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The Evaluation of Uster Hairiness Results with an Image Analysis Approach

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Abstract

In this study, the images of the yarns were taken using a stereomicroscope. MATLAB software was used in image processing studies. The recommended image acquisition and processing steps in previous studies were followed, and the obtained results from textural parameters of images were compared with the results of Uster H and sh. The highest correlation in Uster H hairiness was obtained in the entropy textural parameter of the Sobel technique. The highest correlation in Uster sh hairiness was obtained in the mean of matrix elements (mean2) from the textural parameters in the Sobel technique. In general, higher correlation results were found in Uster sh than in Uster H. It has been observed that the Uster H results have deficiencies in determining the hairiness of dyed yarns. The different from the literature, this study presents that among the hairiness parameters, Uster sh shows the values closest to the real.

Keywords: Yarn hairiness, Uster tester, Image processing, Edge detection algorithm, Textural parameters of image

Bir Görüntü Analiz Yaklaşımı ile Uster Tüylülük Sonuçlarının Değerlendirilmesi

Öz

Bu çalışmada ipliklerin görüntüleri stereomikroskop kullanılarak alınmıştır. Görüntü işleme çalışmalarında MATLAB yazılımı kullanılmıştır. Önceki çalışmalarda önerilen görüntü elde etme ve işleme adımları izlenmiş ve görüntülerin dokusal parametrelerinden elde edilen sonuçlar, Uster H ve sh sonuçlarıyla karşılaştırılmıştır. Uster H tüylülüğündeki en yüksek korelasyon, Sobel tekniğinin entropi dokusal parametresinde elde edilmiştir. Uster sh tüylülüğünde en yüksek korelasyon, Sobel tekniğinde dokusal parametrelerden matris elemanlarının ortalamasında (mean2) elde edilmiştir. Genel olarak Uster sh'de Uster H'ye göre daha yüksek korelasyon sonuçları bulunmuştur. Uster H sonuçlarının boyalı ipliklerin tüylülüğünü belirlemede eksiklikleri olduğu görülmüştür. Literatürden farklı olarak, bu çalışma, tüylülük parametrelerinden Uster sh'in gerçeğe en yakın değerleri gösterdiğini ortaya koymaktadır.

Anahtar Kelimeler: İplik tüylülüğü, Uster Tester, Görüntü işleme, Kenar belirleme algoritması, Görüntü doku parametreleri

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1. INTRODUCTION

Yarn hairiness is an important part of total yarn quality control. Excessive hairiness can cause production problems in weaving and knitting. In addition, variation in hairiness can adversely affect the quality of the final product. There are studies in the literature for the development of existing techniques used for the determination of yarn hairiness. For instance, it is stated that changes in test speed affect yarn hairiness results. To remedy this, placing a blowing pipe outside the hairiness test area is among the sensible suggestions [1]. There are many studies in the literature with similar recommendations. In recent years, digital image acquisition and processing techniques are also recommended as an alternative to existing techniques in order to determine yarn hairiness more accurately.

To determine yarn hairiness, Ozkaya et. al., proposed an image processing technique using both the number of hairs and hair lengths. In this way, hair density distribution profile was obtained. They pointed out that their results were compatible with Uster Tester's H index. Researchers also stated that it can give better results than Uster Tester in color and material change [2]. Zhang and Xin, compared the new digital image processing techniques proposed in the literature with traditional detection methods to evaluate the yarn appearance. It was emphasized in their study that new techniques can give more appropriate results depending on the developments in this field in terms of objectivity, speed and accuracy [3]. Sun et. al., captured the yarn images by MOTIC video system to determine the hairiness and to detect the edges of the yarn body. Differently from other studies, images were separated into many small segments for the evaluating long hairs by different measurement lines and different segmentation steps [4]. Wang et. al., proposed an image processing method using the yarn blackboard. From the image of the yarn blackboard, the yarn diameter was determined by algorithms, and the yarn body and hairs were divided into sections. Based on these data, the hairiness index was calculated and compared with the Uster H results. [5]. Jing et. al., unlike other studies, examined the results of yarn segmentation with five different algorithms. They used the Uster Zweigle HL400 hairiness tester for comparison [6]. Guo et. al., suggested an online yarn image acquisition on the sizing machine. Researchers processed the received images and compared them with the Uster Zweigle Tester [7]. Telli, presented a different image processing approach to determine yarn hairiness. Researchers examined seven different edge detection algorithms and seven textural parameters and compared the results obtained with Zweigle G567 results. A strong correlation was obtained between image processing results and Zweigle hairiness. In the study, 100% cotton yarns produced in three different spinning systems were used [8]. When the study was repeated with yarns in different raw materials, numbers and colors, the correlation values show a decrease [9]. On the other hand, in the different version device (Uster Zweigle HL400) using hairiness length classification system, no correlation was found between Zweigle hairiness [10]. It also has been emphasized in previous studies that even different version devices using the hairiness length classification system can give different results [11].

Today, the most preferred method commercially is the Uster hairiness (H) value. “H” corresponds to the total length of the protruding fibers of the yarn body for 1 cm yarn. The hairiness value is the average of all 1 cm hairiness values in a tested yarn sample. The standard deviation of the values obtained for 1 cm throughout the entire yarn test length gives the hairiness variation (sh) value. In this study, the image acquisition and processing steps recommended in previous studies were followed, and the obtained results were compared with the results of Uster H and sh.

2. MATERIAL AND METHODS

Thirteen ring yarns with different structures and contents were used in the study. The quality properties of these yarns were measured in the Uster Tester 4 device with a test speed of 400m/min for 1 minute. The obtained unevenness, imperfections and hairiness results were presented in Table 1.

Table 1. Unevenness, imperfections and hairiness results of yarns

Yarn type	Yarn properties	CVm	Thin places -50%	Thick places +50%	Neps +200%	**H**	**sh**
01	Ecru Ne 36/1 CO/CV	13,9	0	93	180	4,47	1,1
02	Ecru Ne 40/1 CO/CV	15,2	8	226	426	5,4	1,34
03	Ecru Ne 28/2 CO/CV/EL	10,1	0	8	9	7,27	1,72
04	Ecru Ne 36/2 CO/CV/EL	13,5	0	93	33	7,41	1,78
05	Ecru Ne 40/2 CO/CV/EL	10,8	0	11	25	5,14	1,28
06	Ecru Ne 50/2 CO/CV	15,8	21	346	190	5,58	1,47
07	Black Ne 28/1 CO/CV	13,7	0	85	123	4,22	1,29
08	Black Ne 40/1 CO/CV	22,6	376	1668	2506	4,15	1,61
09	Black Ne 28/2 CO/CV/EL	10,1	0	8	13	3,89	1,15
10	Black Ne 36/2 CO/CV/EL	13,2	1	84	49	5,45	1,54
11	Black Ne 40/2 CO/CV/EL	11,1	0	16	33	3,44	1,05
12	Black Ne 50/2 CO/CV/EL	11,8	0	35	79	3,52	1,04
13	Black Ne 60/2 CO/CV	15,2	6	266	161	3,39	1,06

The images of the yarns were taken using a Novel NSZ 808 stereomicroscope. Image acquisition was performed at a magnification of 10x from twenty different regions of the yarn randomly. MATLAB R2018a software was used in image processing studies. The following steps were followed in image processing, respectively [8,10].

1. The image, which has a three-dimensional matrix in RGB format, has been converted into two-dimensional matrices.
2. The matrices have been converted to a "double" format consisting of values between 0-1.
3. 2D median filtering was preferred to reduce noise in the image.
4. With the histogram equalization technique, the image input density values were matched to the new values and the contrast of the image was increased.
5. The yarn body and hairs separated from each other with Sobel and Prewitt edge detection algorithms, which were prominent in previous studies.
6. Textural parameters of images were calculated. In the study, three different parameters recommended in previous studies were investigated: the mean of the matrix elements (mean2), the standard deviation of the matrix elements (std2) and the entropy (entropy).

The relationship between textural parameters and H and sh from Uster hairiness parameters was investigated statistically with Pearson correlation analysis. The degree of correlation between the variables was shown by the correlation coefficient (r).

3. RESULTS AND DISCUSSION

The obtained textural parameter results as a result of image processing studies were presented in Table 2.

Table 2. Textural parameters mean results of different edge detection algorithms

Yarn type	**SOBEL**			**PREWITT**		
	mean2	std2	entropy	mean2	std2	entropy
01	0,0102	0,1003	0,0820	0,0101	0,0997	0,0818
02	0,0120	0,1085	0,0934	0,0118	0,1079	0,0925
03	0,0150	0,1213	0,1122	0,0149	0,1208	0,1114
04	0,0144	0,1189	0,1085	0,0143	0,1185	0,1079
05	0,0118	0,1081	0,0924	0,0117	0,1073	0,0917
06	0,0121	0,1092	0,0944	0,0120	0,1088	0,0939
07	0,0113	0,1055	0,0893	0,0113	0,1053	0,0891
08	0,0135	0,1147	0,1025	0,0134	0,1146	0,1023
09	0,0110	0,1042	0,0874	0,0110	0,1040	0,0871
10	0,0138	0,1164	0,1049	0,0138	0,1161	0,1046
11	0,0101	0,1001	0,0817	0,0101	0,0999	0,0814
12	0,0088	0,0930	0,0724	0,0087	0,0928	0,0721
13	0,0107	0,1027	0,0854	0,0107	0,1026	0,0852

All matrix elements consist of 0 in a completely black image and all matrix elements consist of 1 in a completely white image. It is expected that the values of the Uster hairiness will increase as the values of the textural parameters in Table 2 approach 1, and decrease as they approach 0. In Table 2, the highest and lowest values for textural parameters in different edge detection algorithms were marked. According to Table 2, the highest values were seen in yarn numbered 03 in both algorithms and in all three textural parameters. The lowest values were obtained in yarn numbered 12 in both algorithms and in all three textural parameters. In order to understand the change in textural parameters more easily, the situations before and after image processing of the third image taken from yarn number 03 and the twelfth image taken from yarn number 12 were presented in Figure 1.

Higher values in the images of yarn 03 having higher yarn hairiness were observed in all three textural parameters compared to yarn 12. In both different edge detection methods, the textural parameter values of yarn 03 were higher than yarn 12. When the textural parameters of the same yarns were compared in terms of edge detection algorithm, Sobel had higher values than Prewitt in all parameters. However, there were insignificant differences between them.

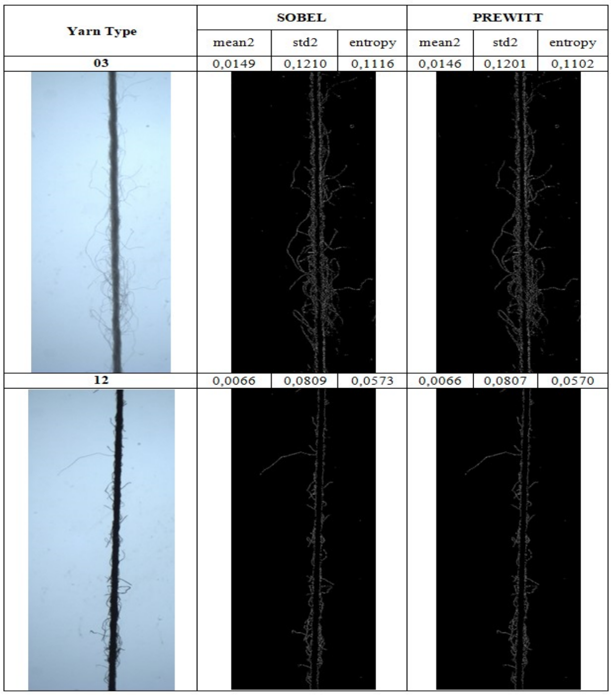

Figure 1. The situations before and after image processing of images taken from yarn numbered 03 and 12

When the H and sh values in Table 1 were examined, the second highest H and sh values were determined in the yarn 03. The lowest sh value was observed in yarn 12 similar to the results in textural parameters. Yarn 12 was the third lowest value in terms of H value. When the values in Table 2 were evaluated in terms of edge detection algorithms, it was seen that there were little differences between them. The values obtained from Sobel were slightly higher than Prewitt in all parameters. In order to make more comprehensive evaluations, the correlation results between Uster hairiness data in

Table 1 and the textural parameter data in Table 2 were shown in Table 3-4. In addition to the general evaluation, correlation analyses are also available according to color and number of ply in Table 3-4.

Table 3. The correlation coefficient (r) results between textural parameters and Uster H

Pearson correlation coefficient (r)	SOBEL			PREWITT		
	mean2	std2	entropy	mean2	std2	entropy
All 13 yarns (1-13)	0,827	0,824	0,825	0,818	0,814	0,818
Ecru yarns (1-6)	0,983	0,980	0,983	0,984	0,982	0,985
Black colored yarns (7-13)	0,806	0,799	0,803	0,808	0,797	0,803
All CO/CV single yarns (1,2, 6, 7,8,13)	0,280	0,305	0,290	0,250	0,266	0,260
CO/CV Ecru single yarns (1,2,6)	0,995	0,997	0,997	0,999	0,998	0,999
CO/CV Black plied yarns (1,2,6, 7,8,13)	0,607	0,623	0,615	0,620	0,621	0,618
All CO/CV/ELS yarns (3,4,5,9,10,11,12)	0,938	0,927	0,931	0,932	0,925	0,929
CO/CV/ELS Ecru plied yarns (3,4,5)	0,973	0,974	0,974	0,975	0,977	0,976
CO/CV/ELS Black plied yarns (9,10,11,12)	0,947	0,928	0,935	0,942	0,928	0,936

According to the results in Table 3, a strong correlation was found between all textural parameters and Uster H hairiness in both techniques. The highest correlation for all 13 yarns was observed in the entropy from textural parameters in the Sobel technique (r=0.825). Similarly, in a previous study on Zweigle S3 hairiness, the highest correlation was found in the entropy of images processed using the Sobel technique [8]. When only ecru yarns (1-6) were evaluated instead of all yarns, higher correlation values were obtained. The correlation value decreased in black dyed (7-13) yarns. However, there was strong correlation in both cases. When all single-ply yarns (1,2,6) were evaluated, high correlation values were obtained similarly. However, correlation values in dyed single-ply yarns decreased and became insignificant. This situation has also been expressed in previous image processing studies. It has been stated that Uster H hairiness may be a problem in dyed yarns and various estimates have been asserted for the reason of this situation [2]. In ply yarns, a strong correlation was found between both techniques and all three textural parameters, regardless of color. Considering all the ply yarns, the highest correlation value was found in the standard deviation of the matrix elements (std2), which is one of the textural parameters, in the Prewitt technique (r=0.977).

Table 4. The correlation coefficient (r) results between textural parameters and Uster sh

Pearson correlation coefficient (r)	SOBEL			PREWITT		
	mean2	std2	entropy	mean2	std2	entropy
All 13 yarns (1-13)	0,958	0,950	0,954	0,956	0,951	0,954
Ecru yarns (1-6)	0,967	0,967	0,969	0,970	0,971	0,970
Black colored yarns (7-13)	0,941	0,924	0,930	0,936	0,925	0,931
All CO/CV single yarns (1,2, 6, 7,8,13)	0,957	0,962	0,961	0,957	0,956	0,960
CO/CV Ecru single yarns (1,2,6)	0,953	0,960	0,962	0,969	0,966	0,969
CO/CV Black plied yarns (1,2,6, 7,8,13)	0,975	0,979	0,977	0,978	0,979	0,978
All CO/CV/ELS yarns (3,4,5,9,10,11,12)	0,968	0,957	0,962	0,965	0,958	0,962
CO/CV/ELS Ecru plied yarns (3,4,5)	0,959	0,961	0,960	0,961	0,964	0,962
CO/CV/ELS Black plied yarns (9,10,11,12)	0,961	0,944	0,951	0,957	0,945	0,951

When Uster sh the hairiness values in Table 4 was examined, different results were encountered according to Uster H. A strong correlation was found between all textural parameters and Uster sh hairiness in both Sobel and Prewitt techniques. The fact that it is dyed or plied did not change the results. For all 13 yarns, the highest correlation was obtained with the mean of matrix elements (mean2), one of the textural parameters, in the Sobel technique (r=0.958). When only ecru yarns (1-6) were evaluated instead of all yarns, higher correlation values were obtained. The correlation value decreased in black dyed (7-13) yarns. Furthermore, strong correlation was found in both situations. When only single-ply yarns (1,2,6) were evaluated, high correlation values were obtained similarly. The different from Uster H hairiness results in Table 3, strong correlation values were also obtained in dyed single-ply yarns. In addition, the highest correlation values among all values were obtained here. In the standard deviation of the matrix elements for the both edge detection algorithms, the highest correlation coefficient (r=0.979) among all values was obtained. When all ply yarns were considered, results similar to Uster H hairiness were observed. Considering all the ply yarns, the highest correlation value (r=0.968) was obtained in the Sobel technique, with the mean of the matrix elements (mean2), one of the textural parameters.

4. CONCLUSION

In this study, it was possible to separate the hairs from the yarn body as a result of processing the yarn images taken under the microscope with different techniques. The relationship between the textural parameter values of the obtained images and the hairiness of Uster H and sh was investigated. For all thirteen yarns, the highest correlation in Uster H hairiness was obtained in the entropy textural parameter of the Sobel technique (r=0.825). The highest correlation in Uster sh hairiness for all thirteen yarns was obtained in the mean of matrix elements (mean2) from the textural parameters in the Sobel technique (r=0.958). In general, Uster sh has higher correlation results than Uster H. It has been observed that the Uster H results have deficiencies in determining the hairiness of dyed yarns. Although it was ignored in previous academic studies and in the textile market, strong correlation and better results were obtained regardless of color and number of ply in Uster sh hairiness.

The used technique of processing the images taken from the microscope in the study is a more accurate method in determining the actual yarn hairiness. But it is a static method. It needs further development to be fast and efficient. The deficiencies of hairiness detection methods and devices used in the market are known and have been emphasized in previous studies. When evaluated together with the literature, this study presents that among the hairiness parameters, Uster sh shows the values closest to the real.

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