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Effect of Slub Parameters on Yarn Unevenness, Hairiness and Strength Properties of Slub Yarns

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ABSTRACT

In this study yarn unevenness, diameter variation, hairiness and strength properties of slub yarns with various slub structures were investigated. The yarns (Ne20) in different slub thickness (1.2, 1.4, 1.6 and 1.8), slub length (1 – 3, 5 – 7 and 10 – 12 cm.), slub frequency (0.5, 3 and 6 pcs/m) and slub ramp length (1, 2 and 4 cm.) were produced from PET fibers. The multipopulation slub yarn, which has two-slub length, was also spun. The measurements of the yarns were made on the Fancy Yarn Profile of the Uster Tester 5 and the Uster Tensojet devices. The values of the test result were analyzed and evaluated statically. The slub parameters were found to have a significant effect on the unevenness and strength properties of the yarns. As the slub thickness, slub length and frequency increased, the yarn unevenness, hairiness increased and the yarn strength decreased. Medium ramp length was found suitable for higher breaking strength and elongation of the slub yarns and it was determined that the number of population was found statistically significant for these properties.

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KEYWORDS

Slub yarn, slub parameters, slub population, yarn unevenness, breaking strength, elongation

1. INTRODUCTION

In recent years because of the competition conditions, manufacturers, in order to survive, must be different from others and be able to produce products with high added value. In the textile industry, it is important to be able to produce different fabrics in order to meet the consumption demands that are always in expectation of change and innovation. One way to obtain these fabrics is to use fancy yarn [1]. Slub yarns, the defining feature of which are repeated regularly or irregularly along the length of the yarn, and which are obtained by increasing the yarn diameter in varying sizes, are classified as fancy yarns.

Slub yarns are used in fashion design clothes such as shirts, dresses, suits, home textiles, curtains, rugs, furniture and automobile upholstery fabrics, apart from denim fabrics and knitted clothes [2]. There are many variables in the production of slub yarns, which are so widely used. In addition to variations in base yarn such as material, yarn count and twist, the production of slub yarn is carried out by considering many parameters such as the thickness, slub length, frequency (number of slubs per meter) and ramp length (Figure 1). As considered that these parameters can be combined in many different ways, slub yarns can be produced in unlimited variety like other fancy yarns. Although this is an advantage in terms of making a difference in fashion design products, it requires more careful and detailed work in quality management.

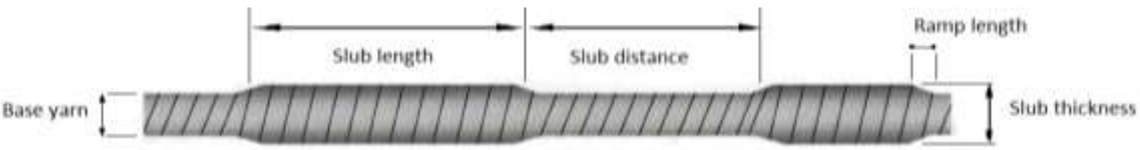

Figure 1. Slub yarn construction

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There are some research related to the slub yarns properties. Rudnik J. and Jackowski T. (2001) investigated the effect of slub yarn twist on the physical and mechanical properties of the yarns [3]. Wang J. and Huang X. (2002) searched the slub yarns produced in the OE spinning system and the factors affecting the slub length. They revealed that the slub length should be at least as much as the rotor circumference and as the rotor diameter and slub thickness increase, the slub length increase [4]. Fritz M. (2006), aimed to create a common language for slub yarns, developed a new algorithm for the analysis of slub yarns and the multiplicity of effect types [5].

İlhan İ. et al (2007) produced plain yarn, yarn with elastane, slub yarns and both elastane and slub yarns using by PES/Viscose fiber. The effect of the winding process on the properties of yarns was examined. It was stated that all the parameters have a significant effect on yarn properties except neps, while the winding process has a significant effect only on hairiness that has causes increased hairiness. It was also found that the slub effect reduces the yarn strength and elongation, and adding elastane together with slub effect increase the yarn unevenness [6]. Souid H et al. (2008) developed a program aimed to provide the production of yarn properties in varying needs and tolerances. By examining the critical yarn parameters (strength, elongation, hairiness, unevenness) in ring and slub yarns, the optimum spacing and feasibility of yarn count and twist variables were tried to be optimized [7]. Öztekin M. (2009) produced slub yarns in 4 different slub thickness and 2 different twist coefficients. It was cocluded as the slub thickness increases the yarn count changes by getting thicker so elasticity, strength and Rkm values of the yarns increase as the thickness increase and the twist value effects yarns strength as well as the fiber values [8]. İlhan et al (2010) defined a relation that can be used to calculate the average number of slub yarn theoretically, depending on the base yarn count, slub length, slub distance, slub thickness, transition time, and production speed variables. An experimental design was made with 64 different types of slub yarn samples. The correlation between the actual average yarn counts obtained from the measurement results and the theoretical average yarn counts obtained from the mathematical relationship was determined. It was revealed that the average count of slub yarns calculated from the theoretical model could be used [9]. The same researchers (2012) investigated the descriptive parameters of slub yarn that have an effect on the yarn breaking strength and elongation using the full factorial design method. They found that the parameters affecting the breaking force were slub length, slub distance and base yarn count whereas the parameters affecting the breaking elongation were slub multiplier, base yarn count and twist coefficient. It was explained that, as the slubs getting longer and thicker the breaking force decrease with an increase in the twist level and the irregular twist distribution on the slub yarn causes decrease of breaking force [10].

El-khalek et al. (2014) developed a computer-based system for evaluation of slub yarn properties. The electrical condenser of the Uster evenness tester was used as the measuring system and capable of measuring slub length, slub frequency, slub distance, slub thickness, percentage of slub and base yarn length, and CV % of tested slub yarn and base yarn. It was revealed that the system could be capable to detect slub yarn defects [11]. Altaş and Özgen (2015), used Taguchi orthogonal experimental design technique instead of full factorial design to find out the optimum slub yarn parameters for increasing yarn tensile strength. They determined that yarn tenacity decreased with the increase of the slub thickness, slub distance have lower effect on strength properties of the yarns. When comparing to the other parameters slub length was found as the least effective parameter [12]. Ray et al., (2016), investigated the effect of base yarn count, base yarn twist level, twist direction and injected fibre components on tensile properties of the slub yarn. Their results showed that the twist direction in the base and final yarn had an affect on the strength and elongation of injected slub yarns. They also determined that for double base injected yarns tenacity and elongation was significantly higher as compared to single base injected yarn [13].

Iqbal and Pramanik (2017) produced multicount cotton yarn with slubs on a ring frame, in three different counts and searched strength properties of the yarns. They found that the yarn twist in the normal sections was higher than the slub sections. They thought that because of the higher number of fibers, yarn breaking strength value was higher at slub sections than at normal sections [14]. Mukhopadhyay et al. (2017), investigated tensile properties and abrasion resistance of injected slub yarn and structural parameters' effect on its. Slub length and slub frequency were found to be very important efffect on yarn breaking strenght, elongation and abrasion resistance. They determined that, at higher slub thickness, as slub frequency increases, tenacity of slub yarn decreases. Opposite to that, at low slub thickness, tenacity of injected slub yarn increases with the increase in frequency. Their study revealed that at longer slub length the hairiness value increases with the increase in either slub thickness or slub frequency, that is causes abrasion damage. The effect of slub thickness was relatively less than slub length and frequency on yarn abrasive damage [15].

ElMessiry and El Deeb (2018) investigated dynamical characteristics of the slub forming mechanism on slub diameter and twist distribution. They found that the distribution of twist angle was governed by the dynamical response of the slub formation mechanism. They offered a mathematical model to calculate the slub diameter and the twist angle along its length [16]. Cui et al. (2020) proposed a novel method for manufacturing a ring-spun slub yarn through multi-channel drafting using a computer numerically controlled (CNC) ring spinning frame. It was found that because of the twist transfer from the slub to the base yarn, as the slub multiplier increase the breaking force and elongation of the yarn increases. The twist distribution is stabilized by the increase of the slub length and thus increases the breaking force and elongation of the yarn [17]. Türksoy at al. (2020), examined the effects of production parameters of dual-core slub yarns on the physical properties of the yarns. They revealed that slub types have not significant effect on hairiness, tenacity and breaking elongation values of the yarn statistically. Unevenness values of dual-core yarns without slub were found to be significantly lower than that of the others. They offered that dual-core slub yarns could be used in denim fabrics construction, like dual-core yarns without slub [18].

As all the references are examined that many of the studies are mostly related with slub yarn production methods and the effect of production parameters on the slub yarn breaking strength and elongation. There is no detailed study examining the effect of all slub parameters (slub length, thickness, frequency, ramp length) on yarn unevenness values (CVm, diameter variation, hairiness etc). There was not any study related with the ramp length and its effect on the slub yarn. The effects of multiple populations on yarn is also a subject that has not been studied before. The breaking strength and elongation values of the slub yarns were also examined. Although fancy yarns and slub yarns are widely used in Turkey and all over the world and have high production quantities, research on this subject is insufficient due to their unlimited variety and complex structure and needs to be examined in more detail. The fact that faulty production of slub yarns, which are in the product group with high added value, is irreversible and this situation will cause serious financial losses, increases the importance of quality control in these yarns. Determining the quality characteristics required for quality management of slub yarns is an important issue.

2. MATERIAL and METHOD

In this study, the effects of different slub structures on yarn unevenness (mass coefficient variation (CVm), diameter variation (CV2D)), hairiness, yarn breaking strength and elongation values were investigated. The yarns were produced from 40 mm long 1.3 dtex fine PET fibers in Ne 20 yarn count and $\alpha_{\varepsilon} = 3.8$ twist coefficient. In slub yarns, structural changes were made in the slub thickness (1.2, 1.4, 1.6 and 1.8), slub length (1 – 3, 5 – 7 and 10 – 12 cm.), slub frequency (0.5, 3 and 6 pcs/m) and slub ramp length (1, 2 and 4 cm.). In order to determine the effect of slub population, the multipopulation slub yarns that in two different slub lengths (1 – 3, and 10 – 12 cm.) were also spun [19].

Yarn production was carried out on a Merlin Spa 1803 sample ring-spinning machine equipped with Pinter slub yarn production equipment [20]. The yarns were tested with the Fancy Yarn Profile of the Uster Tester 5 device at 400 m/min speed [21]. Yarn breaking strength measurements were made by Uster Tensojet device at 400 m/min. in 50 cm measurement length. All the tests were done in standard atmospheric conditions (20±2 °C temperature, % 65±4 relative humidity). The result values were analyzed with the help of SPSS 13.0 statistical program. The effects of slub structure (slub thickness, slub length, ramp length, slub frequency, slub type) on yarn unevenness, diameter variances, hairiness and breaking strength were evaluated using “one-way analysis of variance” (one-way anova). The significance level was chosen as $\alpha = 0.05$ in all analyzes.

3. RESULTS

The test results related with yarn unevenness (CVm, hairiness (H), diameter variation (CV2D)) and strength (breaking strength (tenacity) and elongation) values were given in Table 1.

Table 1. Average values of CVm, diameter variation, hairiness, breaking strength and elongation of the slub yarns

Slub type	Slub frequency (number/m.)	Slub thickness	Slub length	Ramp length	CV_m	Diameter variation (CV2D)	Hairiness (H)	Breaking strength-Tenacity (cN/tex)	Elongation (%)
Basic slub yarns	3	**1.2**	5 - 7 cm	2 cm.	12.12	9.30	5.45	38.85	11.85
	3	**1.4**	5 - 7 cm	2 cm.	16.88	12.62	5.56	36.48	11.38
	3	**1.6**	5 - 7 cm	2 cm.	22.10	16.39	5.65	33.69	10.99
	3	**1.8**	5 - 7 cm	2 cm.	27.50	20.37	5.78	31.77	10.67
	3	1.6	**1– 3 cm**	2 cm.	17.65	13.09	5.50	34.56	11.20
	3	1.6	**10 - 12 cm**	2 cm.	24.10	17.75	5.68	30.75	10.52
	3	1.6	5 - 7 cm	**1 cm.**	22.07	16.52	5.62	32.50	10.89
	3	1.6	5 - 7 cm	**4 cm.**	22.30	16.35	5.55	32.66	10.88
	0.5	1.6	5 - 7 cm	2 cm.	14.58	10.74	5.43	37.82	11.81
	6	1.6	5 - 7 cm	2 cm.	21.24	16.07	5.75	29.57	10.23
Slub yarn with two populations	3	1,6 - 1,6	**1-3, 10-12**	2 cm.	23.24	17.28	5.70	33.21	10.89
Yarn without slub	-	-	-	-	9.92	7.85	5.44	39.00	11.94

3.1 Effect of Slub Thickness

3.1.1 Effect of slub thickness on yarn unevenness and hairiness

Figure 2 shows the changes of yarn unevenness and hairiness in terms of changing slub thickness when the other slub parameters are same. According to the results of the statistical analysis, it was determined that the varying slub thickness in slub yarns had an effect on yarn unevenness, diameter variation and hairiness (p=0.000) (Table 2). It is seen in Figure 2 that the CVm and diameter variations values of the yarn without slub were lowest and these values increase with the increase of the slub thickness, as expected. The CVm and diameter variations of the yarns at the 1,8 slub thickness is the highest. When the yarn hairiness results are examined, the hairiness values increase with the increase in the slub thickness (Figure 2). It is thought that hairiness is higher in thicker places because of lower twist caused by looser fiber. Because of having lower amount of twist in the slub part, the looser fibers generating hairiness are higher.

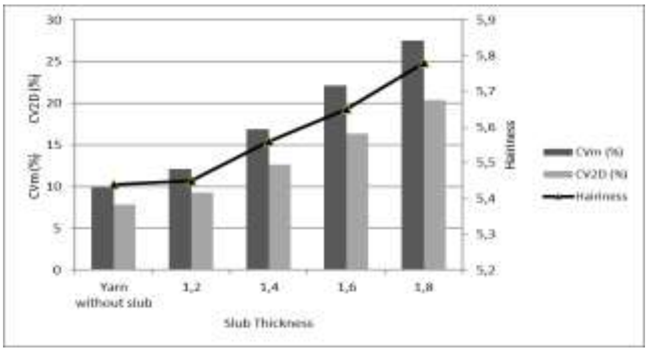

Figure 2. Effect of slub thickness on yarn unevenness, diameter variation and yarn hairiness

According to the SNK test performed to compare the yarn unevenness and diameter variations of the yarns with 4 different slub thicknesses, it was determined that the difference between all thicknesses was significant (Table 2).

The yarn hairiness values were found insignificant among the yarns without slub, with 1.2 and 1.4 slub thickness and the yarns between 1.4 and 1.6 slub thickness. The hairiness value of the slub yarn with 1.8 slub thickness was found significantly higher as compared with the others (Table 3).

3.1.2. Effect of slub thickness on yarn strength

As the breaking strength values were evaluated, it was seen that the yarn breaking strength values decrease as the slub thickness increases similar to the findings by previous research (6,10,12,15). This is due to the lower twist values in the thickened slub regions of the yarn. According to the results of the previous study (Iqbal and Pramanik (2017)) the twist value of the slub sections is lower than normal sections. With the increase of slub thickness, the number of uncontrolled fibers increase and cause lower strength of the yarn. The effect of slub thickness on the yarn breaking strength and elongation was found significant in the SNK multiple comparison test, all slub thickness were included in different subgroups (Table 4).

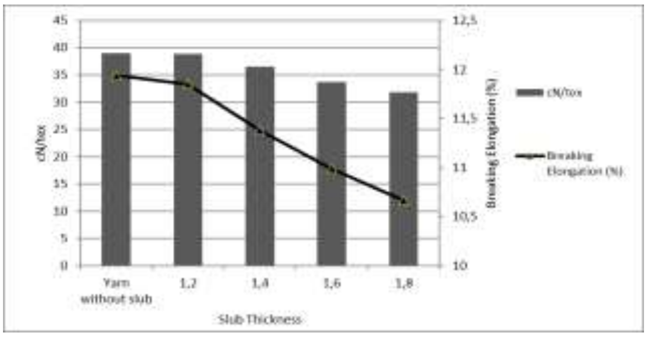

Figure 3. Effect of slub thickness on yarn breaking strength and elongation

Adding slub to base yarn caused reduce the yarn elongation value [6]. At higher slub thickness, twist flow in the slub part is restricted and the structure becomes less compact This causes lowering of cohesive force between fibres in the slubs which promotes easy sliding/slippage of fibres on application of load resulting in lower breaking elongation [15]. (Figure 3).

Table 2. SNK test results showing the effect of slub thickness on yarn unevenness

Slub thickness	N	Effect of slub thickness on CVm					Effect of slub thickness on CV2D				
		1	2	3	4	5	1	2	3	4	5
without slub	9	9.92222					7.84667				
1.2	9		12.12222					9.29889			
1.4	9			16.87556					12.62444		
1.6	9				22.09444					16.38444	
1.8	9					27.49889					20.36667
Sig.		1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Table 3. SNK test results showing the effect of slub thickness on yarn hairiness

Slub thickness	N	Subsets		
		1	2	3
without slub	9	5.43778		
1.2	9	5.45333		
1.4	9	5.55556	5.55556	
1.6	9		5.64667	
1.8	9			5.78111
Sig.		.067	.082	1.000

Table 4. SNK test results showing the effect of slub thickness on yarn strength

Slub thickness	N	Effect of slub thickness on yarn breaking strength				Effect of slub thickness on yarn breaking elongation				
		1	2	3	4	1	2	3	4	5
without slub	9	39,00243				11,93556				
1.2	9	38,85250					11.85000			
1.4	9		36,48465					11.38556		
1.6	9			33,69292					10.99222	
1.8	9				31,77729					10.66778
Sig.		,266	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

3.2 Effect of Slub Length

3.2.1 Effect of slub length on yarn unevenness and hairiness

In Figure 4, it is seen that the yarn unevenness increases as the slub length increases. Since the slub sections in the yarn causes an increase on the yarn unevenness, the CVm value of the yarn increases with the increase of slub length. It is seen that the diameter variation values increase as the slub length increases as well. Long slubs cause an increase in diameter variation due to thicker and uneven regions. When the hairiness values of the yarns are examined, as similar to the findings of Mukhopadhyay et al., yarn hairiness increases as the slub length increases. This is because of the fact that in case of longer length of slub, more amount of fibres are present in slub part of the yarns which causing hairiness easily because of having lower amount of twist in the slub part. Hairiness values were found to be lower in short slub yarns as the fibers would be released in shorter regions compared to long slub yarns (Figure 4).

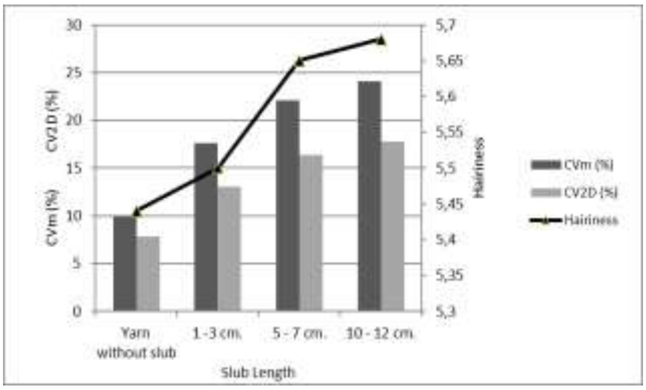

Figure 4. Effect of slub length on yarn unevenness, diameter variation and hairiness

Since the difference between the variances was found to be insignificant in the homogeneity test of the variances, the SNK multiple comparison test was performed and the effect of the slub length on the yarn unevenness was found significant (Table 5). Also the effect of slub length on the diameter variation of the yarns were found significant. The CVm and diameter variation values of the yarn without slub were found lowest within all type of the yarns.

According to the results of the SNK multiple comparison test, when the effect of slub length on hairiness was examined, yarns with short slub lengths were in different classes, while the difference between medium and long slub yarns at the 95% confidence level was not significant (Table 6).

3.2.2 Effect of slub length on yarn strength

When the effect of slub length on yarn strength and elongation examined, the difference between all slub lengths was found statistically significant (Table 7) and slub length is an effective parameter on yarn strength and elongation value. It was seen from Figure 5 that as the slub length increased, the yarn breaking strength and elongation values decreased. The yarn that have longest slub has lowest breaking strength. The slub frequency is same for all yarn type, so as the slub length increases the regions, which have lower twist increase. And the irregularity in twist distribution increases further with the increase in slub length. As a result of that the yarn tenacity is lower for longer slub yarns.

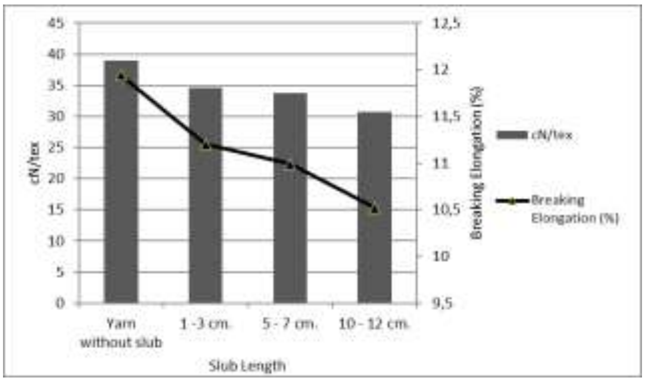

Figure 5. Effect of slub length on yarn breaking strength and elongation

Table 5. SNK test results showing the effect of slub length on yarn unevenness

Slub length	N	Effect of slub length on CVm				Effect of slub length on CV2D			
		1	2	3	4	1	2	3	4
without slub	9	9.92222				7.84667			
1 – 3	9		17.64444				13.09333		
5 – 7	9			22.09444				16.38444	
10 – 12	9				24.10111				17.74556
Sig.		1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Table 6. SNK test results showing the effect of slub length on yarn hairiness

Slub length	N	Subsets 1	2
without slub	9	5.43778	
1 – 3	9	5.50000	
5 – 7	9		5.64667
10 – 12	9		5.68111
Sig.		.226	.499

Table 7. SNK test results showing the effect of slub length on yarn strength and elongation

Slub length	N	Effect of slub length on yarn breaking strength				Effect of slub length on yarn breaking elongation			
		1	2	3	4	1	2	3	4
without slub	9	39,00243				11.93556			
1 – 3	9		34,56716				11.20000		
5 – 7	9			33,69292				10.99222	
10 – 12	9				30,75834				10.51889
Sig.		1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

3.3. Effect of Slub Frequency

3.3.1 Effect of slub frequency on yarn unevenness and hairiness

Figure 6 shows the effect of slub frequency on yarn unevenness. The slub regions on the yarn creates uneven structure, so the yarn without slub has lowest coefficient variation and diameter variation. Since the yarns with lowest slub frequency (0,5 slub/m) have more base yarn structure than the slub part, the unevenness value is lower. In this low-frequency yarn, the diameter variation is low since the slub areas are in a very small part of the yarn along the measurement length.

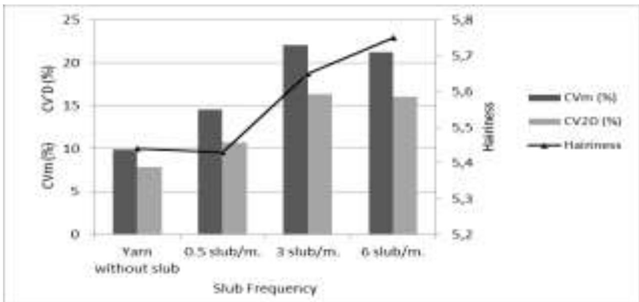

Figure 6. Effect of slub frequency on yarn unevenness, diameter variation and hairiness

The low diameter variation of the frequent-frequency (6 slub/m) yarn compared to the medium-frequency (3 slub/m) yarn is due to the fact that it has more slubs at a certain length. The slub and base yarn lengths are equal in yarns with a frequency of 6 pieces/m, diameter variation is lower than the yarns with a frequency of 3 pieces/m. According to the statistical analyses, the effect of slub frequency on yarn CVm, diameter variation values was found significant and all slub frequencies were included in different subgroups (Table 8). As the effect of slub frequency on yarn hairiness is examined, the hairiness values of the yarns without slub and lowest frequency slub yarns values were close each other (Table 9). As the number of slubs per unit length increases, the amount of lower twisted places and free fibers will increase, so yarn hairiness increase (Figure 6).

3.3.2 Effect of slub frequency on yarn strength

Figure 7 shows the effect of slub frequency on yarn breaking strength. With the increase in the number of slubs per unit length, the amount of less twisted places and free fibers increase; this situation cause decrease on the yarn strength. The yarn which has highest slub frequency showed lowest tenacity. It was also defined that the yarns with a high slub frequency obtained lower yarn elongation value.

According to the SNK multiple comparison test, the effect of the differences in slub frequency on yarn tensile strength and elongation was found significant (Table 10).

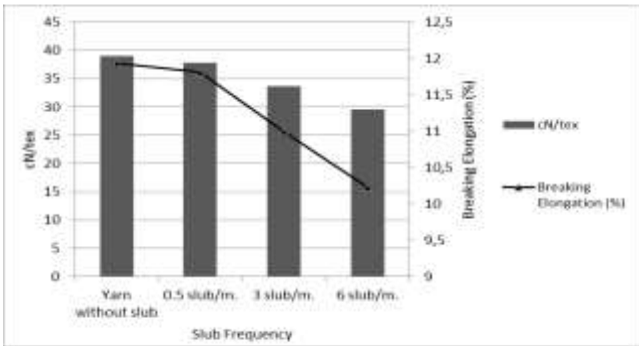

Figure 7. Effect of slub frequency on yarn breaking strength and elongation

Table 8. SNK test results showing the effect of slub frequency on yarn unevenness

Slub frequency	N	Effect of slub frequency on CVm				Effect of slub frequency on CV2D			
		1	2	3	4	1	2	3	4
without slub	9	9.92222				7.84667			
0.5 slub/m.	9		14.58333				10.74000		
6 slub/m.	9			21.2422				16.07222	
3 slub/m.	9				22.09444				16.38444
Sig.		1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Table 9. SNK test results showing the effect of slub frequency on yarn hairiness

Slub frequency	N	Subsets		
		1	2	3
without slub	9	5.43778		
0.5 slub/m	9	5.42889		
3 slub/m.	9		5.64667	
6 slub/m.	9			5.75667
Sig.		.844	1.000	1.000

Table 10. SNK test results showing the effect of slub frequency on yarn strength

Slub frequency	N	Effect of slub frequency on yarn breaking strength				Effect of slub frequency on yarn breaking elongation			
		1	2	3	4	1	2	3	4
without slub	9	39.0024				11.93556			
0.5 slub/m.	9		37.8221				11.81222		
3 slub/m.	9			33.6929				10.99222	
6 slub/m.	9				29.5791				10.23667
Sig.		1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

3.4 Effect of Ramp Length

3.4.1 Effect of ramp length on yarn unevenness and hairiness

Figure 8 shows the effect of ramp length on the yarn unevenness. When the difference between CVm and hairiness values according to ramp length was statistically analyzed in terms of SNK multiple comparison test, it was found insignificant at the 95% confidence level (Table 11). In terms of diameter variation significant differences was found between the the yarns in low ramp length and the others. In slub yarn structure short ramp length cause sudden mass change. To avoid this, it is recommended that the ramps should be long. However, it is seen from the Figure 8 that as the ramp is longer than it should be, the unevenness increases. A short ramp length constitute high diameter variation in short distance. Because of that, the yarn which have lowest ramp length has the highest CV2D, as the ramp length increase, the diameter variation values decreases. It was not found significant differences between the values of the slub yarns in medium and highest ramp length. In terms of yarn hairiness medium and lowest ramp length yarns showed highest values (Figure 8).

3.4.2 Effect of ramp length on yarn strength

It is seen from Figure 9 that the yarn with medium ramp length have the highest strength value, short ramp length one have the lowest yarn strength, however, there was not found any significant difference between the yarn values of short and long ramp length statistically (Table 12). The sudden mass change in thickness for short ramp length slub yarns and the increase in low twisted regions in long ramp yarns causes reduction in yarn breaking strength.

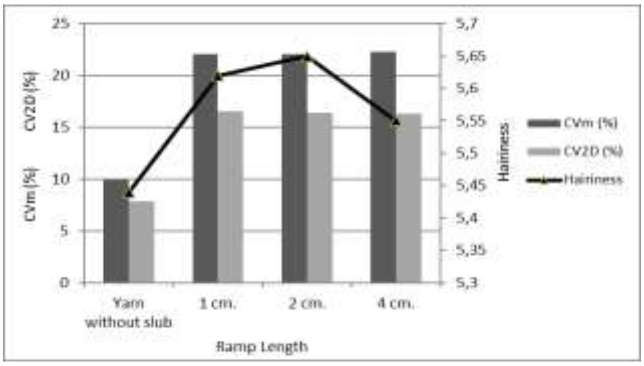

Figure 8. Effect of ramp length on yarn unevenness, diameter variation and hairiness

As the elongation values were evaluated, it was seen that the yarn with medium ramp length have the highest yarn breaking elongation value and the yarns with long ramp length have the lowest yarn elongation value (Figure 9). However, there is not significant difference between the values of short and long length ramp yarns statistically similar to the yarn strength results (Table 12).

Table 11. SNK test results showing the effect of ramp length on yarn unevenness and hairiness

Ramp length	N	Effect of ramp length on CVm		Effect of ramp length on CV2D			Effect of ramp length on yarn hairiness	
		1	2	1	2	3	1	2
without slub	9	9.92222		7,84667			5,43778	
1 cm.	9		22.06889		16.52222			5.62333
2 cm.	9		22.09444			16.38444		5.64667
4 cm.	9		22.30000			16.35556		5.54778
Sig.		1.000	.168	1.000	1.000	0.668		.093

Table 12. SNK test results showing the ramp length on yarn breaking strength and elongation

Ramp length	N	Effect of ramp length on yarn breaking strength 1	2	3	Effect of ramp length on yarn breaking elongation 1	2	3
without slub	9	39.00243			11.93556		
2 cm	9		33.69292			10.99222	
4 cm	9			32.66406			10.87667
1 cm.	9			32.50170			10.89222
Sig		1.000	1.000	0.206	1.000	1.000	0.695

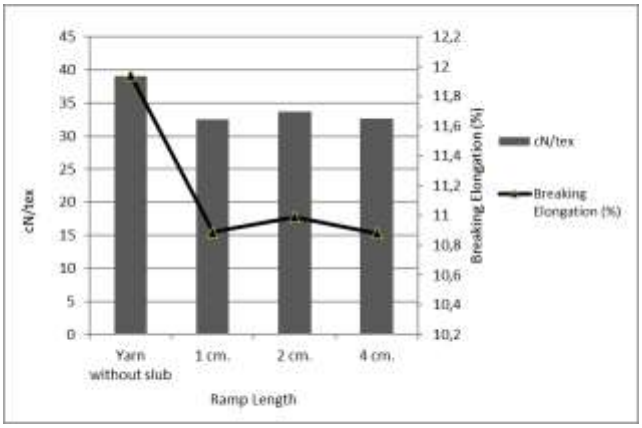

Figure 9. Effect of ramp length on yarn breaking strength and elongation

It can be concluded that a mid-length ramp is ideal for this type of slub yarns in terms of yarn breaking strength. Similar to its effect on yarn breaking strength, it can be said that a medium-length ramp is ideal for breaking elongation values.

3.5 Effect of Slub Population

In order to examine the yarns with more than one population, polyester yarns with two different slub sizes were produced in different slub lengths as short (1-3 cm.) and long (10-12 cm.). Other features such as frequency and slub thickness were the same; the properties of the yarns were compared with long length (10-12 cm.), short length (1-3 cm.) slub yarns and base yarns.

3.5.1 Effect of two populations on yarn unevenness and hairiness

The coefficient variation (CVm) value of two-populated yarn containing each two-slub lengths was found between the other slub yarns in direct proportion to their slub lengths. Similar to that, diameter variation increased as the amount of slubs in different length increase. Whereas the value of two populated yarn were found between the single size slub yarns, long length slub yarn showed highest value. In terms of yarn unevenness values, basic slub yarns in short and long slub length and two populated yarns are in different subgroups at 95% confidence level according to the statistical analyses (Table 13).

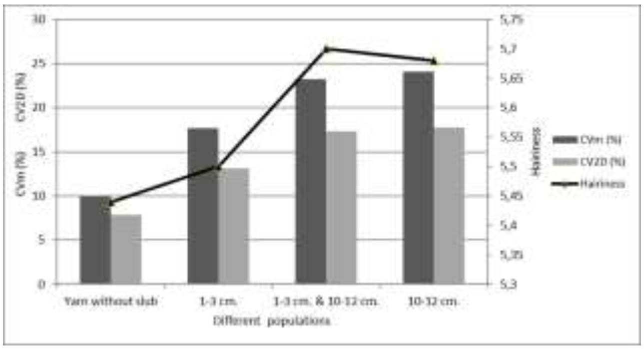

Figure 10. Unevenness, diameter variations and hairiness values of single and two- population slub yarns

As the hairiness values of single and two-populated yarns are examined, it was seen that the hairiness values of two-populated yarns were highest. The presence of short length slubs decreases the amount of free fiber, therefore the lowest hairiness value was defined in the single population yarn which has short length slub (Figure 10, Table 14).

3.5.2 Effect of two populations on yarn strength

As compared single and two-populated slub yarns in Figure 11, it was seen that when the amount of long length slub yarn increases, the breaking strength decreases. Long length slubs create regions with lower twist on the yarn and the strength of these parts is lower. The yarn elongation at break also showed similar properties to the breaking strength and decreased as the amount of longer slub increased. The effect of differences in slub population on yarn breaking strength and elongation was found statistically significant (Table 15).

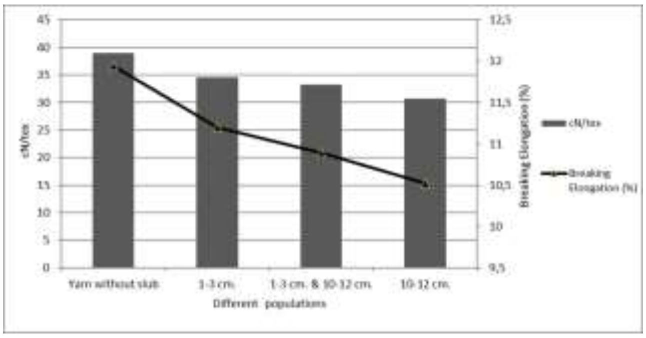

Figure 11. Breaking strength and elongation values of single and two-population slub yarns

Table 13. SNK test results showing comparison of CVm, diameter variation, hairiness of single and two- population slub yarns

Slub (length) populations	N	Effect of population on CVm				Effect of population on CV2D			
		1	2	3	4	1	2	3	4
without slub	9	9.92222				7.84667			
1 – 3 cm.	9		17.64444				13.09333		
1 –3, 10–12 cm.	9			23.23889				17.27889	
10 – 12 cm	9				24.10111				17.74556
Sig.		1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Table 14. SNK test results showing the effect of slub population on yarn hairiness

Slub length	N	Subsets	
		1	2
without slub	9	5.43778	
1 – 3 cm	9	5.50000	
10–12 cm.	9		5.68111
1 –3, 10 – 12 cm	9		5.70000
Sig.		.152	.659

Table 15. SNK test results showing comparison of breaking strengths of single and two- population slub yarns

Slub (length) populations	N	Effect of population on yarn breaking strength				Effect of population yarn breaking elongation			
		1	2	3	4		1	2	3
without slub	9	39.00243				11.93556			
1 – 3 cm.	9		34.56717				11.20000		
1–3, 10–12 cm.	9			33.21827				10.89000	
10 – 12 cm.	9				30.75835				10.51889
Sig.		1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

4. CONCLUSION

In this study the effect of the slub structure on the yarn properties was searched in detailed. In experimental part 11 different type of slub yarns from PET fibers which have different parameters (different slub thickness, slub length, slub frequency and ramp length) were produced and a yarn without slub was used for comparison. The results obtained from study can be given as follows;

- The effect of slub thickness on yarn evenness, hairiness, diameter variation, yarn breaking strength and elongation was found to be statistically significant. Similar to the previous studies (6,10,12,15) as the slub thickness increased, the yarn strength decreased because of the lower twist values of this regions**.** Higher thickness of the slubs caused higher the yarn unevenness and yarn hairiness.
- As the slub length increases, the yarn coefficient variation and dimeter variation values increase due to the thicker sections of the slub yarn. The effect of the slub length on the yarn unevenness and strength was found statistically significant. As the hairiness values of the yarns are examined, as similar to the findings of Mukhopadhyay et al., yarn hairiness increases belong to the slub length. The yarn tenacity and elongation were found lower for longer length slub yarns due to the long lower twisted regions.
- It was found that higher slub frequency increases the unevenness and hairiness, decreases the yarn strength. The lower diameter variation of the frequent-frequency yarn (6 slub/m) compared to the medium-frequency yarn (3 slub/m) is due to the fact that it has more slubs at a certain length. But unlike this case, the yarns with lowest slub frequency (0,5 slub/m) have more base yarn structure than the slub part, the unevenness value is lowest. As the number of slubs per unit length increases, yarn hairiness increases due to the higher amount of less twisted slub places. The slubs are the weak parts of the yarns. As a result of this, the increase of the slub frequency cause increase the number of weak places and lower strength value of the yarns. The yarn, which has highest slub frequency, showed lowest tenacity and elongation.
- The effect of ramp length was found to be statistically significant for breaking strength and elongation, and it was concluded that 2 cm. is the most suitable ramp for the produced yarn structure since it has higher strength and elongation. It is thought that the sudden increase in mass for short ramp length slub yarns and the increase in low twisted regions in long ramp yarns causes reduction in yarn breaking strength. The effect of slub ramp length on the CVm and hairiness values of the yarns was found insignificant.
- For two- population slub yarns, in direct proportion to the length of the slub in the population, similar results were obtained with the effect of the slub length. The two populated yarn unevenness values were found between the single size slub yarns, whereas the yarn in long

length slub showed highest value. The yarn breaking strength decreased with the increase of the amount of long slubs in the population.

The analysis of slub yarns is a very comprehensive subject as in other fancy yarns. This study found out the effect of slub parameters on the yarn unevenness and strength properties in detailed. In future, different studies can be carried out to eliminate the faults in the yarns with production errors and conducted on quality control of slub yarns.

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