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Hairiness Values of the Polyester/Viscose Ring-Spun Yarn Blends

Abstract
In this work, 0.133 - 0.166 tex and 38 mm of fiber length of polyester and viscose rovings of 591 tex (α_{tex} 8) were blended variously (polyester/viscose 35/65%; polyester/viscose 50/50%; polyester/viscose 65/35%; polyester 100% and viscose 100%) and the yarns were produced at spindle speed of 18000 rev/min with 48 mm of ring diameter and C type of traveller 50 mg (No.1/0) in ring frames. Later, the resulted 20 tex yarns were examined by measuring its tenacity, elongation, irregularity and hairiness. The aim of this study is to investigate the hairiness of ring-spun polyester/viscose blends, which are commonly used in the textile industry, by using three different test methods. The pilling values of these produced samples were also determined. The outcomes have been assessed according to the blend ratios and fiber locations which were scanned on the scanning electron microscope; the observations were concluded both on the hairiness and pilling values depending on the blend proportions. As a result, within the produced yarns the worse hairiness was obtained on the viscose (100%) yarns and the worse pilling values were existed on the knitted fabrics which are formed from these spun yarns.

Key words: *polyester, viscose, blends, ring-spun yarn properties, hairiness, pilling.*

Introduction

As it is well known, hairiness is one of the important parameters for spinners and for further processors in textiles; some researchers [1] indicated that for cotton yarns the statistical distribution of the number of protruding ends of different lengths is exponential. On the other hand, due to the hairiness in the yarn some defaults on the fabric may be appeared. Warp drawer-in and warp yarn tangling during weaving process and hence warp yarn breakages, pilling on the knitted and woven fabrics and some defaults on the appearance of fabrics can be given as an example [2]. Hairiness has become one of the measurable yarn parameters from the beginning of 1950's and since then is used regularly in yarn testing. Yarn hairiness does not only depend on a single parameter and is difficult to be prevented [3]. Hairiness is defined as yarn protruding ends from the yarn body and the factors that affecting it are fiber parameters, processes of production, yarn and machine parameters etc. Some of the studies carried out previously [4, 5] have expressed that the cause of hairiness that are due to fiber characteristics such as short fibers, long fibers, fiber bridges, fiber loops, loose fibers, vertical fibers etc. are due to the positioning within the yarn body itself were examined from the photographs by the scanning electron microscope.

Table 1. *Fiber properties.*

Fiber	Fiber linear density, tex	Fiber length, mm
Polyester	0.166	38
Viscose	0.133	38

Table 2. *Ring machine parameters.*

Parameters	Values
Spindle speed, rev/min	18000
Ring diameter, mm	48
Flange, mm	3.2
Traveller speed, m/s	45
Spool length, mm	210

The aim of the research work presented in the article was firstly to confirm the hairiness values, which are measured using three different test methods, of the five different blends of polyester/viscose ring-spun yarns when any results related to the fiber of mixed blends are known from literature and secondly are or to indicate with same lengths of two different fibers of almost same linear densities which may cause various fiber protruding ends that may effect the percentage of yarn hairiness and hence its pilling value

Table 3. *Data of yarn processing.*

Machine	Parameters					
	Doubling	Drafting	tex_{input}	tex_{output}	α_{tex}	n_{spi}, rpm
Card	1	100	492,118	4,922	-	-
Drawframe I	8	9.3	4,922	4,219	-	-
Drawframe II	6	5.5	4,219	4,543	-	-
Rowing frame	1	7.6	4,543	591	8	1100
Ring frame	1	30	591	20	35.4	18,000

Table 4. Yarn linear density, twist and tensile parameters.

Yarn abbreviations	Yarn types	Yarn count, tex	Twist level, turns/m	Breaking tenacity, cN/tex	CV, % of tenacity	Elongation, %	CV, % of elongation	Work-to-break (cN.cm)
A	Viscose (100%)	20.4	735	17.9	9.5	15.0	5.8	1600.2
B	PES (100%)	19.8	715	29.2	5.2	18.8	9.5	1621.3
C	PES / Viscose (50/50%)	19.7	748	22.3	12.4	14.2	7.4	1455.4
D	PES / Viscose (65/35%)	20.0	770	25.5	5.4	14.8	4.0	1902.9
E	PES / Viscose (35/65%)	20.5	809	19.5	5.1	12.7	9.4	1362.1

when the relations between the fiber ends are unknown.

Experimental

Materials and production parameters

In this work polyester and viscose fiber and its different blends were used at twist constant of α_{tex} 35.4 and 20 tex ring-spun yarns were produced. The yarn tests were carried out at 20 ± 2 ^{0}C, 65% ± 2 RH conditions after the samples reaching equilibrium. The fiber properties of these materials are given in ***Table 1***, the specification of the ring machine is presented in ***Table 2***, the process data is given in ***Table 3*** and yarn parameters are presented in ***Table 4***.

Traveller specifications

In this study, C type 1/0 (50 mg) Reiners Fürst brand traveller was used and has been abbreviated as C1 hr EMT in the work. The coded symbols are given below:

C: Type of traveller (normal profile of C type traveller)
1: Type of ring flange (3.2 mm)
hr: Wire profile (half round cross section)
EMT: Traveller shape (Narrow and medium low shape).

Yarn linear density, twist parameters, yarn breaking tenacity and elongation

In this work, five different types of yarns were produced at the same yarn linear densities and these were abbreviated as A, B, C, D, E in the tables and in the graphs. The linear densities, twist parameters and yarn breaking tenacity with elongation are tabulated in ***Table 4***. Breaking tenacity and elongation of the yarns were determined on the Zweigle F425 Tester. Clamping length was 500 mm; pre-tension was 10 cN and testing speed was chosen 500 mm.

Yarn imperfections

Yarn imperfections were tested on the Uster Tester 3. All samples run through the tester at 400 m/min. The imperfection results are listed in ***Table 5***.

Yarn hairiness

The yarns were acclimatized at the standard atmosphere conditions for 48 hours and later their hairiness values were tested on the Uster Tester 3, Shirley Yarn Hairiness Tester and on the Zweigle 566 Hairiness meter.

Table 5. Yarn imperfections.

Yarn abbreviations	Mean linear irregularity (Um)	Index (I)	Thin places, 1/km	Thick places, 1/km	Neps, 1/km	CV_m, %
A	8.7	1.2	9	6	12	11.0
B	10.2	1.6	26	5	6	12.8
C	9.9	1.5	25	25	55	12.5
D	9.2	1.3	20	15	65	11.6
E	9.5	1.4	30	30	25	11.9

Table 6. Yarn hairiness data (UsterTester 3).

Yarn abbreviations	Hairiness (H)	Standard deviation of hairiness - sh, 1 m	Standard deviation of hairiness - sh, 10 m	CV, % of hairiness
A	6.0	0.3	0.10	4.2
B	5.9	0.3	0.07	4.5
C	5.8	0.3	0.10	4.7
D	5.0	0.2	0.07	3.3
E	5.2	0.2	0.06	3.0

Table 7. Yarn hairiness data on the Zweigle G566 Hairiness meter and Shirley Yarn Hairiness Tester.

Yarn abbreviations	Zweigle G566 Hairiness meter				Shirley yarn hairiness tester, hairs/m
	N1 < 1mm long	N2 <2 mm long	N3 <3 mm long	S3 >3 mm long	
A	6746	370	356	498	71.6
B	6629	340	267	443	48.1
C	5508	370	314	456	57.6
D	4072	215	128	177	40.4
E	4829	274	179	246	42.0

Table 8. Percentage of fiber protruding ends according to Zweigle G 566 Hairiness meter.

Yarn abbreviations	The number of total protruding ends (N1+N2+N3+S3)	N1, %	N2, %	N3, %	S3, %
A	7970	84.6	4.7	4.4	6.3
B	7679	86.3	4.5	3.4	5.8
C	6648	82.9	5.6	4.6	6.9
D	4592	88.7	4.6	2.8	3.9
E	5528	87.4	4.9	3.2	4.5

The meaning of hairiness in Uster Tester 3

Hairiness (H) can be defined as the total protruding fiber lengths that projects from the yarn body and measured by the hairiness measurement unit; in this unit approximately 1 cm yarn lengths are considered. Provided that H is the relationship between two lengths (of hairs and yarn), it is therefore a non-dimensional quantity. For example, H = 4 means that

Table 9. Pilling data of the knitted fabrics.

Yarn abbreviations	Pilling values
A	2
B	3
C	3
D	3
E	3

the proportion of protruding ends from the yarn body is total of 4 cm in fiber length to the measuring field of 1 cm. ***Table 6*** shows results from the tests made on the Uster Tester 3 which the yarn samples run through at 400 m/min.

The meaning of hairiness on Zweigle G 566 Hairiness meter

The yarn delivery speed was 100 m/min and the number of protruding fibers, N1(<1mm long), N2 (<2mm long), N3 (<3mm long) and S3 (>3mm long) were observed. Each sample was measured 5 times and the results are given in ***Table 7*** and percentage trend of general fiber protruding ends are listed in ***Table 8.***

The meaning of hairiness on Shirley yarn hairiness tester

This instrument could test fibers at distances of every 5 mm which protruded at an angle of 70° and were longer than 3 mm. Testing times could be set as 5, 10, 20, 30 and 40 seconds. A total of 250 m of yarn length were measured for their hairiness and 30 tests were made on each sample yarn with 8.33 m/10 seconds on the Uster Tester I during 50 m/min of test speed. The results can be seen in ***Table*** *7*.

Fabric production and pilling

To be able to reflect the hairiness values on the produced fabrics, each type of yarns were then knitted on the socks machine of Harry Lucas brand (E20 and a total of 240 needles). The samples were conditioned under the standard atmosphere for 48 hours and each 4 samples from the knitted fabrics have been tested for their pilling on the Nu-Martindale Abrasion Tester. 1000 rubs considered for the pilling tests and the comparison has been made according to ASTM D4970-89 [6]. The related standard gives the pilling values of the fabrics as 1, 2, 3, 4, 5 from the worse to the best numeric. The test results are given in ***Table 9***.

Electron microscopy studies

Cross section and surface of the produced yarns were also analyzed for the hairiness and for their surface appearance on the knitted fabrics by the scanning electron microscope Jeol JSM – 5910 LV.

Results and discussion

Performance of the yarn hairiness

According to the test results of the three yarn hairiness measurements with the use of Uster Tester 3, Zweigle G566 Hairiness meter and Shirley Yarn Hairiness meter, the protruding ends of the fibre seen on the outer surfaces of the yarns cause less hairiness in PES/viscose (65/35%) blended yarns which is denoted as "D". On the other hand, the most hairy yarn obtained was that of the sample coded as "A" which was 100% viscose yarn. From the SEM photograph in ***Figure 10*** we can conclude that the circular shaped polyester fibres in rather gathered together towards the yarn center, whereas the rest of the viscose fibres, can be seen on the outer surface of the yarn. The results were also confirmed by the graphs presented in ***Figures 1 - 6***.

Pilling values of the produced fabrics and their relationship with hairiness

As can be seen from Table 9, the worst pilling value was obtained for the fabric coded as "A" which was produced from 100% viscose yarn. The rest of the samples have pilling values equal to 3. This was also confirmed by fotos presented in ***Figures 7 - 11***. The hairiness of the fabrics' surfaces show entirely similar values to those of the hairiness of the yarns same which were used to manufacture the fabrics.

On the SEM photographs, we can observe that as the hairiness increases, the protruding ends of the fibres are greater. Therefore the knitted samples manufactured from these yarns have a more hairy surfaces. The worst pilling is seen on the photos in ***Figure 7.a*** and ***c***.

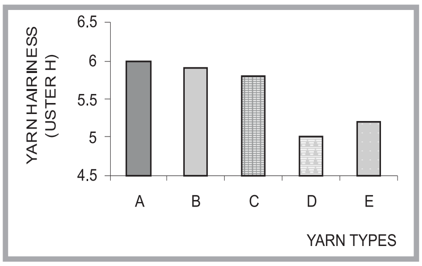

Figure 1*. Yarn hairiness (Uster Tester 3) values versus yarn types.*

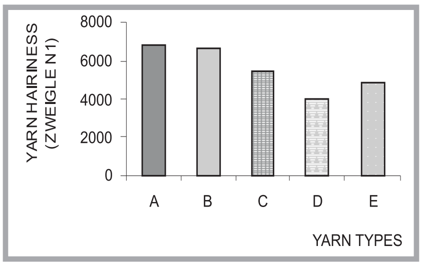

Figure 2*. Yarn hairiness (Zweigle N1) values versus yarn types.*

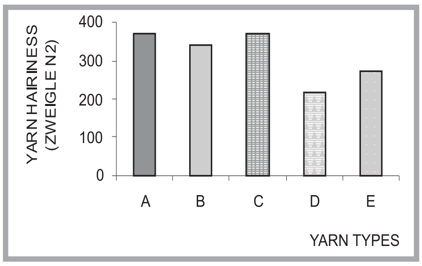

Figure 3. *Yarn hairiness (Zweigle N2) values versus yarn types.*

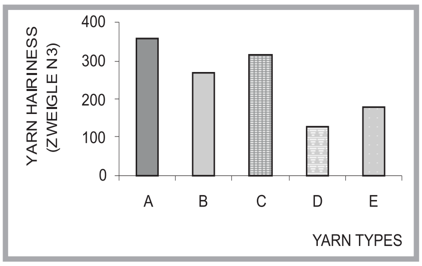

Figure 4. *Yarn hairiness (Zweigle N3) values versus yarn types.*

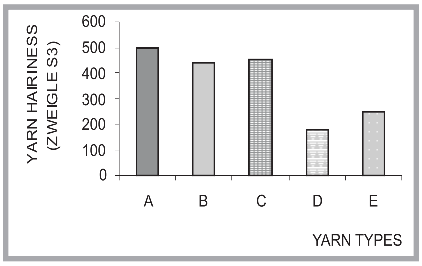

Figure 5*. Yarn hairiness (Zweigle S3) values versus yarn types.*

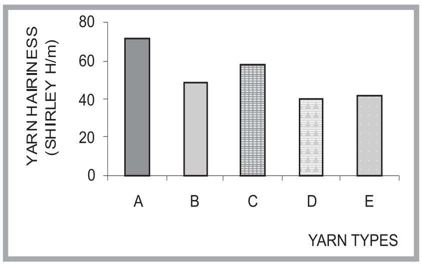

Figure 6*. Yarn hairiness (Shirley H/m) values versus yarn types.*

On the other hand, less protruding ends of the fibres (as in ***Figures 10*** and ***11***) result in less hairy fabric surfaces. The lowest hairiness (see ***Table 7***, S3 values) were presented by samples D and E. Apart from the 100% viscose sample, the pilling values of the fabrics were all similar (see ***Table 9***).

Evaluation of the sem photographs

As mentioned earlier the protruding ends of the fibers were determined, by counting the cross section of both round shaped PES fibers and multilobal viscose fibers, by the scanning electron microscope (Jeol JSM-5910 LV) both on the surface and cross-sectionally to correlate a relationship with hairiness data of the yarns and on the surface of the knitted fabrics which are made of from these yarns; the photographs can be seen in ***Figures 7 - 11***.

If the relevant figures were studied, protruding ends that may cause hairiness and related to fabric appearance values were mostly seen on the viscose (100 %) (see ***Figure 7***) and the less ones on the PES/Viscose (65/35%) blends. This result was also supported by the hairiness data of the yarns that are obtained from the other hairiness instruments and from the fabric pilling values of the samples where can be seen at the ***Table 9***. It has been thought that circular cross shaped polyester fibers placed in the center of the yarn and although viscose fiber's percentage amount is small it migrates towards the yarn surface.

It can be noted from the ***Table 5*** that, apart from the A coded sample which is viscose (100 %) the yarn irregularity (U%) matches with the Uster H values (see ***Figure 1***). The reason for the A coded sample has the highest hairiness value and that it presents the best irregularity value (U %) might be from the low values of the thin and thick places of the yarn [7, 8].

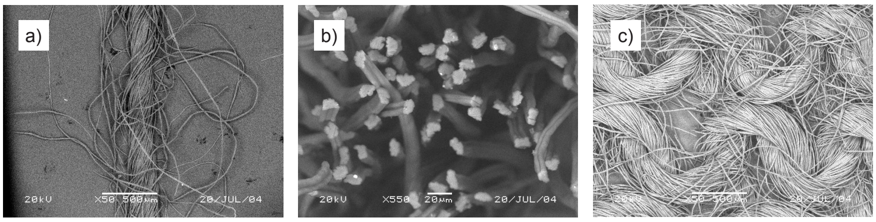

Figure 7. *SEM photographs of the viscose (100%); a-yarn longitudinal view; b-yarn cross-section; c-knitted fabric.*

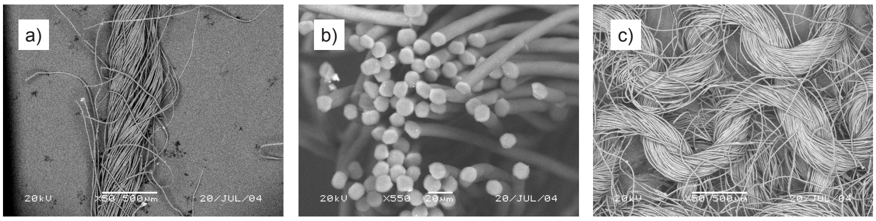

Figure 8. *SEM photographs of the PES (100%); a-yarn longitudinal view; b-yarn cross-section; c-knitted fabric.*

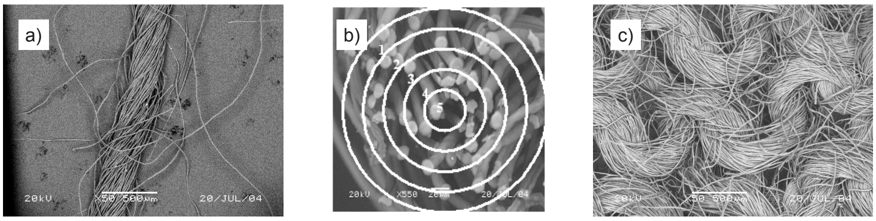

Figure 9. *SEM photographs of the PES/Viscose (50/50%); a-yarn longitudinal view; b-yarn cross-section; c-knitted fabric.*

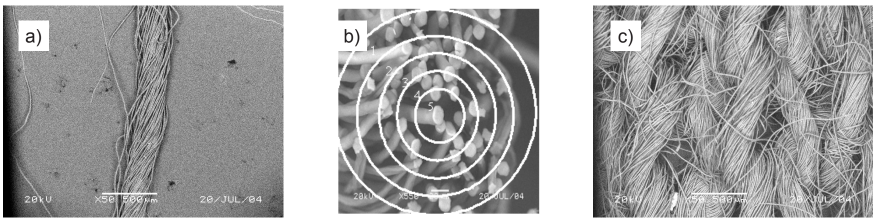

Figure 10. *SEM photographs of the PES/Viscose (65/35%); a-yarn longitudinal view; b-yarn cross-section; c-knitted fabric.*

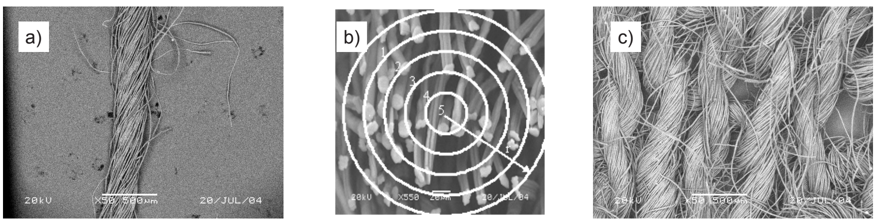

Figure 11. *SEM photographs of the PES/Viscose (35/65%); a-yarn longitudinal view; b-yarn cross-section; c-knitted fabric.*

Table 10. *Number of Polyester and viscose fibers and their percentage data in the cross-section of the yarn.*

Yarn abbreviations	Number of the polyester and viscose fibers in the outer surface (1st and 2nd zone) and their percentage				Number of the polyester and viscose fibers in the inner surface (3rd, 4th and 5th zone) and their percentage			
	Number of PES fibers	% of PES fibers	Number of viscose fibers	% of viscose fibers	Number of PES fibers	% of PES fibers	Number of viscose fibers	% of viscose fibers
C	17	53.1	12	46.9	14	53.8	15	46.2
D	18	60.0	12	40.0	17	51.5	14	48.5
E	10	26.3	11	73.7	2	12.5	14	87.5

Table 11. *Variance analysis between yarn blends and hairiness values.*

Source of variance	Level of significance ($\alpha_{0.05}$)
Yarn blends-hairiness	significant

Contribution of the percentage of yarn hairiness to the number of total protruding ends of the fibers depending on the lengths of fiber protruding ends

The results of the Zweigle G 566 Hairiness meter have shown that the percentage trend of general fiber protruding ends gives a correlation as seen in ***Table 8*** and at below:

N1 (<1 mm long) > N2 (<2 mm long) > N3 (<3 mm long) < S3 (> 3mm long)

Taking into consideration that the data of ***Table 8*** were evaluated for the percentage of protruding fibre ends in relation to the total number of fibres, results that the sample coded "D" (PES/viscose 65/35%) has the smalest hairiness. This was caused by the value S3 (3.9%), however the greatest influence was obtained by fibres less than 1 mm in length (see ***Table 8*** for N1 (88.7%)). This indicates that in order to obtain low hairiness the values of the S3 value (>3 mm long) for PES/viscose blended yarns should be approximately as low as 4 (%).

Table 5 presents that within the C, D and E coded PES/Viscose blended yarns the "D" coded sample does have the lowest hairiness value and also gives lower thin and thick places than the two yarns (C and E).

Additionally, in the ***Table 10***, number of the polyester and viscose fibers, within the inner and the outer zones of the cross-section of the yarn, were determined from the electron microscope (SEM) photographs and later the ratio of these fibers to the total number of the fibers within the yarn section were calculated; the results were then contributed (by means of %) theoretically to the yarn hairiness.

Statistical analysis

As was already mentioned that the "D" coded PES/Viscose (65/35 %) sample has the lowest hairiness value within the yarns produced for this work; the most important parameter for this is the S3 (>3 mm long) of the Zweigle G 566 Hairiness meter and Shirley Yarn Hairiness meter values. Thus, to be able to analyse the above lengths of 3 mm fiber protruding ends on hairiness of the yarns with 95% confidence limits (level of significance $\alpha_{0.05}$) one-way analysis of variance (ANOVA) was carried out on the Zweigle G 566 Hairiness meter for each type of yarn's S3 (>3 mm long) values. The analysis has shown that hairiness values between the yarn types have been found significant (S3), see ***Table 11***.

As a result, less hairiness initially can be obtained on the PES/Viscose (65/35%) blended yarns.

Conclusions

- If yarn hairiness is considered according to the fiber blend proportion and amount of fiber location, the hairiness decreased with the excess amount of PES fibers on the outer zone of the yarn. This can be clearly observed when compared with fiber amounts on the "D" coded PES/Viscose (65/35 %) yarn type and "E" coded PES/Viscose (35/65 %) yarn type at the ***Tables 6, 7*** and ***10***.

- If yarn hairiness is evaluated relation to the amount of fiber location on the "E" coded yarn, the quantity of PES and viscose fibers are almost equal on the outer zone (1st and 2nd zone) of the yarn and its hairiness has been appeared second best after the "D" coded yarn type. This state can be noticed easily on the fiber amount of the outer zone (see Table 10).This indicates that, hairiness becomes less when amount of PES fibers too many or is equal to on the outer zone of the yarn cross-section. On the other hand, it is not possible to point out this as blend proportion is the same on the "C" coded PES/Viscose (50/50 %) yarn type.

- Measurements of the hairiness by the three different instruments have given alike results on the best two yarns. When codes are arranged from little hairiness to more hairiness the below results can be obtained. The abbreviation list is also given underneath.

  Uster Tester 3:

  D < E < C < B < A

  Shirley Yarn Hairiness Tester:

  D < E < B < C < A

  Zweigle G566 Hairiness meter:

  D < E < B < C < A

  A : Viscose (100%),
  B : PES (100%),
  C : PES / Viscose (50/50 %),
  D : PES / Viscose (65/35 %),
  E : PES / Viscose (35/65 %)

  From the three hairiness measurements, it has been observed that the worse hairiness was obtained on the "A" coded Viscose (100%) yarns and the best hairiness was obtained on the "D" coded PES/Viscose (65/35 %) yarns. The highest hairiness value of the Viscose (100%) yarns was reflected as the fabric's worse pilling value. This may be resulted from the low breaking tenacity of the yarns. For this reason, it is recommended that not to underestimate the more pilling value regarding to the use of fabrics which will be produced from Viscose (100%) yarns.

- A general tendency for the PES/Viscose ring-spun yarn blends have shown that as the CV % of tenacity reduces the hairiness decreases.

From the above remarks, it is therefore is recommended that different linear densities and various lengths of fibers may be considered to study further on the hairiness and fiber location within the yarn cross-section of the PES/Viscose blends.

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