(REFEREED RESEARCH)

A COMPARITIVE STUDY ABOUT SOME OF THE KNITTED FABRIC PROPERTIES OF COTTON AND VISCOSE VORTEX, OE-ROTOR AND CONVENTIONAL RING SPUN YARNS

BAZI ÖRME KUMAŞ ÖZELLİKLERİ AÇISINDAN PAMUK VE VİSKON VORTEX, OE-ROTOR VE KONVANSİYONEL RİNG İPLİKLERİN KARŞILAŞTIRILMASI ÜZERİNE BİR ÇALIŞMA

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ABSTRACT

In this study, some of the yarn and fabric properties of vortex, OE-rotor and conventional ring spun yarns produced from cotton and viscose fibres in three different yarn counts were compared. Particularly, fibre distribution in yarn structure yarn-to-yarn and yarn-to-solid friction properties, water absorbency after repeated washings, drying and flame resistance of vortex yarns were investigated. The results indicated that contrary to expectations, vortex spinning system cannot always enhance to produce the less hairy yarns than OE-rotor and ring spun yarns, and hairiness of vortex yarns changes depending on fibre type and yarn count. Furthermore, vortex yarns were characterized with the moderate yarn irregularity and yarn-to-yarn coefficient, lowest strength and elongation, highest yarn-to-solid friction coefficient, stiffer character, higher water uptake and quicker water absorption, slower drying ability, higher resistance to washing but lower durability to the ignition.

Keywords: Vortex yarn, water absorbency, hairiness, fabric drying, spinning systems.

ÖZET

Bu çalışmada, çeşitli iplik numaralarında pamuk ve viskon liflerinden üretilen vortex, OE-rotor ve konvansiyonel ring ipliklerin bazı iplik ve kumaş özellikleri karşılaştırılmıştır. Özellikle, vortex ipliklerin iplik içerisindeki lif dağılımı, iplik-iplik ve iplik-metal sürtünme katsayıları, tekrarlı yıkama sonrası emicilik, kuruma davranışı ve yanmaya karşı direnç özellikleri incelenmiştir. Çalışma sonunda, beklenenin aksine, vortex eğirme sisteminin OE-rotor ve konvansiyonel ring ipliklere kıyasla her zaman az tüylü iplik üretemediği ve iplik tüylülüğünün kullanılan elyaf türü ve iplik numarasına bağlı olarak değiştiği belirlenmiştir. Ayrıca, elde edilen sonuçlar doğrultusunda vortex iplikler orta derecede iplik düzgünsüzlüğü ve iplik-iplik sürtünme katsayısı, düşük mukavemet ve kopma uzaması, yüksek iplik-metal sürtünme katsayısı, sert iplik karakteri, yıkamaya karşı yüksek direnç ancak yanmaya karşı düşük direnç özellikleri ile karakterize edilmiştir.

Anahtar kelimeler: Vortex iplik, emicilik, tüylülük, kumaş kuruması, eğirme sistemleri.

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1. INTRODUCTION

Murata (Muratec) firm developed a relatively new spinning system called as vortex spinning technology. Vortex spinning is one of the most promising new inventions in the spinning market. The main attraction of this system is that it is claimed to be capable of spinning 100% carded cotton fibres at very high speeds (400m/min) and the resulting yarn structure is more similar to ring yarn than to OE-rotor yarn. In addition to these, the yarns produced by this method have low hairiness compared to normal ring yarns. Low hairiness results in reduced fabric pilling and outstanding abrasion resistance, moisture absorption, color-fastness and fast drying characteristics. Thus, it seems that this spinning system presents more of a threat to conventional ring and rotor spinning.

Many researchers were interested in this new spinning system and they mainly studied the effect of some machine parameters on vortex yarn properties and the comparison of different yarn types produced with various fibre types and yarn fineness. Tyagi et al. (2004a), and Örtlek and Ülkü (2005) analysed the effect of air pressure which is one of the most important parameter in vortex spinning [1-2]. It was found that hairiness and tensile properties improve with an increase in air pressure due to the formation of tight wrapper fibres. However, tenacity and elongation values with abrasion resistance is getting worse at higher air pressures [3-4] and hence there is an optimum air pressure level depending on yarn count [4]. Another parameter of vortex spinning is the production speed and it was reported that higher delivery speed leads to worse hairiness and yarn tenacity values [2, 4]. On the other hand, better yarn imperfections and hairiness values were obtained with shorter distance between the nozzle and front roller of the vortex system [5]. Regarding the effect of raw material properties, it was determined that waste of fibre increases together with a reduction in productivity, strength, evenness and hairiness values as the amount of short fibres in raw material increases [6]. Başal and Oxenham (2003) observed that it is impossible to spin the vortex yarn when the polyester content in cotton-polyester blends is under the 50%.

When the vortex yarn properties were compared with other yarn types, many researchers indicated that vortex yarns are considerably less hairy than ring, OE-rotor and compact yarns [2, 8-12]. Therefore, the findings about vortex yarn hairiness were agreed with each other. Soe et al. (2004) and Örtlek and Ülkü (2005) found that vortex yarns have moderate tensile properties in comparison to ring and rotor yarns. Beceren and Nergis (2008) and Kılıç and Okur (2011) showed that compact yarn has the highest tenacity and vortex yarn has the lowest. Özdemir and Oğulata (2010) determined that OE-rotor and vortex spun yarns display different fabric stiffness than conventional ring and compact spun yarns. In regard to fabric properties, pilling behaviour, abrasion resistance and bursting strength of vortex yarn fabrics were mostly studied [2, 6, 9-10]. However, there are limited findings about water absorption and drying properties of vortex yarns. Absorbency and drying is one of the outstanding properties of vortex yarns. On the other hand, due to its lower product costs, vortex yarn has price advantage and hence there is an interest about the usage of vortex yarns in terry towel production. Therefore, we believe that water absorbency and drying properties should be studied with independent institution. In present study, it was aimed to compare the water absorbency and drying properties of vortex yarn fabrics with other yarn types. Additionally, in the study, it was also investigated internal structure of vortex yarn together with yarn and some other fabric properties. Vortex yarns were compared with OE-rotor and ring spun yarns in regard to fibre distribution in yarn structure, yarn characteristics such as irregularity, hairiness, tensile, yarn-to-yarn and yarn-to-solid friction properties, water absorbency after repeated washings, drying, flame and pilling resistance.

2. MATERIAL AND METHOD

In present study, it was taken 100% cotton vortex, OE-rotor and conventional ring spun yarns having different yarn fineness such as Ne 12/1 and Ne 16/1 yarn counts. Additionally, 100% viscose yarns having Ne 28/1 yarn fineness were also analysed. In addition to Ne 12/1, Ne 16/1 and Ne 28/1 yarns, Ne 36/1 viscose vortex and conventional ring spun yarns were used for the determination of water absorbency property. The fibre properties of the cotton and viscose yarns are given in Table 1. However, it should be stated that the raw materials used for all yarn counts were not the same. It is also worth mentioning that one of the most important our aim was to compare the water absorbency and drying properties of vortex yarn fabrics with other yarns. As mentioned above, in recent years, vortex yarns have been gaining a usage in terry towel production as other yarns such as ring and OE-rotor spun yarns. Additionally, Ne 8/1, 10/1, 12/1, 16/1, 20/1, 16/2, 20/2, 24/2, 30/2 etc. yarn counts were commonly used in terry towel production. Nowadays, the fibres having absorbency with other superior comfort properties such as cotton, viscose, bamboo etc. have been selected for the terry towel production. Therefore, coarser and medium yarn counts such as Ne 12/1, 16/1 and 28/1, and cotton and viscose fibres were analysed in the study. Moreover, yarn counts and fibre types were selected with the guide of the factory which produces terry towel in Denizli. The evaluations and comparisons were made within each group. Hairiness, unevenness and imperfections values of the yarns were measured by Uster Tester 4 with 400 m/min test speed throughout 2.5 minutes. Yarn hairiness was also tested on Zweigle G566 and test length was 100 m and three measurements were done on one bobbin. Breaking force and elongation values of yarns were measured by Uster Tensojet tester. Tensile tests were performed for 500 times for each bobbin and 500 mm was gauge length. Three bobbins were tested for each yarn types and fineness. Additionally, the yarn images were taken by Motic microscopy. The coefficient of yarn-to-yarn friction and yarn-to-pin friction values of the three types of the yarns were measured according to ASTM D 3412 and ASTM D 3108 standards, respectively. The experiments were carried out on three bobbins for each yarn type. In the test, input force (T_1) was 20 gram and test speed was 100 m/min.

Table 1. Fibre properties

Parameter	Cotton fibre	Viscose fibre
Fibre length	29.7 mm	32 mm
Fineness	4.4 Micronaire	1.4 dtex
Strength	29.7 g/tex	
Breaking elongation	7.1%	
SFI	8.3	
CG	31-1	

3.2. Method

In the study, the vortex, OE-rotor and conventional ring spun yarns were knitted on sample knitting machine (Lonati 462). All machine settings were kept constant while all the fabric samples were being knitted. The machine diameter was 3 ¾˝, speed was 120 rpm and number of needle was 156.

Fabric densities were measured and three measurements were realized for each fabric type. The mean density values varied as 110-113 loop/cm^2 for Ne 12/1, 121-125 loop/cm^2 for Ne 16/1, 132-138 loop/cm^2 for Ne 28/1 and 142 loop/cm^2 for Ne 36/1 yarn counts.

Water Absorption

Absorption ability of the fabrics is an indication of the wettability of a textile material and can be measured either by the time of its sorption or by the changes in the fabric weight waited into the liquid at a certain time. The measuring of the velocity of soaking of textile fabrics was made in accordance with TS 866 (drop test) and TS 629 (sinking test) standards under laboratory conditions which are 20±2 °C and 65% relative humidity. In drop test, the fabrics were cut with the dimensions of 25 cm x 25 cm and then a water drop was dripped onto the fabrics. The sorption time of the drop was measured by chronometer. According to TS 629, the fabrics were cut 7.5 cm x 7.5 cm and prepared samples were put in a pot full of water with the horizontal direction. The sinking time of a sample was measured. Ten measurements for drop and three tests for sinking test procedures were done with different samples for each yarn type and the arithmetical mean of the results were taken. In order to evaluate the water absorption capacity of the yarn types, it was used the static immersion method and the fabric samples in 4 cm x 4 cm dimension were soaked in distilled water for one minute according to BS 3449. The samples were suspended vertically for 15 seconds and the weights of the fabrics were measured. Water absorption was calculated according to ratio of weight of absorbed water to dry fabric weight. Before the tests, the cotton fabric samples were washed at 90°C to remove the materials such as wax, oil etc. Six specimens were tested for each fibre type and mean values were determined. Water absorption of the samples were also tested after washing cycles to determine the effect of repeated application on the water absorption performance of the fabrics. The samples were washed five and ten times at 40°C according to AATCC 61-1993:5A test method.

Drying capacity

For drying test, we followed the test procedures stated in the studies of Beskisiz et al. (2009) and Mukhopadhyay et al. (2011). The fabric samples after first water absorption test (static immersion method) were laid on a flat surface at the standard atmospheric conditions and the weights of samples were measured after a certain time intervals such as 30 min, one, two and three hours. The drying capacity was calculated based on the difference between absorbed water weight and remained weight of water dried per in three hours. This process was repeated three times for each sample and arithmetical mean of the results were determined.

Flame Resistance Measurements

The samples were placed on to the Govmark TC 45-X 45° flammability tester and the flame was applied to the fabrics at 40 seconds. At the end of the test, burning time of the samples was recorded. Three tests were done and the mean value was determined.

Pilling Behaviour

Pilling is a very serious problem for the fabrics that arises after the usage of the fabric. Pilling behaviour of all fabrics was tested on the Nu-Martindale Abrasion Tester according to TS EN ISO 12945-2 test method.

3. RESULTS AND DISCUSSION

3.1. Yarn Properties

In this part, it was given the yarn properties of Ne 12/1 and Ne 16/1 cotton and also Ne 28/1 viscose vortex, OE-rotor and conventional ring spun yarns.

Yarn hairiness

Hairiness (H) and Zweigle S3 values of Murata vortex, OE-rotor and conventional ring spun yarns are given in Figure 1. The H index corresponds to the total length of the protruding fibres within the 1 cm length, while the Zweigle S3 parameter is the total number of protruding hairs of 3 mm or more in 100 m yarn. According to H and S3 results, OE-rotor spun yarns have the lowest results for Ne 12/1 and Ne 16/1 yarn counts compared with the other two yarns. For Ne 28/1, hairiness values of the vortex spun yarns are the lowest of all yarns (Figure 1).

However, Uster H and Zweigle S3 results are not completely agreed with each other. According to H results, vortex yarns have the highest hairiness for Ne 12/1 and Ne 16/1 yarn counts while the values of ring spun yarns are higher than the other yarns for Ne 28/1. As to S3 values, ring spun yarns have the highest S3 hairiness values for all yarn counts. The differences in the H and S3 values of vortex, OE-rotor and ring spun yarns were mostly found statistically significant at 5% level (Table 2). As a result, vortex spinning system can not produce less hairy yarns with cotton fibres or in coarser yarn counts while the system enhances significantly lower hairiness values with viscose fibres or in finer counts.

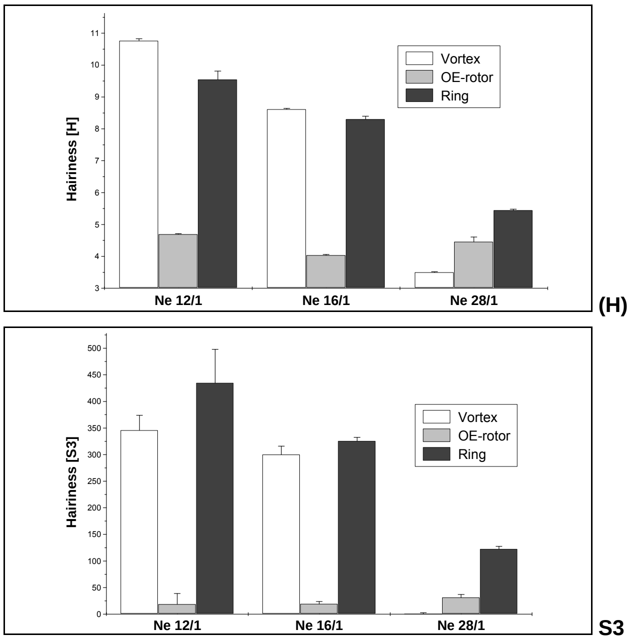


Figure 1. Yarn hairiness results

Table 2. Anova test results of yarn hairiness

Property	Yarn type		Ne 12/1	Ne 16/1	Ne 28/1
H	Vortex	OE-Rotor	0.000*	0.000*	0.000*
		Ring	0.000*	0.000*	0.000*
	OE-Rotor	Ring	0.000*	0.000*	0.000*
S3	Vortex	OE-Rotor	0.000*	0.000*	0.000*
		Ring	0.000*	0.213	0.000*
	OE-Rotor	Ring	0.000*	0.000*	0.000*

*:The mean difference is significant at the 0.05 level.

Yarn appearances

Images of vortex, OE-rotor and conventional ring spun yarns are presented in Figure 2. As seen, ring spun yarns seem more hairy than the other yarns for all yarn fineness. Contrary to H hairiness results, ring spun yarns have more protruding fibres than that of the vortex yarns. Additionally, protruding fibres from ring spun yarn body are longer comparing to the vortex yarns. Therefore, ring spun yarns appear more uneven than the other yarns. Vortex and OE-rotor yarns have lower projected fibres. Particularly, in Ne 12/1 and Ne 16/1 yarn counts, the length of protruding fibres in vortex spun yarns is longer than that of the OE-rotor yarns. This case confirms the higher hairiness results of vortex yarns compared with OE-rotor yarn for coarser yarn counts.

Appearance of OE-rotor yarns differs with the belt fibres while wavy yarn body view and irregular yarn diameter distribution is the one of the characteristic of the vortex yarns. In literature, OE-rotor and conventional ring spun yarns were investigated and the structure of the yarns has already been reported. And OE-rotor yarns are defined as higher number of belly-band fibres while ring spun yarns are categorized with the core fibres completely embedded in the yarn in a helical position [8]. Vortex spun yarn is one of the new spinning systems. Therefore, in the study, the arrangement of the individual fibres of vortex spun yarns were analysed to understand the internal structure and to explain the resulting yarn properties in a better way. For the analysis, a sample block was formed from viscose vortex yarns and hardened block was then cut as the slices with 15 µm thickness by microtome. The cross-sectional images were captured by a camera and 40-50 sample blocks were analysed to find precise and proper images. As seen in Figure 3, some of the fibres are positioned periodically and they are called as wrapper fibres. Therefore, vortex yarn consists of mostly core fibres held with wrapper fibres. Core fibres are encircled by the wrapper fibres. Soe et al. (2004) indicated the vortex yarn structure consisting of core fibres with wrapper fibres on longitudinal yarn appearance.

Contrary to expectations, vortex yarns have higher hairiness in coarser yarns counts. The reason for this may be that the coarser yarn has more fibres than the finer yarn and the length of the wrapping fibres may be insufficient to wrap the yarn body completely. As mentioned in literature, wrapper fibres cover the yarn surface and lead to a reduction in yarn hairiness. The longer length of fibre might constitute a longer length of wrapping resulting in fewer fibres protruding from the yarn surface. Erdumlu et al. (2009) also indicated that cotton fibres produce more hairy vortex yarns than the viscose rayon vortex yarns. The longer length of viscose rayon fibre, compared with cotton, might constitute a longer length of wrapping resulting in fewer fibres protruding from the yarn surface. In cotton yarns, fibre length may be insufficient to wrap the coarser yarn body. As a result, the main important parameter for vortex yarn production is the fibre length and hence raw material is the strongest parameter affecting system performance.

Yarn Irregularity

Yarn irregularity results are shown in Figure 4. In general, conventional ring spinning system gave the best irregularity results while OE-rotor spun yarns showed the worst results. This case is consistent with previous findings [9]. On the other hand, mass variation values of vortex yarns are between that of the ring and OE-rotor yarns as reported before [9-10, 23-24]. However, except Ne 28/1 yarn count, the differences between the values of vortex and ring spun yarns were not significant (Table 3). Therefore, both yarns have similar yarn irregularity. Higher irregularity values of OE-rotor yarns may result from the lack of fibre parallelization in the sliver and hence irregular fibre arrangement in rotor yarn structure [24]. Another reason might be the belt fibres of rotor yarns.

Yarn imperfections

Values of thin places are given in Table 4. In general, the effect of spinning system on thin places is seen to be statistically insignificant (Table 5). On the other hand, thick places and neps results of the yarns are shown in Figure 5. The number of thick places for OE-rotor yarns is significantly higher than that of the other yarns. The situation of ring and vortex yarns changes depending on fibre type and yarn count. Different from yarn irregularity and thick places results, conventional ring spun yarns gave the worst neps values. On the other hand, the lowest values were obtained with coarser OE-rotor and finer vortex yarns. For coarser yarns, differences between vortex and ring spun yarns were found statistically insignificant (Table 5) and hence both yarns have similar character regarding neps values.

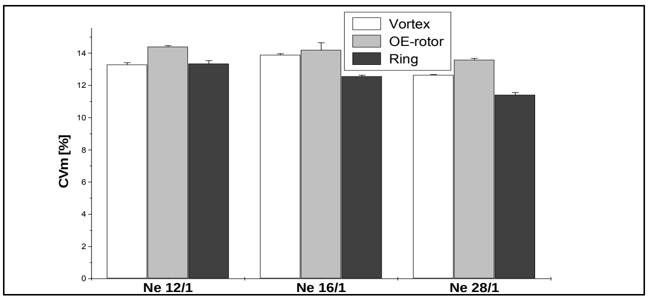


Figure 4. Yarn irregularity results

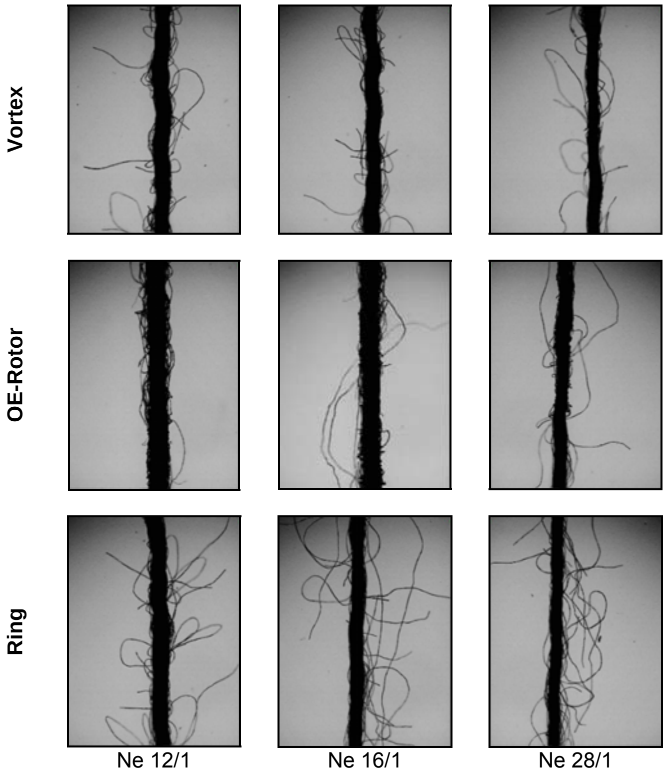


Figure 2. Yarn appearances

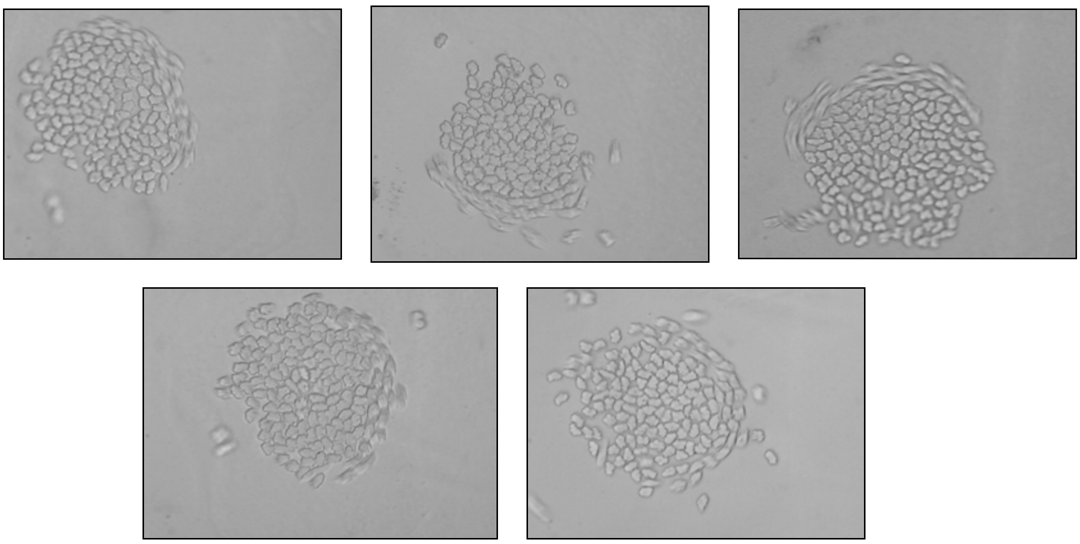


Figure 3. Typical cross-sectional views of viscose vortex yarns (Ne 28/1) (100x)

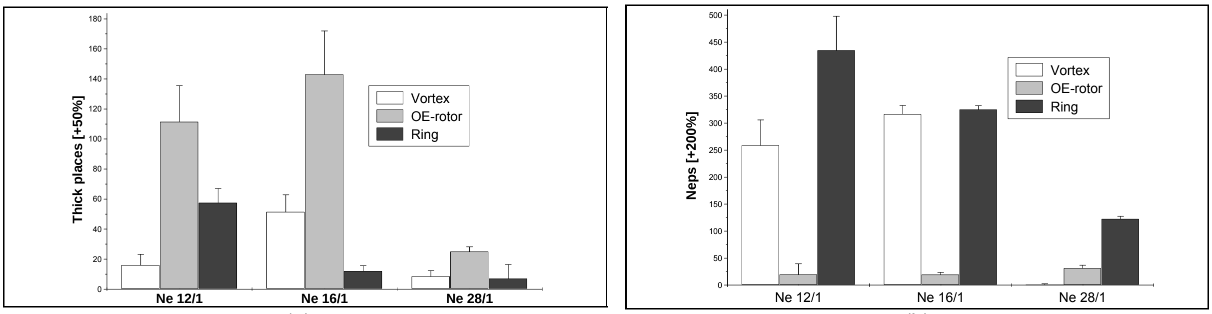
Table 3. Anova test results of yarn irregularity

Yarn type		Ne 12/1	Ne 16/1	Ne 28/1
Vortex	OE-Rotor	0.000*	0.000*	0.000*
	Ring	0.415	0.090	0.000*
OE-Rotor	Ring	0.000*	0.000*	0.000*

*: The mean difference is significant at the 0.05 level.

Table 4. Thin places (-50%) results

Yarn type	Ne 12/1	Ne 16/1	Ne 28/1
Vortex	0	10,5	8
OE-rotor	5	1	150,5
Conventional ring	2	10,5	0



(a) (b)

Figure 5. Thick places (a) and neps (b) results

Table 5. Anova test results of yarn imperfections

Property	Yarn type		Ne 12/1	Ne 16/1	Ne 28/1
Thin places	Vortex	OE-Rotor	0.002*	0.698	0.087
		Ring	0.117	10.000	0.070
	OE-Rotor	Ring	0.076	0.698	0.002*
Thick places	Vortex	OE-Rotor	0.000*	0.005*	0.001*
		Ring	0.000*	0.000*	0.705
	OE-Rotor	Ring	0.000*	0.000*	0.001*
Neps	Vortex	OE-Rotor	0.000*	0.000*	10.000
		Ring	0.080	0.003*	10.000
	OE-Rotor	Ring	0.000*	0.004*	10.000

*: The mean difference is significant at the 0.05 level.

Tensile Properties

Yarn tenacity and elongation results of the yarns are indicated in Figure 6. Tenacity results show that ring spun yarns are the strongest yarns due to their highest values. On the other hand, vortex yarns are the weakest for Ne 12/1 and Ne 16/1 yarn counts while OE-rotor yarns have the lowest values for Ne 28/1. Higher tenacity values of ring yarns is coincided with the previous findings due to the twisted fibres. Untwisted core of the vortex spun yarn creates weaker bond between fibres and weaker yarn structure. As in yarn irregularity, insufficient fibre parallelization in finer OE-rotor yarn structure may be lead to low tensile values [8-9]. When the yarn elongation results were analysed, it was determined that ring spun yarns have the highest values. However, OE-rotor yarns have the lowest values for Ne 12/1 and Ne 28/1 while vortex yarns have the worst values for Ne 16/1. As seen in tensile properties, tenacity and elongation values of the yarns change depending on the spinning system.

Yarn-to-yarn friction

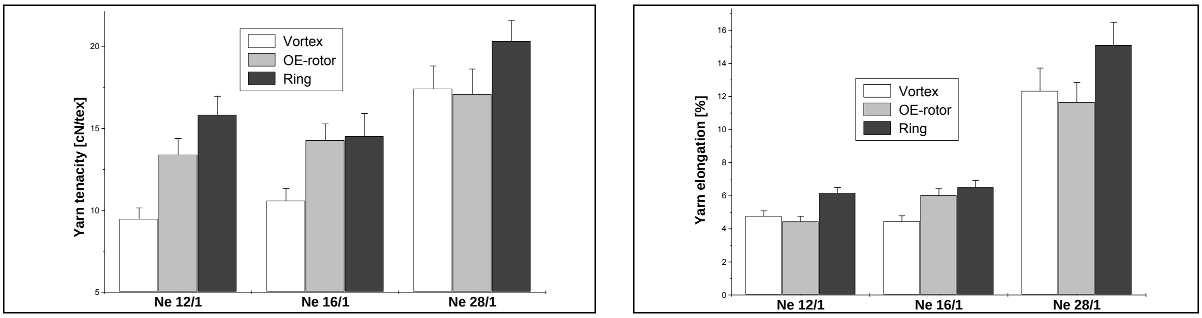
Yarn-to-yarn friction is an indication for the performance of yarn during weaving and other downstream processes [25]. In the study, due to insufficient sample length, it was only determined coefficient of yarn-to-yarn friction of Ne 28/1 viscose vortex, OE-rotor and conventional ring spun yarns. The results were summarized in Table 6 and it was found that ring spun yarns have the highest coefficient while OE-rotor yarns have the lowest values. The results means that ring spun yarns are going to cause the highest friction during the yarn-to-yarn contact and hence more problems will occur with the ring spun yarns compared with OE-rotor and vortex yarns. On the other hand, as reported by Altaş and Kadoğlu (2009), yarn-to-yarn friction results may be related with irregularity values of the yarns and lower unevenness values of ring spun yarns lead to higher yarn-to-yarn friction.

Yarn-to-pin friction

Yarn-to-pin friction coefficient gives information about the surface characteristics and smoothness of yarn [25]. Yarn-to-pin friction coefficient of Ne 28/1 viscose yarns was given in Table 6. As seen, vortex yarns have the highest coefficient values while conventional ring spun yarns have the lowest ones. The values of OE-rotor are between vortex and ring spun yarns. The results indicate that vortex yarns have smoother surface and lower friction than ring and OE-rotor yarns. When the hairiness results of the yarns take into consideration, it was observed that pin friction coefficient decreases as the hairiness increases. More hairy yarns have softer characteristic and this case causes lower coefficient and friction. On the other hand, vortex yarns will generate more yarn breakage than ring spun yarns because of the high friction [26].

Table 6. Friction coefficient results

Property	Vortex yarn	OE-rotor yarn	Ring spun yarn
Yarn-to-yarn	0.15	0.13	0.17
Yarn-to-pin	0.21	0.13	0.12



(a) **(b)**

Figure 6. Yarn tenacity (a) and elongation (b) results

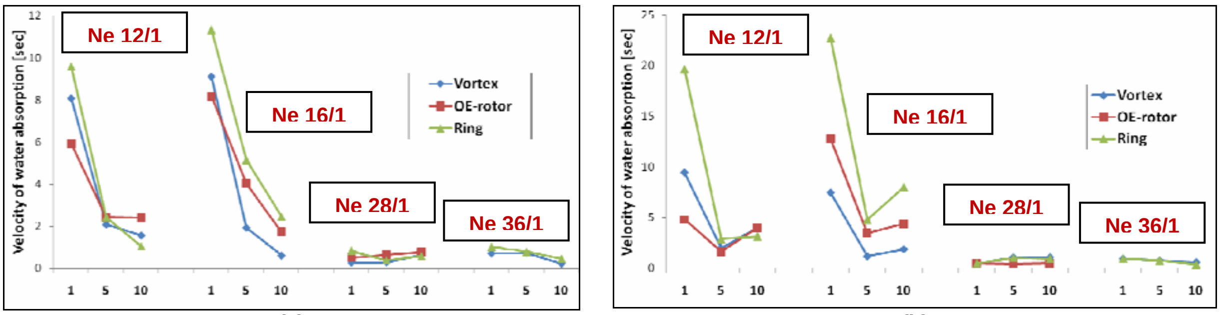
3.2. Fabric Properties

In this part, it was analysed some fabric properties produced from Ne 12/1 and Ne 16/1 cotton and also Ne 28/1 viscose vortex, OE-rotor and conventional ring spun yarns. In addition, fabrics knitted from Ne 36/1 viscose vortex and conventional ring spun yarns were used for the determination of water absorbency property.

Water absorbency

Absorption ability of the fabrics was evaluated three different test methods. In drop and sinking tests, mean absorption time identifies the hydrophility degree of the samples. The smaller value of the time which is measured, higher hydrophility degree will be [17-18]. Drop and sinking test results demonstrate that the fabrics knitted from OE-rotor and vortex yarns have significantly lower absorption time while the fabrics of ring spun yarns have higher values (Figure 7). Therefore, hydrophilicity degrees of OE-rotor and vortex fabrics are higher and the fabrics knitted from ring spun yarns have the lowest hydrophilicity. In particular, OE-rotor fabrics in Ne 12/1 and vortex fabrics in Ne 28/1 and Ne 36/1 yarn counts transmit the liquid significantly quicker than other fabrics. On the other hand, absorption time of all fabrics was found statistically different from each other (Tables 7-8) and hence OE-rotor yarns in coarser counts and vortex yarns in medium and finer yarn fineness enhance higher hydrophilicity than ring spun yarns.

After repeated washing cycles, water absorption velocity of all fabrics changes. In particular, hydrophilicity degree of ring spun yarn fabrics improves while the degree of OE-rotor yarn fabrics deteriorates after 10 washing cycles. Fabric deformation resulted from many washings could be the reason for decreased hydrophilicity degree of the washed OE-rotor fabrics, and better resistance to the washing of the fabrics knitted from ring and vortex yarns may provide considerably higher absorption velocity.



(a) **(b)**

Figure 7. Drop (a) and sinking (b) test results

Table 7. ANOVA test results for drop test

Yarn count	Fabric type		After 1 time washing	After 5 times washing	After 10 times washing
Ne 12/1	Vortex	OE-Rotor	0.000*	0.002*	0.000*
		Ring	0.000*	0.002*	0.001*
	OE-Rotor	Ring	0.000*	0.942	0.000*
Ne 16/1	Vortex	OE-Rotor	0.280	0.000*	0.000*
		Ring	0.000*	0.000*	0.000*
	OE-Rotor	Ring	0.000*	0.000*	0.000*
Ne 28/1	Vortex	OE-Rotor	0.000*	0.000*	0.000*
		Ring	0.000*	0.000*	0.002*
	OE-Rotor	Ring	0.000*	0.075	0.299
Ne 36/1	Vortex	Ring	0.000*	0.000*	0.000*

*: The mean difference is significant at the 0.05 level.

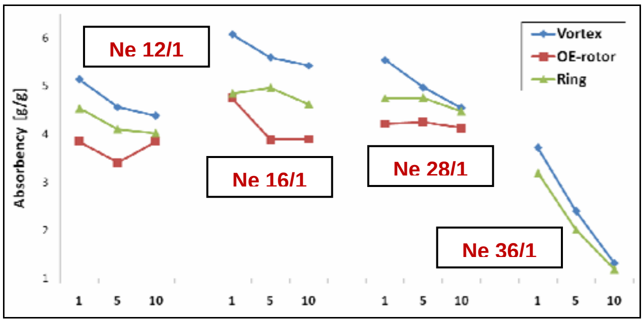
Table 8. ANOVA results for sinking test

Yarn count	Fabric type		After 1 time washing	After 5 times washing	After 10 times washing
Ne 12/1	Vortex	OE-Rotor	0.000*	0.117	10.000
		Ring	0.000*	0.004*	0.037*
	OE-Rotor	Ring	0.000*	0.001*	0.037*
Ne 16/1	Vortex	OE-Rotor	0.022*	0.000*	0.017*
		Ring	0.000*	0.000*	0.000*
	OE-Rotor	Ring	0.001*	0.000*	0.004*
Ne 28/1	Vortex	OE-Rotor	0.737	0.000*	0.000*
		Ring	0.210	0.402	0.054
	OE-Rotor	Ring	0.333	0.000*	0.000*
Ne 36/1	Vortex	Ring	0.151	0.021*	0.001*

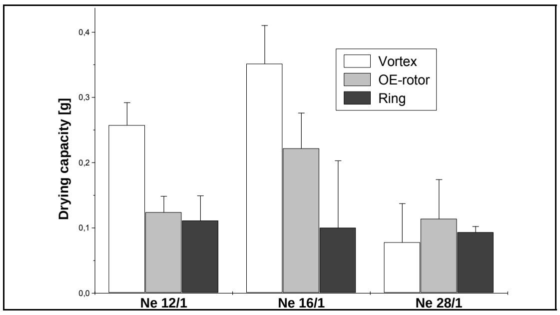
*: The mean difference is significant at the 0.05 level.

The static immersion test results are presented in Figure 8. Higher ratio of absorbed water weight to dry fabric weight displays higher water absorption capacity or hydrophility of the fabric [18]. As seen, knitted fabrics with vortex yarns always have higher water absorption values than the other fabrics (Table 9). On the other hand, the fabrics obtained from OE-rotor yarns, in contrast to higher water absorption velocity, have the lowest water absorption values. Therefore, the results of static immersion and drop/sinking tests are not agreed with each other. The reason may be that both test methods decide hydrophility of the fabrics according to different scales. Therefore, we can conclude that vortex yarns present higher water uptake with medium absorption velocity while OE-rotor yarns enhance lower absorption capacity with moderate hydrophility degree. After washing, the absorbency of all fabrics decreases because porosity of the fabrics is getting smaller and this case reduces water uptake. However, even after washings, the hydrophility degree of vortex fabrics is better than that of the other fabrics.

As observed in cross-sectional views of vortex yarns, vortex yarns consists of mostly core fibres held with wrapper fibres and core fibres lying in vortex yarn as parallel may help to take higher water uptake. However, belly-band fibres of OE-rotor yarns are thought to make water penetration inside the rotor yarn more difficult and this reduces the water absorption.



(a)



(b)

Figure 8. The results of water absorption (a) and water drying capacity after three hours (b)

Table 9. Anova results for static immersion test

Yarn count	Fabric type		After 1 time washing	After 5 times washing	After 10 times washing
Ne 12/1	Vortex	OE-Rotor	0.057	0.516	0.545
		Ring	0.763	0.603	0.903
	OE-Rotor	Ring	0.087	0.892	0.472
Ne 16/1	Vortex	OE-Rotor	0.652	0.609	0.776
		Ring	0.226	0.303	0.035*
	OE-Rotor	Ring	0.416	0.147	0.024*
Ne 28/1	Vortex	OE-Rotor	0.112	0.943	0.010*
		Ring	0.101	0.009*	0.510
	OE-Rotor	Ring	0.943	0.010*	0.023*
Ne 36/1	Vortex	Ring	0.000*	0.016*	0.000*

***:** The mean difference is significant at the 0.05 level.

Drying

In the study, the fabric samples following to the static immersion test were dried and drying capacity was determined as the difference of remained water after three hours to the absorbed water weight. Smaller value shows quicker drying. As observed from Figure 8, water drying capacity of the fabrics changes depending on yarn fineness. In Ne 12/1 and Ne 16/1 yarn counts, drying of vortex yarn fabrics is considerably slower than that of other yarn fabrics. However, drying in these yarn counts, ring spun yarn fabrics have better values. The difference between vortex and ring spun yarn fabrics was found statistically significant (Table 10). However, ring and OE-rotor yarn fabrics have statistically similar drying behaviour in these yarn counts. In Ne 28/1, vortex and then ring spun yarn fabrics have quicker drying behaviour. However, there is no substantial difference in drying capacity between all yarn fabrics. Therefore, all yarns provide similar drying ability. Better drying behaviour of ring spun yarn fabrics can be explained with moderate water absorbency and absorption velocity. On other hand, higher water uptake of vortex yarn fabrics in coarser yarn counts may lead to slower drying while quicker spreading of water and hence greater wicking assists in faster drying in Ne 28/1.

Table 10. Anova test results of drying

Yarn type		Ne 12/1	Ne 16/1	Ne 28/1
Vortex	OE-Rotor	0.062	0.057	0.365
	Ring	0.046*	0.004*	0.691
OE-Rotor	Ring	0.835	0.081	0.594

*: The mean difference is significant at the 0.05 level.

Flame resistance

Fabric samples knitted from different yarn types were placed on to the 45° flammability tester and the flame was applied to the fabrics for 40 seconds. Burning time of the samples was recorded and results were given in Table 11. As seen, the fabric knitted from OE-rotor yarns requires more time to burn the entire sample. Therefore, total burning time of the OE-rotor fabric samples is higher than that of the other fabric samples. However, the fabrics obtained from vortex yarns have the lowest burning time values for all yarn counts. As a result, OE-rotor yarns enhance more resistance to flame than the other yarn types. One of the reasons for the flame resistance of the yarns is number of fibre in the yarn structure and number of fibres in OE-rotor yarns is higher than vortex spun yarns. Moreover, belly-band wrapper fibres of OE-rotor yarns are thought to provide more durability to the ignition.

Table 11. Comparison of burning time of the knitted fabrics

Fabric type	Ne 12/1	Ne 16/1	Ne 28/1
Vortex	17.22	15.10	16.93
OE-rotor	30.97	27.83	19.77
Ring	27.73	17.53	19.60

Pilling resistance

Table 12 displays the pilling rates of the knitted fabrics produced from different yarns. The fabrics knitted from OE-rotor yarns of Ne 12/1 and Ne 16/1 have more pill-resistant than the other fabrics obtained from vortex and then ring spun yarns. As to Ne 28/1 yarn count, the fabrics knitted from vortex yarns display better resistant than the other fabrics. On the other hand, the fabrics produced from ring spun yarns have the worst resistant to the pilling for all yarn counts. Pilling results may be explained with the hairiness values of the yarns. As the hairiness of the yarns increase, the pilling resistance of the fabrics decrease. On the other hand, pilling results confirms the Zweigle S3 results.

Table 12. Pilling resistance results

Yarn count	Fabric type	Pilling cycles						
		500	1000	2000	3000	4000	5000	7000
Ne 12/1	Vortex	3-4	3-4	3-4	3-4	3	2	1-2
	OE-rotor	4-5	4	4	4	3	2-3	2
	Ring	3	2-3	2-3	2-3	1-2	1	1
Ne 16/1	Vortex	4	3-4	3-4	3-4	3	3	2-3
	OE-rotor	5	5	5	4-5	4-5	4-5	4
	Ring	3-4	3	2-3	2-3	1-2	1	1
Ne 28/1	Vortex	5	4-5	4-5	4-5	4	4	4
	OE-rotor	4-5	4	3	2-3	2-3	2	1-2
	Ring	4	4	3-4	3	3	2-3	2

4. CONCLUSIONS

In this study, some of the yarn and fabric properties of vortex yarns were analysed and compared with that of the OE-rotor and ring spun yarns. The results are summarized as follows:

- Uster H and Zweigle S3 hairiness results and also pilling behaviour of the fabrics indicated that OE-rotor spun yarns have the lowest hairiness values for Ne 12/1 and Ne 16/1 yarn counts while vortex spinning system produce less hairy yarns in Ne 28/1. Contrary to statements, in cotton yarn production, vortex spinning system could not always enhance better hairiness results than the other yarns and hence hairiness of vortex yarns changes depending on fibre type and also yarn count.
- In vortex yarn, it was observed that most of the fibres in the yarn structure are encircled by the helically positioned fibres called as wrapper fibre. Therefore, the

length of the wrapping fibres should be sufficient to wrap the yarn body completely for the less hairiness.

- The results indicate that the strongest parameter affecting vortex system performance is the fibre length and length of the raw material is an extra important in coarser yarn production.
- However, untwisted and parallel lying core fibres in vortex and also OE-rotor yarns lead to lower yarn tenacity and elongation values than that of the ring spun yarns.
- Regarding the friction properties of the yarns, it was found that higher yarn-to-yarn friction value of ring spun yarns are going to cause more problems in weaving and other downstream processes. On the other hand, less hairiness of vortex yarns provide smoother yarn surface but leading stiffer character and more contact with solid materials.
- The fabrics knitted from OE-rotor and vortex yarns transfer the water quicker than ring spun yarn fabrics. However, after repeated washing cycles, water absorption velocity of OE-rotor yarn fabrics decreases resulting from fabric deformation. Better resistance to the washing of the fabrics knitted from ring and vortex yarns provide considerably higher absorption velocity.
- On the other hand, as claimed, vortex yarns enhance higher water uptake and hence hydrophility than the other yarns, even after many washings.
- Contrary to statements, vortex yarns do not always provide the best water drying performance, and yarn fineness and fibre type affects the drying behaviour of the vortex yarns. Higher water uptake and moderate water absorption velocity of vortex yarn fabrics in coarser yarn counts may lead to slower drying while quicker spreading of water and hence greater wicking assists in faster drying in Ne 28/1.
- Today, consumers have expectations from any textiles about providing some functional properties. In the study, it was determined that OE-rotor yarns enhance more resistance to flame than that of the ring and then vortex yarn fabrics for three yarn counts.

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