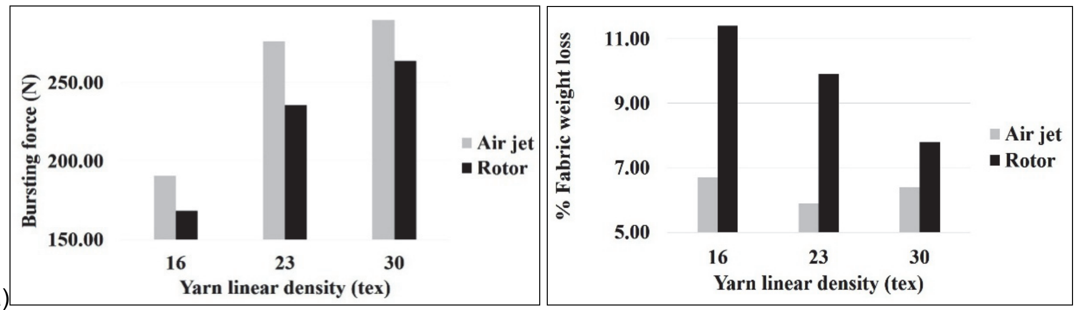
Figure 5a shows the average rotor and air jet fabric bursting strength values. Results shown in the figure demonstrate that bursting strength of air jet fabrics differs significantly than rotor fabrics, i.e. air jet fabrics exhibit higher bursting strength than rotor fabrics at all levels of yarn count by about 10-17%. The reason for that is the superior structure of air jet yarn compared to rotor yarn whereas, the core fibres of the air jet yarn are arranged parallel to yarn axis and wrapped better than rotor yarns. Beceren, Y. et al. stated that MVS yarn tenacity is directly reflected in their corresponding fabric bursting strength behaviour [7]. Leitner et al. [6] also concluded that the MVS knitted fabric bursting strength is higher than that of rotor knitted fabrics. By increasing yarn linear density, fabric bursting strength also follows its corresponding single yarn tenacity trend where as coarser fabrics bursting force is higher than finer fabrics by 52% and 56% for air jet and rotor respectively. This difference is statistically significant only when changing yarn count from 16 to 23 Tex according to post hoc test results.

3.2.2. Fabric abrasion resistance

Figure 5b shows the average fabric weight loss ratio after 10,000 rubbing cycles. The higher the fabric weight loss ratio, the lower the abrasion resistance. Results show that air jet yarns are more abrasion resistant than rotor yarns by a ratio ranges from 17% to 41% approximately, and this is believed to be a result of the wrapper fibres role in air jet yarn which wraps the core fibres well and prevent them from moving towards the outside boundary of the yarn during abrasion process. It can be seen also that coarser counts exhibits different trends for both systems; coarser rotor fabrics have high abrasion resistance while air jet fabric shows higher abrasion resistance value at 23 tex then fabric abrasion resistance deteriorates at 30 tex. However, this difference is statistically significant only when changing yarn count from 16 to 23 Tex according to post hoc test results. For rotor fabric, the trend is analysed to be related to yarn linear density whereas thinner yarns produce less abrasion resistant fabrics [17]. While for air jet fabric, the trend is analysed to be strongly related to yarn hairiness, shown in Figure 4, whereas yarn which has high hairiness value has more protruding fibres which can be detached from yarn body easily during abrasion process [18].

3.2.3. Fabric frictional properties

As shown in the Table 2, knitted fabrics manufactured from Rieter air jet yarns are thicker than corresponding fabrics made of rotor yarns at all levels of yarn counts, which is also supported by the findings of A.K Soe [4]. Table 6 shows the average air jet and rotor fabric coefficient of friction. However, results presented in Table 5 shows that neither spinning system nor yarn count statistically affects fabric coefficient of friction at 95% confidence limit. However, spinning system and yarn count influence fabric surface roughness significantly. As shown in Figure 7, the geometric roughness of air jet fabrics is less than rotor fabrics, i.e. air jet fabrics are smoother than rotor fabrics and this is may be due to the smooth and regular wrapping in air jet yarn structure. Also, for both spinning systems, fabrics become rougher when they are manufactured from coarser yarns and this is because, in fine fabrics, the number of yarns is more in fabric, therefore the number of contacting points increase causing a reduction in fabric coefficient of friction and fabric becomes smoother.

(a)


(b)

Figure 5. Air jet and rotor fabric a) bursting strength, b) abrasion resistance

Table 6. Average air jet and rotor fabric coefficient of friction.						
Spinning system	Air jet			Rotor		
Yarn count (tex)	16	23	30	16	23	30
Coefficient of friction (-)	0.078	0.078	0.076	0.072	0.071	0.075

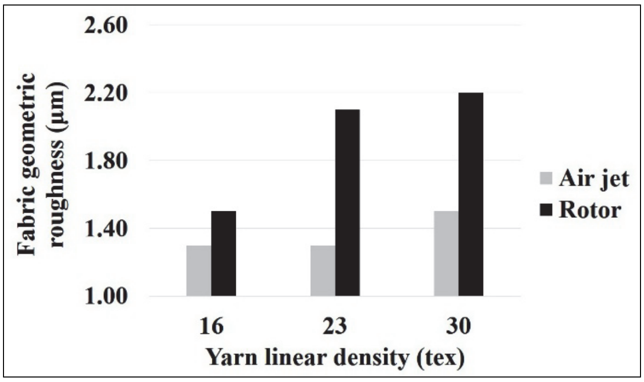


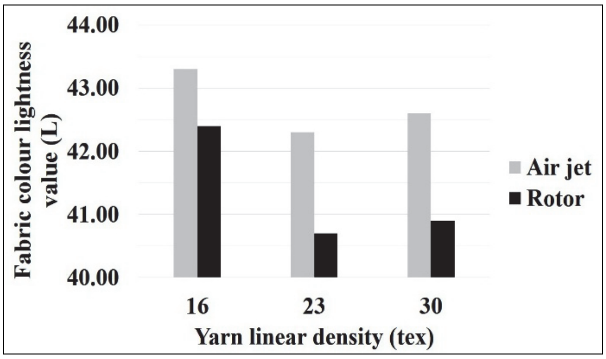
Figure 7. Air jet and rotor fabrics surface roughness.

3.2.4. Fabric colour properties

Results of colour lightness values shown in Figure 8 reveal that air jet fabrics have slightly higher lightness shade than corresponding rotor fabrics which may be explained by the regular wrapping of core fibers in air jet yarns that gives a better reflectance of light than rotor yarns. This finding agrees with results of Ortlek et al [12] who found that reflectance (R%) values of MVS fabrics were higher than ring and rotor fabrics. By analysing the colour difference value (ΔE_f) after washing process shown in Figure 8, rotor fabrics exhibits higher colour fastness than air jet fabrics at all levels of yarn linear density. This difference can be due to the fact that rotor yarn has twist to the core of its structure whereas the airjet yarn core is without any twist, therefore after washing the fibers were displaced in the airjet yarn which negatively influence its colour fastness. Also, this result agrees with Ortlek et al. [12] where they observed that the color decrease in MVS fabrics was the highest after abrasion cycles.

4. CONCLUSION

In the first part of this study, the properties of rotor and Rieter air jet yarns have been compared and findings were explained by differences in both yarns structure. The test results revealed that air jet yarns are stronger, have less irregularity, imperfections, and hairiness than corresponding rotor yarns. In the second part of the study, we extended the comparison to the knitted fabric manufactured from both types of yarns. As far as the fabric physical properties are concerned, results show that air jet fabrics are more abrasion resistant and have higher bursting strength than rotor fabrics. The geometric roughness of air jet fabrics is found to be less than rotor fabrics and air jet fabrics have higher lightness shade than corresponding rotor fabrics. Despite results showing that air jet yarn is superior in many aspects, the economics and final end use for each spinning system should be taken into consideration. It can be concluded that Rieter air jet spun yarn exhibits almost the same trend with MVS yarn when compared to rotor open end spun yarn.

(a)


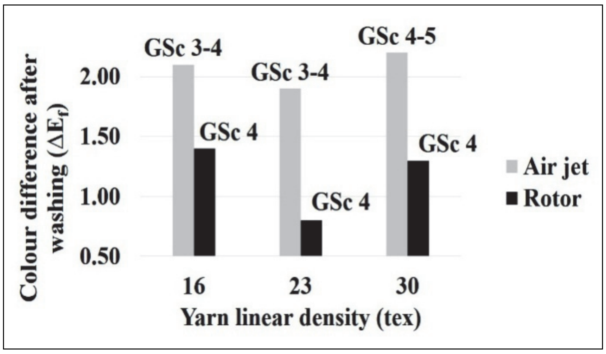
(b)


Figure 8. Air jet and rotor fabrics colour parameters, (a) lightness values, (b) colour difference after washing and the equivalent grey scale value.

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