AN INVESTIGATION ON HAIRINESS CHARACTERISTICS OF RING SPUN YARNS WITH SLUB EFFECT

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Abstract

Hairiness is one of the main influential properties on slub yarn performance as well as flat yarns. Due to its unique structure, slub yarns have different characteristics from flat yarns. In this study, the effect of structural yarn parameters on hairiness was experimentally investigated for ring slub yarns produced from cotton fibres. The effect of raw material properties was ignored in order to be focused on researching the effect of structural parameters of slub yarn. Slub yarn samples were produced in accordance with an experimental design using a modernized ring spinning frame to create slub effect on the yarn. Then, quality and control tests were applied to all the samples and the results were analyzed by statistical methods. As a result, a significant statistical model was acquired to estimate the hairiness level of slub yarn produced from cotton fibers. The main effective factors were obtained as slub multiplier, base yarn count and twist level in the model.

Keywords: *slub yarn, hairiness, modified ring spinning frame, statistical analysis*

1. INTRODUCTION

Slub yarn is a kind of fancy yarn, whose slub appearance is gained by the variation of the yarn linear density during the spinning process and because of its special appearance, has been widely used in a variety of garments [1]. Therefore, slub yarn manufacturing is not a niche market anymore [2]. It is used widely in textile industry in order to produce primarily denim fabric, clothing and upholstery fabric. The reasons of preffering of the slub yarns are to present special effects to customers and to increasing sales and profits for manufacturers.

In literature, there have been many studies to investigate the influence of fibre and yarn parameters on hairiness of flat yarns. However, the researches with the same aim has not been sufficient for slub yarns in the literature. As known, slub yarn has additional structural parameters compared to flat yarn such as slub length, slub distance, base yarn count and slub multiplier. Besides, distribution of twist on yarn is more variable than flat yarn and the friction between slub yarn and traveller is not steady during spinning [3].

Yarn hairiness has great influence on the weaving process and parameters of textile product such as pilling, porosity, permeability, transport of moisture, comfort, aesthetic properties and hand feeling. In addition, the high level hairiness may leads to increasing of yarn breakages in warping, weaving and knitting processes. The differences of hairiness on weft yarns lead to occurence of visual defects as band on fabric surface. Generally, the main effective factors on flat yarn hairiness are accepted as type of fibres, blending ratio, yarn production technology, twist level and count of yarn. Among the yarn parameters, the most effective factors on hairiness are linear density and twist level. Generally, it is accepted that the increase in the yarn linear density (Tex) increases yarn hairiness and the increase in twist level decreases yarn hairiness to some extend. Besides, the production parameters and method also affect the yarn hairiness and increase in spindle speed increases the yarn hairiness [4,5,6]. In the literature, it is emphasized that the slub sections have more hairiness than base yarn sections on slub yarns, since slub sections have higher number of fibres in crosssection [1]. This fact is an important aspect for an air-jet loom to reduce yarn hairiness. The decrease of slub yarn hairiness increases of shed clarity and loom efficiency [7].

In this study, it is aimed to investigate the hairiness characteristics of slub yarn and effective factors. For this purpose, many slub and flat yarn samples were produced from same cotton blend (100%) according to an experimental design using a modernized ring spinning frame to produce slub yarn. Then, quality and control tests were applied to all yarn samples and the results were statistically analysed. The effect of fibre properties on slub yarn hairiness was not considered in this study. The effect of slubby structure of yarn samples on hairiness was also examined by using visual methods.

2. EXPERIMENTAL

As known, fiber properties are very effective on yarn hairiness but it was excluded in this work. Because the aim of this study is especially to research the effect of structural parameters of slub yarn on hairiness. In the experimental design, the dependent variable is hairiness and the effective factors are given in Table 1.

Table 1. The dependent and effective factors in the experimental design [8]

Qualification of factors	Factors	Unit	Levels (low / high)
Dependent	Hairiness (H)	-	-
Effective	Slub Length	mm	50 - 100
	Slub Distance	mm	80 - 150
	Slub Multiplier	-	1.75 – 2.75
	Ramp Time	ms	60 - 120
	Base Yarn Count	Ne	20 - 30
	Twist Level	T/m	608-755-933 (α_e=3.5-4.3)

In accordance with the experimental design matrix, 64 samples of the slub yarn which includes all combinations of different factor levels were produced. Flat yarn samples with Ne 20 (α_e=3.5 and 4.3) and Ne 30 (α_e=3.5 and 4.3) were also produced to compare with the slub yarn samples. The raw material is 100% combed cotton blend. The production conditions of slub yarn samples are given in Table 2. All the measurements and tests were performed under the standard atmosferic conditions (temperature of 20±2 ^{0}C, %65±2 Rh.). The raw material was transformed into the roving with requested properties by passing through the conventional opening, blending and preparing process of the combed cotton line.

Table 2. Conditions for production of the slub yarn samples [8]

Climate	Temperature 25-27 ^{0}C, 55-60% Relative Humidity
Traveller	Type El 2f LB of Reinerfürst, number 2 for short slubs, number 4 for long slubs
Breaking Draft	1.15
Total Draft	For Ne 20 of Base Yarn Count; 9.1-25.0 For Ne 30 of Base Yarn Count; 13.6-37.5
Speed of Spindle (rpm)	6000
Delivery Speed (mpm)	6.43;7.95;9.87 (depend on twist level and yarn count)

Slub yarn samples were produced in a ring spinning frame with 56 spindels modernized mecatronically with an original slub attachment for producing slub yarns. The modernization was carried out as part of a thesis performed in the Department of Textile Engineering in

Çukurova University [8]. Before measurement of hairiness, the dimensional properties of slub yarn samples (slub length, slub distance, slub multiplier) were measured. Besides, count, twist and hairiness of all samples were measured.

In order to measure lengths, first a yarn sample was lied on a black ground without tension, the begining and finishing points of the slubs were marked by a colour pen and then the lengths were measured by means of a steel ruler. Total 20 measurements were taken in duplicate from 10 cops for each combination. The measurement of slub multiplier were made by both manual and visual analysis methods. For manual measurement, many parts were cut from slub and base yarn sections except ramp sections for the selected 8 different samples. We paid attention that total length of parts for any sample is over 1 m. The yarn parts were weighted and the sectional yarn counts were calculated. Then we acquired the slub multipliers by calculating the proportion of base yarn counts (Ne) to slub counts (Ne) for each sample. In image analysis method, the diameters of the same yarn samples for base yarn and slub sections were also measured by using SDL Microscope System with Digital Camera. The average of total 20 measurements were obtained and the slub multipliers were calculated as the proportion of slub diameters to base yarn diameters for each selected sample in order to evaluate the harmony between theoretical and measured values.

For measurement of yarn count, 10 skeins (100 m per cop) from 10 cops of each sample were wrapped by a wrapping reel, the skeins were weighed by a precision balance of which sensitivity is 1/10000 g and the average counts (Ne) of all samples were obtained. Twist measurements for all samples were performed by means of a conventional twist tester designed to measure yarn twist by untwist/retwist method.

The hairiness measurements were carried out by using Uster Tester IV. Uster Tester IV determine the quantity of protruding fibers from the yarn body by means of an optical sensor. The hairiness (H) corresponds to the total length of the protruding fibres within the measuring field of 1 cm [10]. The hairiness measurements were carried out for 5 cops of each combination as one test for each cops. The 1000 m of each yarn sample was measured for 2.5 min at 400 m/min speed by using Uster Tester IV. In statistical analysis, we applied stepwise multilinear regression analysis (MLR) to the test results and acquired a significant statistical model to predict the hairiness level for slub yarns produced from same fiber blend. During study, we have only considered the effect of structural parameters of slub yarn excluding the properties of raw material. All the statistical analysis were performed by using SPSS 20.0 software package.

3. RESULTS AND DISCUSSION

3.1. Results of Measurements for Dimensional Properties of Slub Yarn Samples

The dimensional properties of slub yarn samples such as slub length, slub distance and slub multiplier were measured and determined deviations from theoretical values for all samples. The obtained results are given in Table 3. As can be seen from this table, the highest deviation from the theoretical lengths is 8%. The highest deviation in length is 9.2 mm. In literature, it has been mentioned that the deviation in length about 10 mm is normal for slub length and slub distance [8]. Thus, we concluded that the deviation levels can be accepted.

Table 3. Results of length measurements for slub yarn samples

	Theoretical vs. Measured Lengths											
	Slub Length (mm)						Slub Distance (mm)					
	50			100			80			150		
	Slub Length	CV (%)	Deviation (%)	Slub Length	CV (%)	Deviation (%)	Slub Distance	CV (%)	Deviation (%)	Slub Distance	CV (%)	Deviation (%)
Average	54.0	6.4	8.0	98.1	5.1	2.5	77.8	6.0	4.0	159.2	3.5	6.1

Slub multipler was measured using two different parameters as yarn diameter and count. Then, the results were compared with the required theoretical values in Figure 1. As seen in the graphic, there are an acceptable differences between the measured and theoretical values of slub multiplier. The highest CV% was obtained as 14.11% for all slub multiplier measurements.

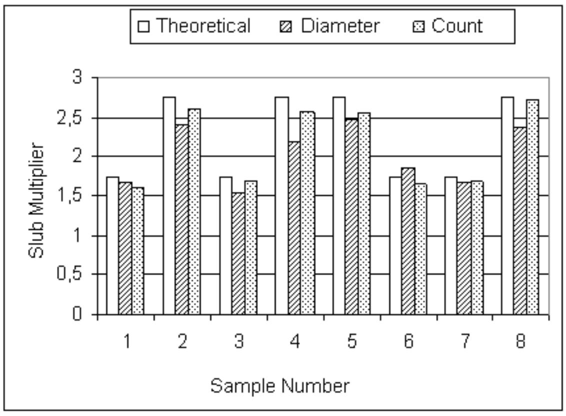


Figure 1. Comparison of the theoretical and measured values for slub multiplier

3.2. Results of Quality Tests Applied to Slub Yarn Samples

Linear Density Measurement

The average deviation of counts of 64 slub yarn samples was obtained as Ne 1.1. The average deviation of counts of flat yarn samples was obtained as Ne 0.3. The results were considered acceptable.

Twist Measurement

The results of twist measurements are briefly given in Table 4. The table shows that all deviations are in acceptable limits.

Table 4. Results of twist measurements for slub yarn samples

Base Yarn Count (Ne)	Twist Coefficient (α_e)	Theoretical Twist Level (T/m)	Slub Yarn		Flat Yarn	
			Average of Measured Twist (T/m)	%CV	Average of Measured Twist (T/m)	%CV
20	3.5	608	616.95	1.82	615.4	6.1
	4.3	755	763.60	1.67	729.7	3.7
30	3.5	755	757.80	1.37	717.8	3.7
	4.3	933	942.70	2.09	947.9	5.3

Hairiness Measurement

The hairiness of slub and flat yarn samples were measured using Uster Tester-IV in accordance with Uster Standards. All the results are plotted in Figure 2.

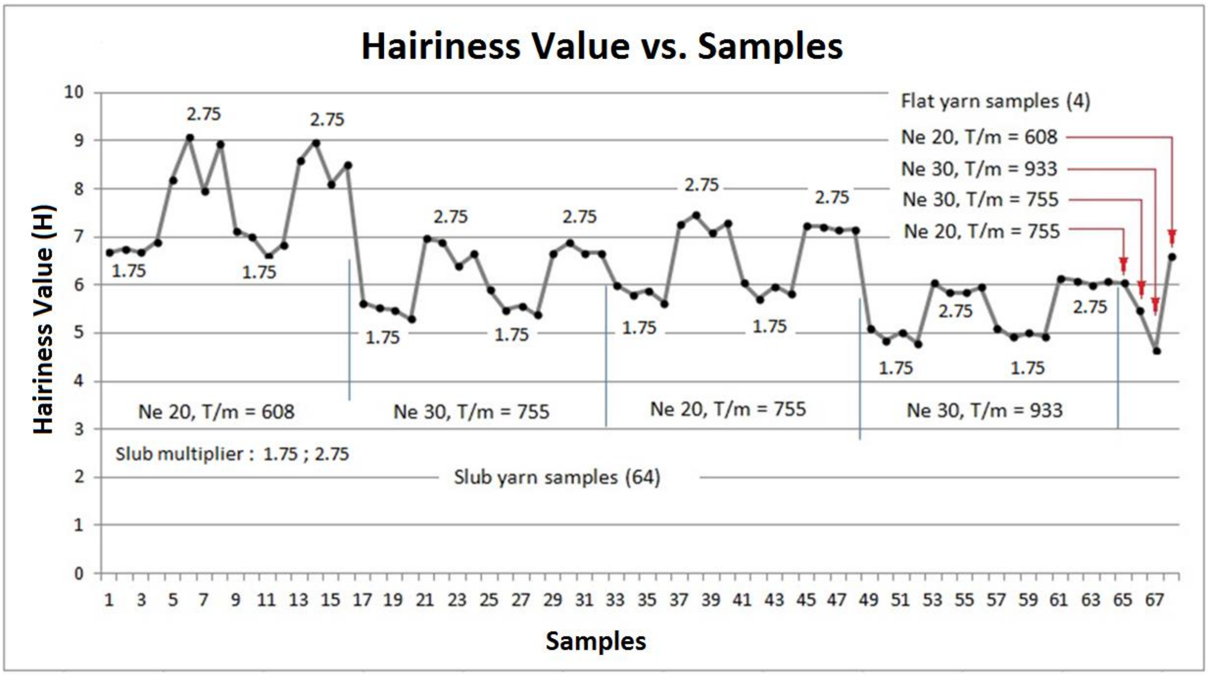


Figure 2. Hairiness levels of the slub (64 samples) and flat (4 samples) yarn samples

In Figure 2, it seems that the hairiness of 64 different slub yarn samples are obtained at different levels changing depends on yarn count, twist coefficient and slub multiplier. It is clearly seemed that the hairiness value of slub yarn samples with 2.75 of slub multiplier are higher than slub yarn samples with 1.75 of slub multiplier. The differences between these two groups of samples with different slub multiplier levels seems are quite significant. It could be explained by increasing the fiber mass with increasing slub multiplier. Besides, the base yarn count factor seems to have a little effect and the twist level factor has quite significant effect on hairiness of the slub yarn samples. The hairiness value sligthly increases with decreasing base yarn count (Ne) and decreases with increasing twist level of slub yarn samples.

3.3. Statistical Analysis

In statistical analysis, stepwise MLR analysis was applied to 54 data sets of slub yarn samples. The remaining 10 data sets were used to evaluate performance of the regression model. In regression analysis, it was found that the normal P-P plot gave a linear relationship and the residuals were normally distributed. There was not any collinearity amongst the dependent factors (VIF=1.000-1.991). The resulting model was statistically significant at $\alpha=0.01$ with $R=0.963$ and $R^2=0.928$. The regression model is given below in Eq. (1).

$$\text{Hairiness (H)} = 8{,}624 - 0.005 \times \text{Twist Level} - 1.327 \times \text{Slub Multiplier} - 0.045 \times \text{Base Yarn Count} \quad (1)$$

All the factors in the model were significant but the other factors which are slub length, slub distance and ramp time were not significant at $\alpha=0.01$. In trials, we have obtained another significant model ($R=0.966$ and $R^2=0.934$) that contains the slub distance in addition to existing factors in Eq. (1) at $\alpha=0.05$. However, we have prefered the model in Eq. (1) because its simplicity and there was no significant difference between the predicted values of two models. The results show that ramp time and slub length have not significant effect on hairiness. In addition, slub distance has negligible effect on hairiness. It is explained that the reducing hairiness in base yarn sections compensates the increasing hairiness in slub sections along whole yarn. Because, Lu et al. (2007) mentioned that the increase of slub length will increase the twist level in base yarn sections and the enhancement of the slub multiplier will decrease the twist level in slub sections significantly. As known that the hairiness level varies inversely proportional to the amount of twist [9,10].

The plots of hairiness vs. the effected factors are given in Figure 3. The plots show that hairiness increases with increasing slub multiplier but decreases with increasing twist level and base yarn count (Ne).

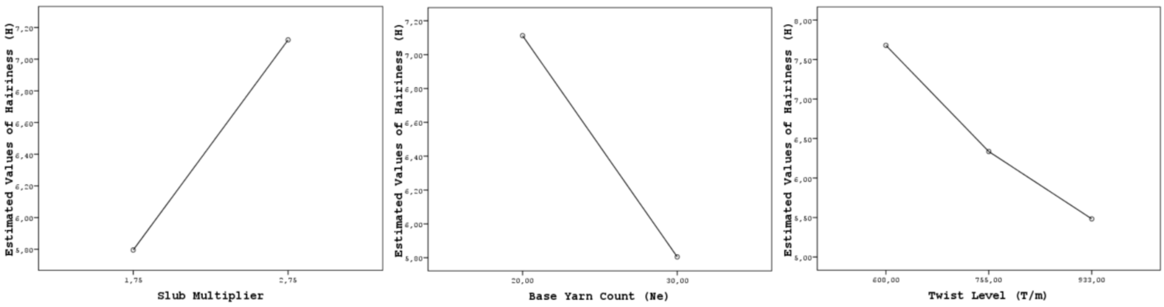


Figure 3. The plots of hairiness vs. the effected factors

For verifiying the statistical model, the predicted values acquired from the regression model were compared with the actual values. So, correlation analysis was applied to 10 data sets which have never been used in regression analysis. The results indicate a strong linear relationship between the actual and predicted values of hairiness with R=0.994 at α=0.01. The predicted and actual values for evaluation are plotted in Figure 4. It seems that the actual and the predicted values acquired from the regression model are very closer and the differences can be negligible technically. The results proved that the success of regression model is satisfied to predict hairiness value of ring slub yarn samples. Of course, the model must be expanded to include fiber properties for generalization.

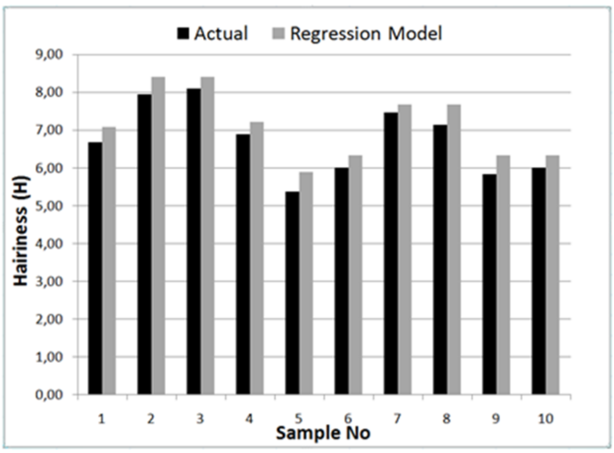


Figure 4. Comparison of actual and predicted values of hairiness value for the regression model

As known that the hairiness of coarse yarns is higher than the hairiness of fine yarns, because the probability of protruding fibers is higher with more fibers in the cross-section [10]. So, stepwise MLR analysis is applied to 54 sets of data to explore the relationship between the hairiness and the average count of slub yarn (Ne) and hairiness value to obtain a simpler model. As a result, we obtained a significant regression equation (R = - 0.847, R^2 = 0.717) at α=0.01 given in Eq. (2).

$$\text{Hairiness (H)} = 9.5 - 0.259 \times \text{Theoretical Avareage Slub Yarn Count} \quad (2)$$

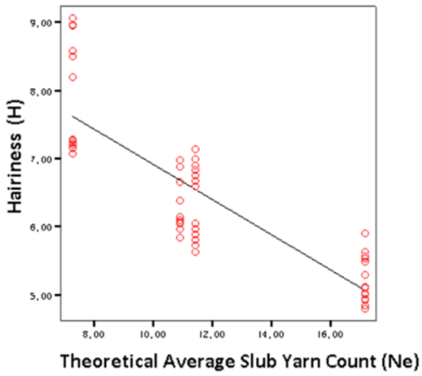
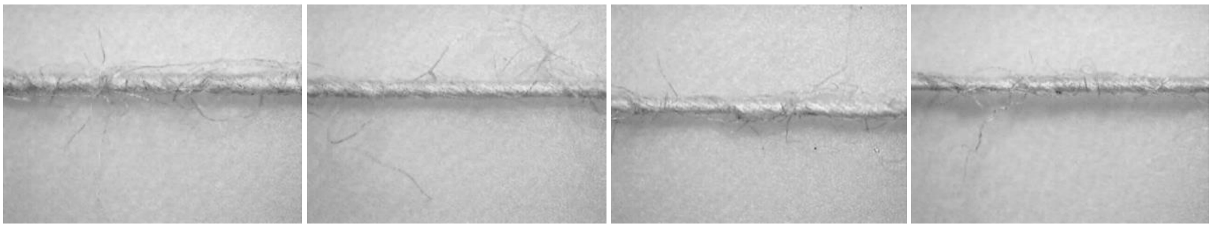


Figure 5. The relationship between hairiness and theoretical average count of slub yarn

The results indicate a reverse linear relationship between the hairiness and average yarn count (Ne) for slub yarn samples (Figure 5). Our trials showed that Eq. (1) can be simplified to include the average yarn count and twist level as dependent factors. So, we established a simpler model to includes these two effective factors using MLR analysis. The simplified model was significant at α = 0.01 with R = 0.919 and R^2 = 0.845.

3.4. Image Analysis

In order to verify the mentioned findings, it is also performed image analysis. Therefore, many photograps of selected yarn samples were taken by using SDL Microscope System with Digital Camera. Then, all the photograps were evaluated and the representitives of them are given in Figure 6 and 7.



(Ne 20, 608 T/m) (Ne 20, 755 T/m) (Ne 30, 755 T/m) (Ne 30, 933 T/m)

Figure 6. The pictures of flat yarn samples

Figure 6 shows that the coarser yarn samples with Ne 20 have significantly more hairiness than the finer yarn samples with Ne 30 and the hairiness decreases a little with increasing the amount of twist.

Figure 7 shows that the hairiness of slub sections is significantly more than the hairiness of base yarn sections. This result can be explained by the increasing of fibre mass and the decreasing of twist level in slub sections. Besides, it is also seemed that the flat yarn samples (Figure 6) have generally more hairiness than the base yarn sections of slub yarn samples at same count (Figure 7). The reason may be the more amount of twist in base yarn sections than the slub sections at same count. Finally, the findings acquired by statistical analysis are supported by the image analysis for hairiness of slub yarn samples.

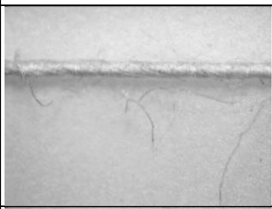
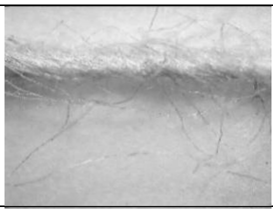
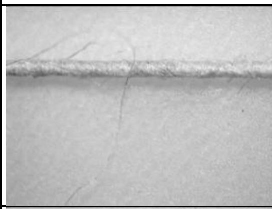
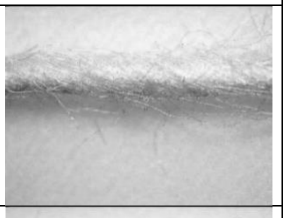
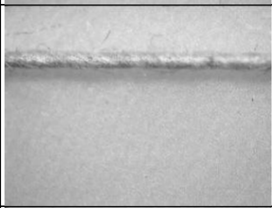
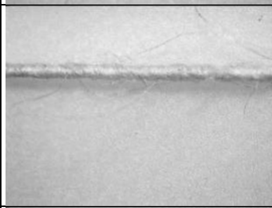
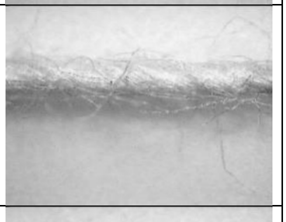
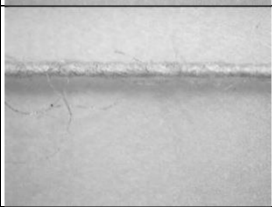
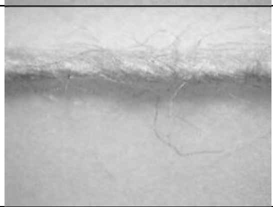
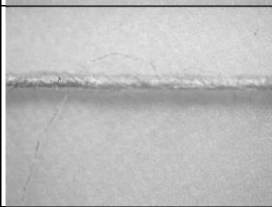
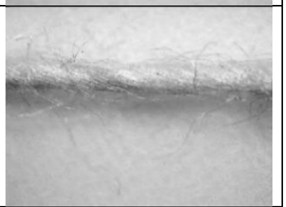
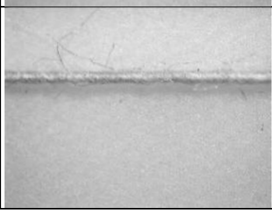
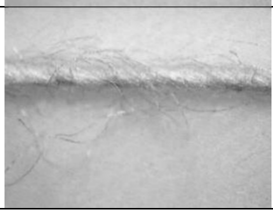
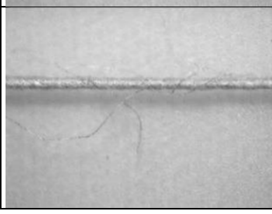
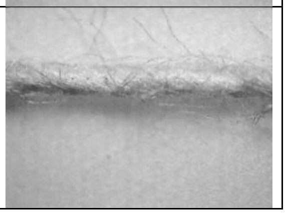
	Slub Multiplier			
Base Yarn Count and Twist Level	1.75 Base yarn section	1.75 Slub section	2.75 Base yarn section	2.75 Slub section
Ne 20, 608 T/m				
Ne 20, 755 T/m				
Ne 30, 755 T/m				
Ne 30, 933 T/m				

Figure 7. The pictures of selected slub yarn samples

All the results show that the slub effect is effective on amount of the yarn hairiness. In the study, it is proved that the hairiness of slub yarns produced from cotton blends can be estimated using a regression model. Consequently, it is clear that the manufacturers who want to decrease slub yarn hairiness must pay attention for the structural parameters of slub yarn as fiber properties.

4. CONCLUSIONS

In this study, the effect of structural yarn parameters on hairiness was experimentally investigated for ring spun yarns with slub effect produced from cotton fibres. The effect of raw material properties was ignored in order to be focused on researching the effect of structural parameters of slub yarn. In the experimental design, the dependent variable was hairiness and the effective factors were slub length, slub distance, slub multiplier, ramp time, base yarn count and twist level. We produced 64 samples of slub yarn which includes all combinations of different factor levels.

In statistical analysis, stepwise MLR analysis was applied to 54 data sets of slub yarn samples. The remaining 10 data sets were used to evaluate performance of the regression model. We acquired a statistically significant model at $\alpha=0.01$ with $R=0.963$ and $R^2=0.928$. Twist level, slub multiplier and base yarn count factors in the model were significant but the other factors which were slub length, slub distance and ramp time were not significant at α=0.01. It is proved that hairiness increases with increasing slub multiplier but decreases with increasing twist level and base yarn count (Ne). For verifiying the statistical model, the predicted values acquired from the regression model were compared with the actual values. The results indicate a strong linear relationship between the actual and predicted values of hairiness with R=0.994 at α=0.01 and the regression model can give acceptable predicted values for hairiness value of ring slub yarn samples. In addition, we explored relationship between the hairiness and the average count of slub yarn and hairiness and obtained a significant regression equation (R = - 0.847, R^2 = 0.717) at α=0.01. For generalization, the models must be expanded to include fibre properties.

Finally, it is proved that the slub effect is effective on amount of yarn hairiness and hairiness of slub yarns produced from cotton blends can be estimated using a regression model. Consequently, it is clear that the manufacturers who want to decrease slub yarn hairiness must pay attention for the structural parameters of slub yarn as fiber properties.

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