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# A COMPARATIVE STUDY ON MECHANICAL & PHYSICAL CHARACTERISTICS OF TENCEL-POLYESTER BLENDED RING AND ROTOR SPUN YARNS

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## ABSTRACT

*The present study aims to compare and analyze the influence of tencel proportion in blend, tex twist factor and rotor speed on various mechanical and physical properties of tencel/polyester blended ring and rotor yarns of 19.6 & 29.5 tex. The improved fibre configuration due to spinning technique, ring yarns exhibit comparatively better tensile characteristics but higher unevenness, imperfections, hairiness and less rigidity than their equivalent rotor yarns. Increase of tencel content in the blend adversely affects the tensile, evenness and hairiness properties of both ring & rotor yarns. Again, with increase of tencel content, imperfections in yarns of both spinning processes show different trends, while tencel majority yarns exhibit higher flexural rigidity. Whereas, yarn characteristics like unevenness, imperfections & flexural rigidity increases and hairiness decrease with increase of tex twist factor. But the tenacity initially increases with increase of twist level and thereafter shows a decreasing trend as twist level increased beyond that level; however, breaking extension continues to rise with increase of tex twist factor. Furthermore, the high speed of rotor undesirably affects the tensile characteristics of yarns. Also yarns spun with high rotor speed show an increase in unevenness, imperfections, hairiness, and flexural rigidity.*

***Keywords:*** *Blended yarn; Twist Factor; Ring-spun yarn; Rotor-spun yarn; Rotor Speed; tencel-polyester yarn*

## INTRODUCTION

Every textile technocrats want to produce a product of desired features to fulfil the necessities of end user, hence, one should be aware about the fibres properties and yarn structure. The effective translation of fibre properties into yarn properties is directly depends on yarn structure which includes fibre packing, migration patterns & level of twist. The arrangement of fibre during yarn formation is directly depends on yarn spinning technique. The most advantageous feature of ring spun yarn is its structure and supposed to be more effective intermingling of fibres, which result in higher yarn strength. While the open end rotor yarn structure posses less adequate fibre migration from sheathe to core of the yarn. Due to change in geometry of yarn configuration of ring & rotor spun yarns, therefore the yarn characteristics of both spinning techniques are differing. In addition to this change in speed of rotor also alters the fibre migration pattern in rotor yarns which considerably affect the resultant yarn properties [10, 11, 13].

Some of the studies have been conducted for comparing the characteristics of yarn spun ring & rotor spinning techniques. Kaushik, Salhotra, & Tyagi, studied about the effect of twist on characteristics of acrylic-viscose rotor spun yarns [1], Kaushik, Salhotra, and Tyagi, examined the properties of polyester-viscose ring & rotor spun yarn in relation to fibre denier and twist [2], Jackowska-Strumillo, Cyniak, Czekalski & Jackowski, compared the quality of cotton yarns spun using ring-, compact-, and rotor-spinning machines as a function of selected spinning process parameters[3], Kilic and Okur, investigated the properties of cotton- tencel and cotton –promodal blended yarns spun on different spinning systems [4]. Gnanasekar, studied the influence of rotor speed on yarn quality [5].

The purpose of blending the fibres with different characteristics is a well established practiced in industries. And it is used to improve the product quality by considering the functional & desirable properties of the substrate along-with cost effectiveness. When a blended yarn is produced using different spinning techniques, such yarns show a different fibre arrangements in their structure and accordingly the yarn properties alters. Tencel, The newly introduced cellulosic fibre and it poses a unique combination of properties of natural as well as synthetic fibres. Fabrics made alone with tencel fibre exhibit comfort feel, silky lustre, soft hand, distinctive drape and excellent colour depth. Tencel can be blended well together with natural as well as synthetic fibres and enhance the desirable & functional characteristics of blended yarns and fabrics made thereof [6-9]. On the other hand, very limited investigation is conducted on comparing the characteristics of yarns made on ring and rotor spinning machines. Therefore, the aim of this work is to evaluate the mechanical & physical characteristics of tencel-polyester blended ring and rotor spun yarns.

## MATERIALS AND METHODS

### Materials

### Fibres

The tencel and polyester fibres were used in the present study. The specifications and stress-strain diagrams of tencel and polyester fibres are given in Table 2.1 and Fig. 2.1 respectively. In both fibres, polyester is stronger and more extensible, while tencel has higher initial modulus.

**Table 2.1-**Specifications of Tencel sand Polyester Fibres

| Fibre Type / Fibre Properties | Length (mm) | Linear Density (dtex) | Tenacity (cN/tex) | Breaking Elongation (%) | Modulus (cN/tex) |
|---|---|---|---|---|---|
| **Tencel** | 38 | 1.40 | 29.63 | 7.04 | 451.58 |
| **Polyester** | 38 | 1.40 | 54.51 | 14.15 | 300.14 |

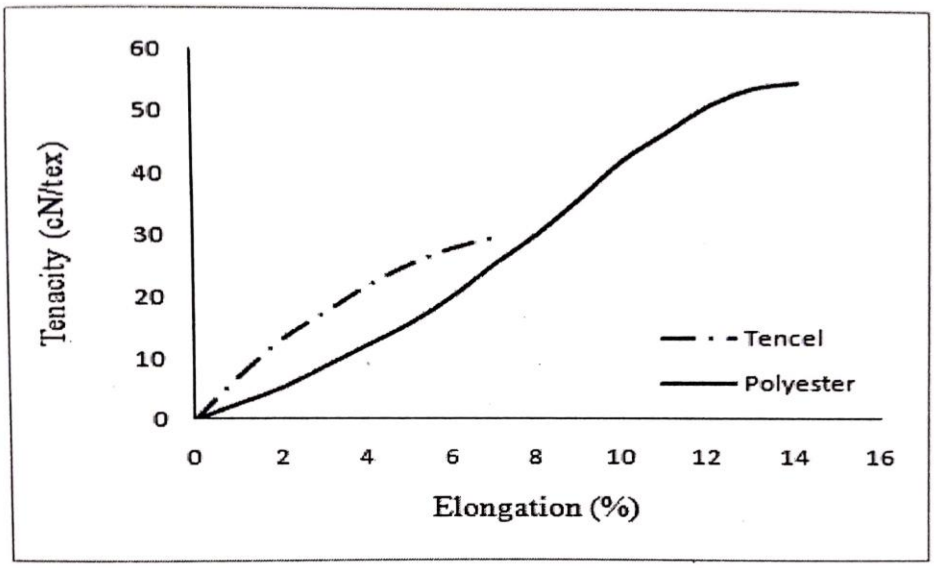


**Fig. 2.1 Stress -strain curve of tencel and polyester fibre**

## Preparation of Yarn Samples

Tencel and polyester fibres were blended to spun ring and rotor yarns of **19.6 tex & 29.5 tex linear densities** using two blend ratios **(30/70* & 70/30*) (* -Tencel/Polyester)** with three different tex twist factors **33.46 ($TF_1$)**, **38.25($TF_2$)** and **43.02($TF_3$)**. For well blending of tencel and polyester fibres, a predetermined quantity of both fibres were manually mixed two times and then processed in a Trutszler blow-room line for homogeneous blend. The conversion to sliver was carried out by using a LR C-1/3 carding machine. Two drawing passages were given to the card sliver and for this LMW LDO/6 as breaker draw-frame and finisher draw-frame LRSB 851 were used, the linear density of sliver of finisher draw-frame being adjusted to 4.217 ktex. The finisher sliver to roving of 513 tex was converted on a LMW LFS 1660 simplex, which was used to produce 19.6 tex & 29.5 tex yarns with two blend ratios and three different tex twist factors 33.46 ($TF_1$), 38.25 ($TF_2$) and 43.02 ($TF_3$) on LMW LR6/S ring frame using a spindle speed of 17000 rpm. On the other hand the rotor yarns were spun on Schlafhorst Autocoro 8 OE rotor spinning machine for two different rotor speeds. Rotor speeds 80,000 rpm & 1,00,000 rpm were kept to produce **rotor yarn-a** and **rotor yarn-b** respectively. Both the yarns were spun at two linear densities of 19.6 tex & 29.5 tex, two blend ratios of tencel/polyester (30/70 &70/30) with three different tex twist factors **33**.46 ($TF_1$), 38.25 ($TF_2$) and 43.02 ($TF_3$) similar to ring spun yarn samples. For both fibre mixes, the sliver prepared up to finisher draw frame for ring spun yarns were also used as feed material for rotor spun yarns.

## TEST METHODS

### Fibre Test

Performance of a yarn in its subsequent processes is influenced by its strength and elongation, and both yarn properties strongly affect by its constituent fibre's strength and elongation. Lenzing's Vibrodyn tester was used to measure the single fibre tenacity, breaking extension and initial modulus as per ASTM (3822-07) standard. The stress strain curve was also obtained for both fibres. For the measurement, single fibres were carefully separated from the bundles and both fibre ends were clamped pneumatically between two jaws at a predetermined tension. The gauge length was kept 20 mm for testing the fibre properties. The tests were conducted on constant rate of elongation principle. The lower jaws were traversed at constant rate while upper jaws were attached to a sensitive load cell. Twenty observations were taken for each sample.

### Yarn Test

All the yarns were tested for single strand strength and breaking elongation on Uster Tenso Rapid-3 (UTR-3) according to ASTM (D2256) standard. The yarn sample is clamped between two jaws with upper jaw connected to load cell and lower jaw is traversed downwards at a constant rate of traverse.

Mass irregularity and imperfections of both types of yarns were recorded according to ASTM standards (D 1425/1425M-09) by Uster Evenness Tester-3 (UT-3). The yarn is passed between two capacitance plates at a constant speed. The capacitance of the condenser varies according to weight per unit length of yarn. The variations in capacitance are converted into voltage and amplified. A continuous record of variations is obtained in a recorder chart. Instantaneous values of Mean Deviation % (U %) or Coefficient of variation (CV %) of the variations is computed by an integrator and displayed. UT -3 were also used for determining yarn imperfection, like thick places, thin places and neps on the basis of their sizes.

All the yarn samples were tested for flexural rigidity on weighted ring yarn stiffness tester by ring loop method [17]. For each yarn sample, fifty observations were taken. The steam setting was given to all yarn samples for 15 minutes before testing to yarns samples, yarns were very twist lively and it was very difficult to make a loop without distortion and deformations.

Flexural rigidity was calculated with the help of Riding and Owens table [17].

$$G = {ML^2}/{Z} \ gcm^2$$

Where, M = Mass of rider, gm

Z = Table value of non-dimensional load corresponding to value of $d_1/L$

L =Length of loop, cm
$d_1$=Deflection in cm produced by weight 'M'

Zweigle hairiness meter (Model G565) based on photoelectric principle was used to measure yarn hairiness (ASTM D5647-01). The projecting fibers interrupt a light beam and a variation in the intensity of light received by photocell. The hairs of varying projected length (perpendicular length of protruding hair to yarn axis from yarn surface) emerging from a yarn from a length of 1 mm to 25 mm were counted by means of a sequence of photoelectric cells placed behind the yarn core.

## RESULTS AND DISCUSSION

### Tenacity

Table 4.1 and fig. 4.1 shows the results of the tensile test of tencel-polyester blended ring and rotor yarns spun with different twist factors. The results show a considerable differences between the yarns spun with different twist factors. Both ring and rotor tencel/polyester blended yarns show an increase in strength when tex twist factor varies from 33.46 to 38.25, but further increase in twist factor to 43.02, a decrease in strength is noticed. The initial increase in yarn tenacity with increase in twist factor is attributed to the effect of improved fibre friction which prevails over the effect of fibre inclination to the yarn axis, however, a further increase in fibre friction due to twist is over come by the decrease in contribution by the component of fibre strength in yarn axis direction and results in overall reduction of yarn tenacity [10, 11].

A significant difference is found in ring and rotor yarns, ring yarns show high strength because of more parallel configuration and comparatively greater extent of its constituent fibres. Also uniform twisting and high spinning tension make the yarn more denser which provide high friction between fibres while rotor yarns show lower strength due to less parallel arrangement of fibres, rather local fibre migration, poor packing and occurrence of folded or buckled, wrapper & belting fibres [1, 12, 13].

While the increase of rotor speed show a detrimental effect on yam strength, because it results in high yarn delivery rate which is the consequence of poor combing efficiency and individualization of fibres at opening stage and in addition to this it also reduces the time for straightening & relaxation of hooked and looped fibres in rotor groove. Whereas increase of rotor speed show continues decrease in yarn strength due to formation of more number of wrappers and which further enhances by the increase of tex twist factor [5].

As the tencel content increases in the blend, all type of yarns show a significant reduction in their strength due to lower strength of tencel in comparison to polyester [6].

**Table-4.1** Influence of Blend Ratio and Tex Twist Factor on Tenacity of Tencel/Polyester* Blended Ring & Rotor Spun Yarns

| Yarn Linear Density | Blend Ratio | Ring Yarn | | Rotor Yarn-a | | Rotor Yarn-b | |
|---|---|---|---|---|---|---|---|
| | | 30/70* | 70/30* | 30/70* | 70/30* | 30/70* | 70/30* |
| 19.6 Tex | $TF_1$ | 28.33 | 17.61 | 19.68 | 13.21 | 17.60 | 11.86 |
| | $TF_2$ | 28.82 | 19.07 | 19.79 | 13.62 | 16.58 | 12.18 |
| | $TF_3$ | 26.68 | 18.04 | 18.50 | 12.09 | 15.94 | 10.42 |
| 29.5 Tex | $TF_1$ | 29.95 | 20.20 | 20.11 | 15.21 | 17.86 | 13.26 |
| | $TF_2$ | 30.09 | 20.07 | 21.41 | 16.43 | 18.58 | 13.89 |
| | $TF_3$ | 28.28 | 19.49 | 20.66 | 14.87 | 16.47 | 13.40 |

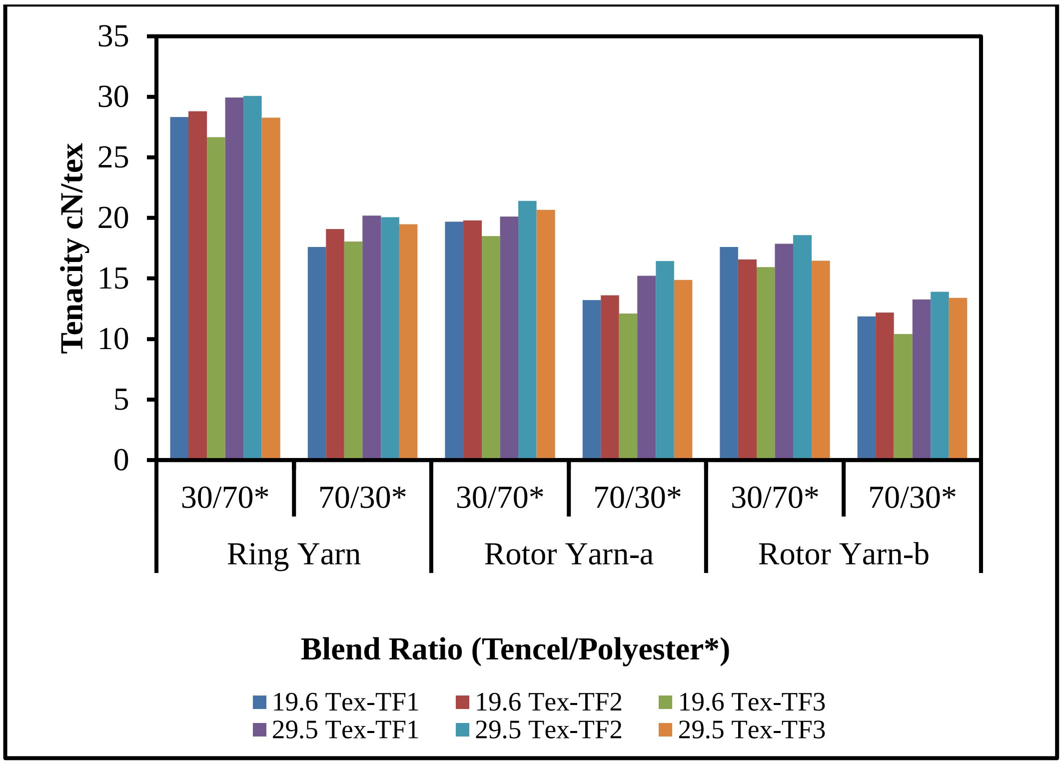


**Fig. 4.1**—Variation in Tenacity with increase of tencel content in fibre-mix of Tencel/Polyester* blended ring and rotor yams spun at different tex twist factors and rotor speeds

## Breaking Elongation

As expected, all the ring and rotor yarns with high polyester content in blends exhibit higher breaking elongation than their equivalent opposite blend due to higher breaking extension of polyester fibre [1].

The breaking elongation of all ring spun yarns increase from 6.85% to 11.22% with the increase in twist factor from 33.46 to 43.02. It is due to increase in inter-fibre cohesion.

However, rotor yarns spun at different rotor speeds show an opposite trend with the increase of tex twist factor. Rotor yarns-b (spun with high rotor speed of 1,00,000 rpm) exhibit a decrease in breaking elongation due to high centrifugal force as exerted on fibre ring in rotor groove results in more compact yarn, and in addition to this high rotor speed results in high frequency of wrappers. Yarn compactness and number of wrappers further enhances with the increase of tex twist factor. High compactness limits the fibre slippage during straining, whereas, more wrappers put the restrictions in the flow of strain along the yarn axis [4, 16].

While the rotor yarns-a (spun with lower rotor speed of 80,000 rpm) exhibit an increasing trend of breaking elongation with increase in twist factor. It can be ascribed as the formation of comparatively low compact yarns with sufficient fibre cohesion and less number of wrapper fibres. This ultimately results in controlled fibre slippage and allows the flow of strain along the yarn axis during tensile testing.

Again, the causes as discussed above can also be used to explain the insignificant difference and significant difference in values of breaking elongation of ring & equivalent rotor yarn-a and ring & rotor yarn-b respectively.

**Table-4.2** Influence of Blend Ratio and Tex Twist Factor on Breaking Elongation (%) of Tencel/Polyester* Blended Ring & Rotor Spun Yarns

| **Yarn Linear Density** | **Blend Ratio** | **Ring Yarn** | | **Rotor Yarn-a** | | **Rotor Yarn-b** | |
|---|---|---|---|---|---|---|---|
| | | **30/70*** | **70/30*** | **30/70*** | **70/30*** | **30/70*** | **70/30*** |
| **19.6 Tex** | **$TF_1$** | 9.75 | 6.85 | 10.07 | 7.52 | 8.02 | 6.63 |
| | **$TF_2$** | 9.97 | 7.14 | 10.38 | 7.79 | 7.86 | 6.65 |
| | **$TF_3$** | 10.06 | 7.29 | 10.01 | 7.46 | 7.54 | 6.49 |
| **29.5 Tex** | **$TF_1$** | 10.56 | 8.2 | 10.19 | 7.65 | 8.54 | 6.9 |
| | **$TF_2$** | 11.14 | 8.32 | 10.41 | 8.33 | 7.94 | 6.15 |
| | **$TF_3$** | 11.22 | 8.46 | 10.69 | 8.95 | 7.03 | 6.05 |

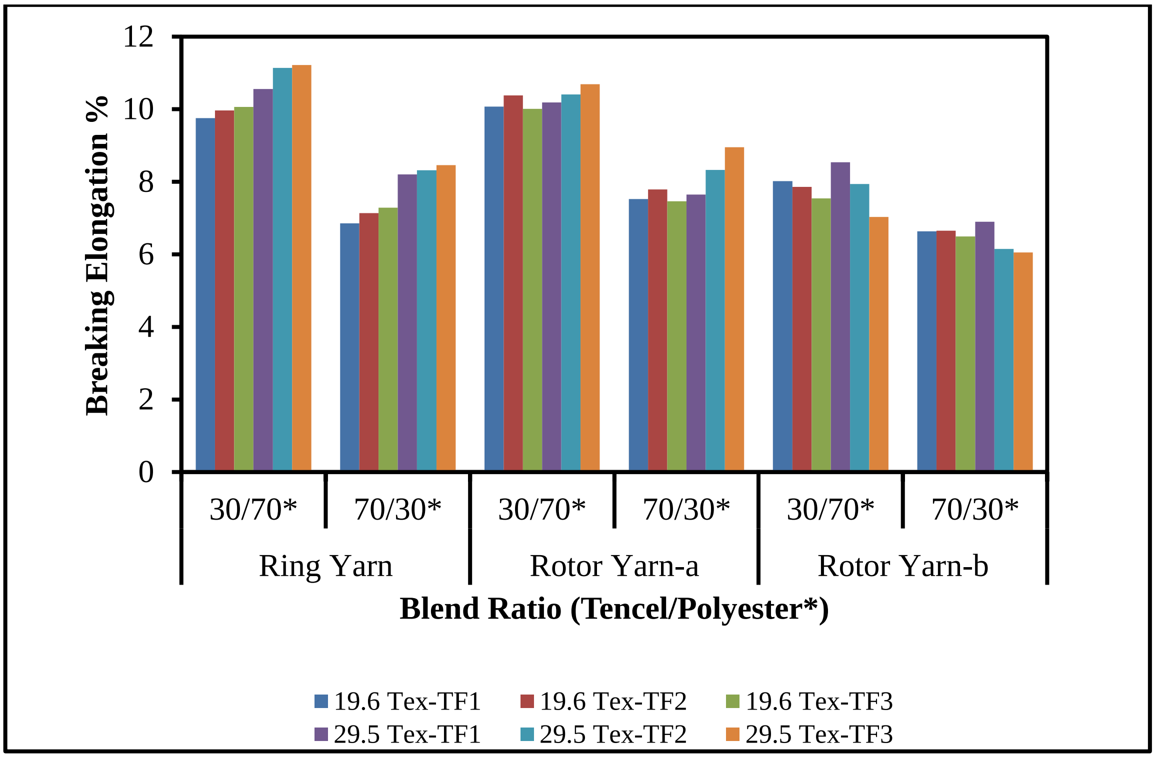


**Fig. 4.2**—Variation in breaking elongation with increase of tencel content in fibre-mix of Tencel/Polyester* blended ring and rotor yams spun at different tex twist factors and rotor speeds

**Mass irregularity**

Mass irregularity (U %) of tencel-polyester blended, spun with different twist factors ring and rotor yarns is shown in table 4.3 and unevenness of ring & rotor yarns vary from 9.61% to 16.25% and 8.84% to 11.76% respectively.

As expected, evenness of yarns spun on both techniques is influenced by twist factor. As the twist increases, ring yarns exhibit a decreasing trend of evenness. With the increase in twist factor the drafting speed reduces, as increase of twist is carried out by reducing front roller delivery. The decrease in drafting speed lowers the inter fibre friction which essentially controls the movement of floating fibres at the time of sudden acceleration in drafting field. Hence, a decline in evenness is observed when twist factor is increased [10, 14].

While rotor yarns show a little variation in U% with twist level but more even then their ring counterparts [11]. The higher evenness of rotor-spun yarns is the result of back doubling of fibres during yarn formation and the nonexistence of drafting irregularities as associated with ring yams. Also finer yarns show more irregularities due to lesser number of fibres in the yarn cross section, as the magnitude of variation in linear density of yarn is inversely proportional to the square root of number of fibres in the yarn cross section.

Whereas the unevenness of rotor yarns was significantly influenced by the increase of rotor speed. High rotor speed enhances the wrappers & belting fibres as well as it reduces the combing efficiency for fibre individualization. Due to these factors yarn evenness decreases [4,5].

There was a different trend of evenness is found with increased tencel content. As the tencel content increases the uster values of both ring and rotor yarn increases. In case of ring yarns the abrupt increase of unevenness about 30% to 50% is observed with increased tencel fibre content. It is due to fibrillar nature of tencel [8]. Fibrillation means micro fibre formation, which ultimately creates undue entanglement between adjacent fibres during drafting and reduces the control on moving fibres in drafting zone, therefore a fall in evenness is noticed. With higher tencel content rotor yarns exhibit much lesser rise in unevenness then ring yarn counterparts. It can be understood as the problems of micro fibres as associated in ring spinning is not affect the rotor spinning.

**Table-4.3** Influence of Blend Ratio and Tex Twist Factor on Mass Irregularity (U %) of Tencel/Polyester* Blended Ring & Rotor Spun Yarns

| **Yarn Linear Density** | **Blend Ratio** | **Ring Yarn** | | **Rotor Yarn-a** | | **Rotor Yarn-b** | |
|---|---|---|---|---|---|---|---|
| | | **30/70*** | **70/30*** | **30/70*** | **70/30*** | **30/70*** | **70/30*** |
| **19.6 Tex** | **$TF_1$** | 11.78 | 15.28 | 9.89 | 10.95 | 10.79 | 11.22 |
| | **$TF_2$** | 12.12 | 15.67 | 10.05 | 11.02 | 10.89 | 11.48 |
| | **$TF_3$** | 12.22 | 16.25 | 10.11 | 11.01 | 11.08 | 11.76 |
| **29.5 Tex** | **$TF_1$** | 9.61 | 14.71 | 8.84 | 8.92 | 9.34 | 9.23 |
| | **$TF_2$** | 9.82 | 14.88 | 9.32 | 9.01 | 9.59 | 9.78 |
| | **$TF_3$** | 9.96 | 15.33 | 9.60 | 9.84 | 9.55 | 10.01 |

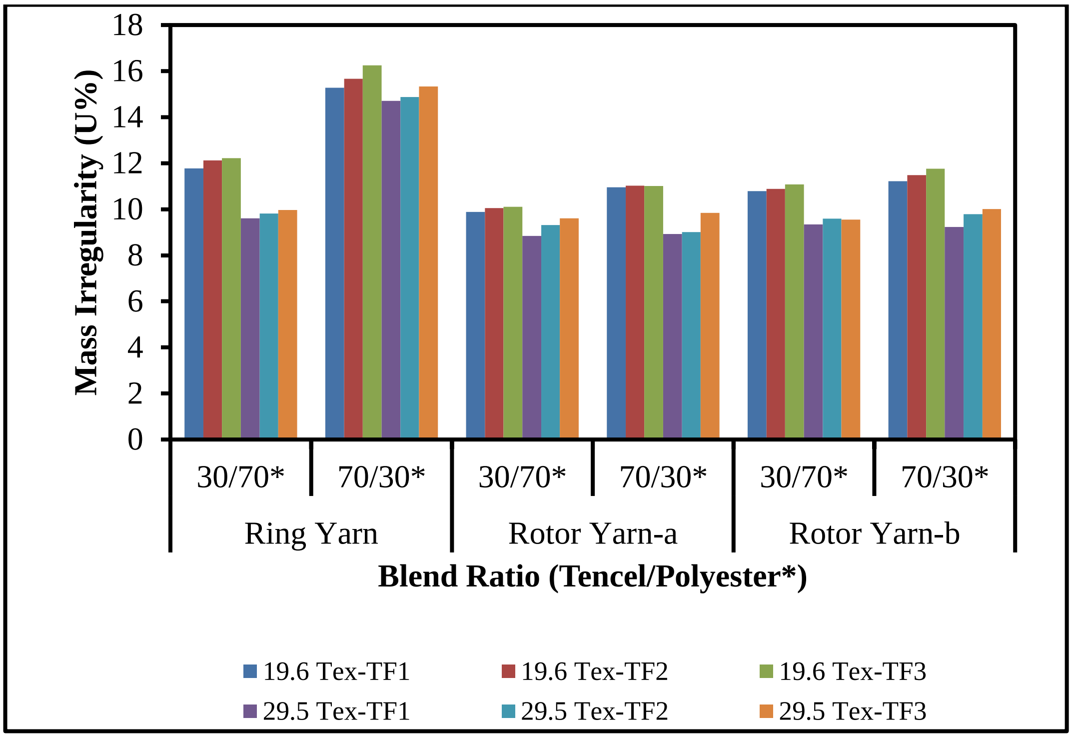


**Fig. 4.3**—Variation in Mass Irregularity (U %) with increase of tencel content in fibre-mix of Tencel/Polyester* blended ring and rotor yams spun at different tex twist factors and rotor speeds

**Imperfections**

It can be observed from table 4.4 (A) & 4.4 (B) and Fig. 4.4 the effect of twist level, constituent fibres and spinning technique on yarn imperfections. The imperfections/km, particularly thick places and neps, of ring yarns shows a steep rise with the increase of tencel. The main cause of this sudden increase in imperfections of ring yarns is the fibrillar nature of tencel [4, 8] and in addition to this some fibres in the form of bunches were also gone with yarn from drafting zone. While the rotor yarns show decrease in imperfections with increase of tencel content. This can be ascribed as polyester fibre possesses low density and high elasticity than tencel which results in more wrappers and belting fibres therefore imperfections/km increases with the increase of polyester content in rotor yarns. Furthermore, the problems associated in regard to fibrillar nature of tencel with roller drafting are not found in rotor spinning. Thin places are not found in both type of coarser yarns.

As the twist factor increases, both type of yams exhibit an increase in imperfections. Ring yarns show more imperfections than their rotor counterparts, as a consequence of increase in twist level decreases the front roller delivery speed and reduces the inter fibre friction in the drafting field. While rotor yarns also exhibit an increase in imperfections with the increase of tex twist factor owing to increase in the incidence of wrapper fibres. But this increase in rotor yarns is much lesser than ring yarn. This tendency could also be attributed to the factors as mentioned in unevenness [1, 14].

Again, the increase of rotor speed results in increase of imperfections as the formation of more number of wrappers and belting fibres in yarn and furthermore, the belting fibres were also get counted as neps during evenness testing and it is the complete agreement with Manohar and coworkers [18].

All the finer yams show higher number of imperfections than their equivalent coarser yams. It is due to more number of fibres in cross-section in yarn as well as better processing control.

**Table-4.4 (A)** Influence of Blend Ratio and Tex Twist Factor on Imperfections of Tencel/Polyester* Blended Ring & Rotor Spun Yarns

| Yarn Linear Density | Blend Ratio | Ring Yarn | | Rotor Yarn-a | | Rotor Yarn-b | |
|---|---|---|---|---|---|---|---|
| | | 30/70* | 70/30* | 30/70* | 70/30* | 30/70* | 70/30* |
| 19.6 Tex | $TF_1$ | 215 | 700 | 80 | 47 | 169 | 81 |
| | $TF_2$ | 241 | 774 | 92 | 54 | 189 | 93 |
| | $TF_3$ | 288 | 870 | 131 | 66 | 220 | 123 |
| 29.5 Tex | $TF_1$ | 40 | 183 | 23 | 12 | 44 | 31 |
| | $TF_2$ | 44 | 257 | 34 | 25 | 58 | 37 |
| | $TF_3$ | 55 | 309 | 35 | 29 | 68 | 45 |

**Table-4.4 (B)** Influence of Blend Ratio and Tex Twist Factor on Thin, Thick, Neps and Imperfections) of Tencel-Polyester Blended Ring and Rotor Spun Yarns

| **Thin Places** | | | | | | **Thick Places** | | | | | | **Neps** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Ring Yarn** | | **Rotor Yarn-a** | | **Rotor Yarn-b** | | **Ring Yarn** | | **Rotor Yarn-a** | | **Rotor Yarn-b** | | **Ring Yarn** | | **Rotor Yarn-** | |
| **30/70*** | **70/30*** | **30/70*** | **70/30*** | **30/70*** | **70/30*** | **30/70*** | **70/30*** | **30/70*** | **70/30*** | **30/70*** | **70/30*** | **30/70*** | **70/30*** | **30/70*** | **70/** |
| 2 | 5 | 0 | 0 | 3 | 2 | 26 | 69 | 12 | 8 | 20 | 16 | 187 | 626 | 68 | 39 |
| 2 | 8 | 1 | 2 | 2 | 2 | 16 | 52 | 10 | 6 | 14 | 12 | 223 | 714 | 81 | 46 |
| 4 | 9 | 3 | 2 | 5 | 3 | 12 | 46 | 10 | 2 | 8 | 7 | 272 | 816 | 118 | 62 |
| 0 | 0 | 0 | 0 | 0 | 0 | 9 | 31 | 4 | 0 | 16 | 13 | 31 | 152 | 19 | 12 |
| 0 | 0 | 0 | 0 | 0 | 0 | 6 | 28 | 4 | 2 | 11 | 10 | 38 | 229 | 30 | 23 |
| 0 | 0 | 0 | 0 | 0 | 0 | 6 | 22 | 0 | 0 | 6 | 6 | 49 | 287 | 35 | 29 |

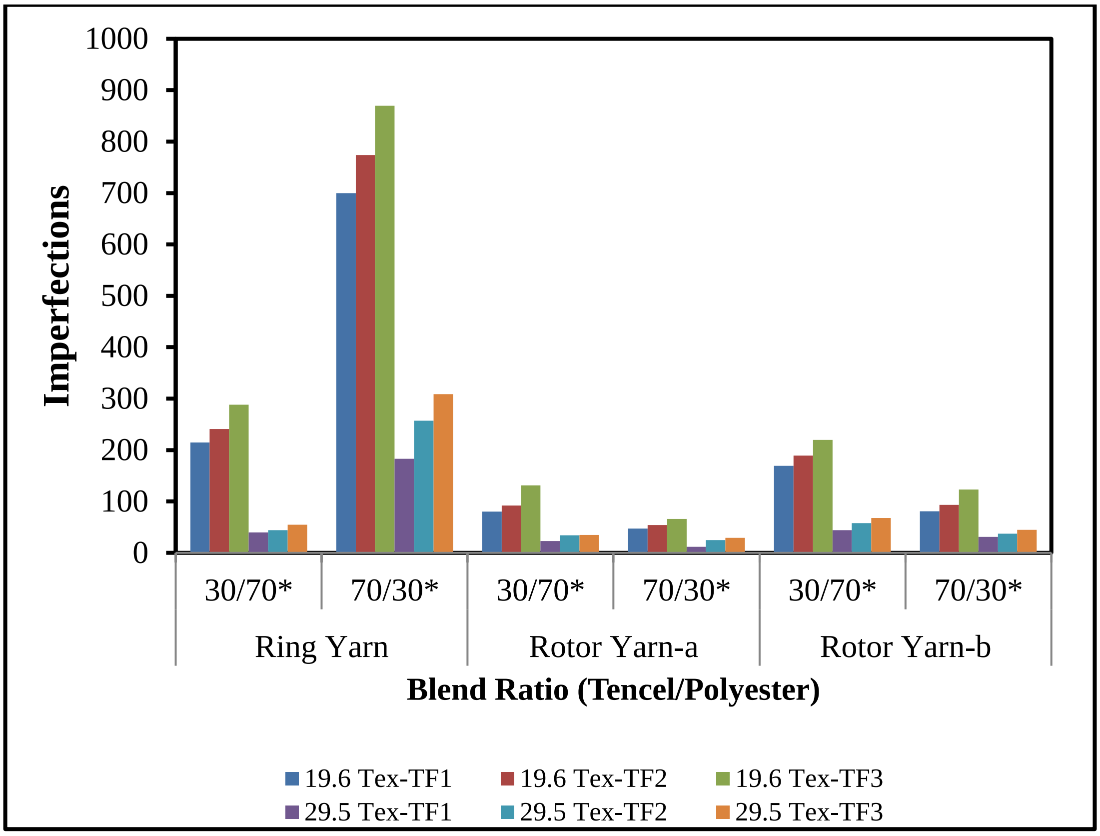


**Fig. 4.4**—Variation in Imperfections with increase of tencel content in fibre-mix of Tencel/Polyester* blended ring and rotor yams spun at different tex twist factors and rotor speeds.

## Flexural Rigidity

Flexural rigidity of a spun yam depends upon its structure and constituent fibres. Coarser as well as finer rotor yarns show high flexural rigidity than their ring equivalent. High flexural rigidity of coarser rotor yarns is due to occurrence of belting and wrapper fibres, while the lower value of flexural rigidity of finer rotor yams due to lesser effective control on fibres during spinning or it can be said to technical limitation of rotor spinning process because high number of fibres in yarn cross section is required in rotor spinning than ring spinning.

While the flexural rigidity of rotor yarns increases with increase of rotor speed due to high centrifugal force and high frequency of wrapper and belting fibres which results in compact yams.

As the tencel content increases both type of yams show an increase in flexural rigidity, it is due to high initial modulus (see stress-strain curve Fig. 2.1) and flexural rigidity of tencel fibre [4,6].

Twist level considerably affect the flexural rigidity of ring as well as rotor yarns. However as the twist factor increases flexural rigidity also increases due to improvement in packing density of yarns which increase the fibre to fibre cohesion and hampers the free movement of fibres. Coarser yarns show slightly higher value of flexural rigidity due to more number of fibres in the cross section which increase the resistance to bend of fibre assembly.

**Table-4.5** Influence of Blend Ratio and Tex Twist Factor on Flexural Rigidity × ($10^{-3}$ Gm.Cm$^2$) of Tencel/Polyester* Blended Ring & Rotor Spun Yarns

| **Yarn Linear Density** | **Blend Ratio** | **Ring Yarn** | | **Rotor Yarn-a** | | **Rotor Yarn-b** | |
|---|---|---|---|---|---|---|---|
| | | **30/70*** | **70/30*** | **30/70*** | **70/30*** | **30/70*** | **70/30*** |
| **19.6 Tex** | **$TF_1$** | 3.14 | 4.43 | 4.06 | 4.63 | 4.24 | 4.89 |
| | **$TF_2$** | 3.26 | 4.57 | 4.24 | 4.72 | 4.49 | 4.85 |
| | **$TF_3$** | 3.37 | 4.60 | 4.37 | 4.90 | 4.72 | 5.06 |
| **29.5 Tex** | **$TF_1$** | 3.19 | 4.56 | 4.48 | 4.15 | 4.73 | 5.43 |
| | **$TF_2$** | 3.38 | 4.74 | 4.63 | 5.32 | 4.96 | 5.45 |
| | **$TF_3$** | 3.48 | 4.82 | 4.88 | 5.3 | 5.19 | 5.76 |

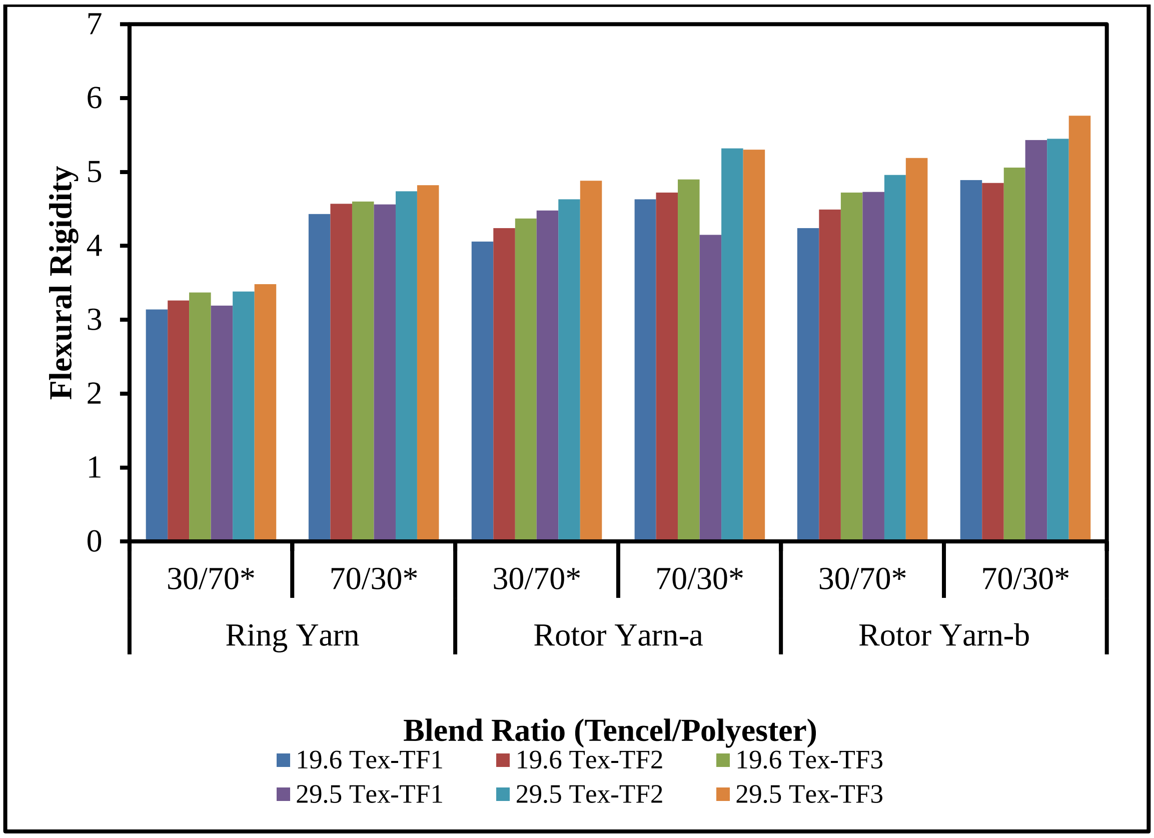


**Fig. 4.5**—Variation in Flexural Rigidity with increase of tencel content in fibre-mix of tencel-polyester blended ring and rotor yams spun at different tex twist factors and rotor speeds

**Hairiness**

A quick look on hairiness results in table 4.6 discloses that the blend components, twist level and 'yarn structure have considerable effect on protruding fibres. Ring yarns show greater hairiness particularly short hairs of 1mm & 2mm length than rotor equivalent; this variation in hairiness can be understood partly as the difference in fibre migration that occur in yarn structure formed by the two spinning techniques and partly due to difficulties in binding of edge fibres of emerging strand from drafting zone and friction as exist between yam & traveler and ultimately leads to more hairiness [15].

As the increase in rotor speed, a marked rise in hairiness is observed due to less efficient combing to individual fibre level with more hooked & looped fibre formation and less time for straightening and relaxation of fibres in rotor groove. Also the increase of rotor speed gets higher wrapper fibres and among them loosely wrapped fibres form loops on yarn surface which may count as hairs during observation [1].

In the case of tencel majority in the blend, both ring and rotor yams exhibit higher number of protruding fibres on yarn surface particularly short hairs 1-2mm, due to higher flexural and torsional rigidity of tencel fibre[8, 9].

Furthermore, an increase in twist level of all yarns, a decrease in yarn hairiness index was noticed due to variation in fibre migration behavior. High twist level migrate the fibres towards the yam axis and firmly bind them within yarn body. Low spinning triangle is also a partly cause of the decline of hairiness of ring yarns on the increase of twist factor [10, 11].

**Table-4.6** Influence of Blend Ratio and Tex Twist Factor on Hairiness (Hairs/10cm) of Tencel/Polyester* Blended Ring & Rotor Spun Yarns

| ≥ 1mm | | | | | | ≥ 2mm | | | | | | $S_3$ ≥ 3mm | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Ring Yarn** | | **Rotor Yarn-a** | | **Rotor Yarn-b** | | **Ring Yarn** | | **Rotor Yarn-a** | | **Rotor Yarn-b** | | **Ring Yarn** | | **Rotor Yarn-** | |
| **30/70*** | **70/30*** | **30/70*** | **70/30*** | **30/70*** | **70/30*** | **30/70*** | **70/30*** | **30/70*** | **70/30*** | **30/70*** | **70/30*** | **30/70*** | **70/30*** | **30/70*** | **70/** |
| 743 | 2639 | 171 | 902 | 318 | 927 | 62 | 124 | 32 | 89 | 63 | 110 | 43 | 60 | 38 | 56 |
| 672 | 1007 | 158 | 785 | 266 | 848 | 57 | 94 | 30 | 81 | 54 | 71 | 36 | 53 | 36 | 49 |
| 623 | 1111 | 160 | 616 | 241 | 821 | 50 | 97 | 32 | 74 | 44 | 58 | 32 | 50 | 34 | 43 |
| 1674 | 2015 | 913 | 1291 | 1349 | 1871 | 163 | 184 | 88 | 112 | 163 | 189 | 56 | 71 | 41 | 61 |
| 1309 | 1721 | 730 | 838 | 1194 | 1352 | 137 | 151 | 90 | 99 | 121 | 166 | 49 | 67 | 37 | 54 |
| 1268 | 1750 | 746 | 690 | 986 | 1086 | 134 | 135 | 82 | 94 | 99 | 147 | 46 | 64 | 36 | 47 |

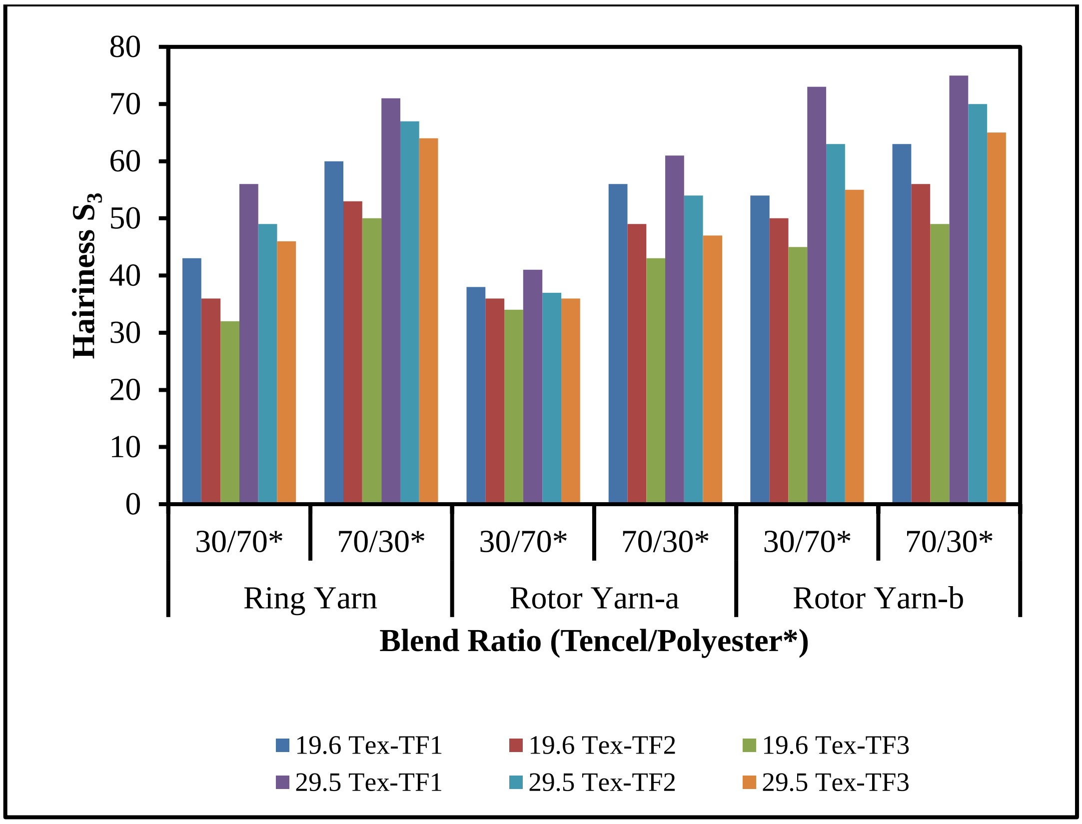


**Fig. 4.6**—Variation in Hairiness with increase of tencel content in fibre-mix of Tencel/Polyester* blended ring and rotor yams spun at different tex twist factors and rotor speeds.

## CONCLUSIONS

**5.1** Tensile properties of tencel-polyester blended ring as well as rotor yarns are greatly influenced by variation in its fibre composition, twist factor and rotor speeds. As the tencel content increases in the blend both types of yarns show a significant reduction in their strength, breaking extension and work of rupture. However, both ring and rotor yarns show maximum strength at 38.25 tex twist factor than show a decreasing trend with further increase in twist level. Again, Ring yarns show an increase in breaking extension with the increase of twist factor. Furthermore, rotor yarn-a (spun at rotor speed of 1333.33 rps) exhibit more or less comparable breaking extension to their equivalent ring yarns because the rotor speed of 1333.33 rps is high enough to make the yarn more compact. But further increase of rotor speed adversely affects the all tensile characteristics. Again, the work of rupture replicates a trend alike to tenacity and breaking extension with varying twist factor.

**5.2** Ring yarns show an abrupt increase in mass irregularity and imperfections (particularly thick places and neps) with the increase of tencel content in the fibre mix. It is due to fibrillar nature of tencel which enhances the fibre entanglement in drafting zone and reduces the effective control on moving fibres. However, rotor yarns also exhibit a rise in mass irregularity with the increase of tencel content in the mix but this rise is much lesser due to nonexistence of drafting irregularities. Furthermore, the rotor yarns show an opposite trend with imperfections with the increase of tencel content. While an increase in twist factor, a rise in unevenness and imperfections of ring and rotor yarns is observed. As expected, all rotor yarns were more even and possess fewer imperfections than their ring counterparts. Furthermore, Mass irregularity and imperfections were increased with the increase of rotor speed.

**5.3** Tencel majority yarns exhibit more flexural rigidity than polyester majority yarns, due to higher initial modulus and bending rigidity of tencel fibre. While an increase in twist factor enhances the flexural rigidity of all the yarns. Again, all the rotor yarns show higher rigidity than their ring counterparts and it further increases with increase of rotor speed.

**5.4** Hairiness value ($S_3$) of rotor yarns was much lesser than ring yarns, which further increases with addition of tencel fibre in the fibre mix, Again, hairiness value ($S_3$) of rotor yarns increases with increase of rotor speed, Also hairiness of all yarns reduces with the increase of twist factor,

**5.5** All rotor yarns were bulkier than their ring equivalents due to structural differences. Among the rotor yarns, increase of rotor speed raises the packing fraction. While increase in twig factor lowers the yarn diameter and increases the packing fraction of all yarns. With the increase of tencel, the diameter of rotor yarns increases, where as the diameter of ring yarns decreases with increase of tencel content due high density of tencel. After steaming treatment all ring and rotor yarns show a rise in diameter,

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