Evaluation of false-twist textured yarns by image processing

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A new method has been introduced to determine the crimp features of false twist textured yarns by applying computer vision and image processing method. Hence, the test results, with accuracy, are achieved more quickly than by the other exciting method. The mean angle of filament orientation in false twist textured yarns with different texturizing variables (heater temperature, texturizing speed and twist) is determined. Similarly, the direct tracking algorithms to achieve a good correlation with crimp contraction are also used. The results show that by this new method a correlation coefficient of more than 95% is achieved between mean orientation angle and crimp contraction.

Keywords: Direct tracking algorithms, Filaments orientation angle, False twist, Image processing, Nylon 6, Textured yarn

1 Introduction

During 1950, a new branch was created in the textile industry astexturizing of continuous filament yarn[1]. Texturizing meant to create a permanent deformation of the filament yarns, which creates different properties. In general texturizing is done by one of these three methods, viz. mechanical, thermal-mechanical and chemical-mechanical. Texturizing by the false twist method is the most important and practical method to produce these yarns. Various factors affect the shape and crimp properties of textured yarn. Important factors are filaments chemical structure, yarn count, number of filaments, shape of surface area and factors related to system such as yarn motion systems, yarn time passes in each step, type of heater and its length and temperature. The computer vision in research and quality control procedures is applicable. Millman *et al.*[2]. have introduced a system that allows further investigation of the samples tested at high speed and accuracy without any contact with the samples. This system was able to detecttangle and sensitive to the diameter changes. A group of researchers used methods such as the measurement of yarn package density, thickness of the fabric production and the amount of water carried by the texture yarn in order to evaluate buckling and stitch density. The main purpose of texturizing the air jet is to produce bulky yarns. Bulk and density of loops is important factors for the quality control of texture yarns[3].

In recent years, many research projects have been carried out to present new methods for determination of crimp, especially crimp concentration in texture yarns. With the advent of modern computers and new programming tools, the use of computer vision for quality control and test products is increasing[4]. The structure of false twisted yarn is similar to the fractal shape. Therefore, some researchers evaluate thecrimp of textured yarn based on their work on the use of fractal geometry. In this study, a new method to quantify the crimp amount of single filaments has been developed. Also the effect of the filaments in the false twist texture yarn in this new method is studied.

2 Materials and Methods

2.1 Materials

The Nylon 6 with yarn count 98 (dtex) and density 1.142 (g/cm^3) for this research was provided by the Lealea Company of Thailand. Modulus and elongation at rupture of samples were 238.8 cN/tex and 49.16% respectively. Texturizing of semi orientation yarn was done by texture devise model Minibulk cs12 600 (Ernest Scarg and Sons Company of England), and the samples shrinkage was 0.69% with double refraction 0.036. Evaluated variables were temperature, speed and twist; effect of each variable was studied, keeping the other variables constant. Table 1 shows the texturizing conditions of all samples in 1.2 draw ratio.

Crimp properties of texturized yarns were measured as per the DIN 53840 standards. In this method, one hank with linear density of 2500dtex was

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kept under tension of 0.01cN/tex at 120 ˚C for 10 min, and after cooling it was again kept under a tension of 2cN/tex for 10 s. Immediately its length (L_g) was measured. Then the yarn was kept under tension of 0.01 cN/tex for 10 min and its length (L_z) was measured. After that samples were kept under tension of 0.1cN/tex for 10s and its length (L_f) was measured. In the final stage, after attaining tension of 10cN/tex for 10 s, it was decreased to 0.01cN/tex in 10 min, and the sample length (L_b) was measured. Crimp concentration, hardness and stability were determined using the following equations:

$$\text{Crimp concentration (CC\%)} = \frac{L_g - L_z}{L_g} \qquad \ldots (1)$$

$$\text{Crimp hardness (CM\%)} = \frac{L_g - L_f}{L_g} \qquad \ldots (2)$$

$$\text{Crimp stability (CS\%)} = \frac{L_g - L_b}{L_g - L_z} \qquad \ldots (3)$$

Table 1—Texturizing condition of samples

Sample number	Draw ratio	Heater temperature, ˚C	Twists per meter	Texturizing speed, m/min
1	1.2	150	2954	80
2	1.2	160	2954	80
3	1.2	170	2954	80
4	1.2	180	2954	80
5	1.2	190	2954	80
6	1.2	170	2165	80
7	1.2	170	2559	80
8	1.2	170	2954	80
9	1.2	170	3189	80
10	1.2	170	3544	80
11	1.2	170	2954	40
12	1.2	170	2954	60
13	1.2	170	2954	80
14	1.2	170	2954	100
15	1.2	170	2954	120

2.2 Methods

2.2.1 Sample Preparation

To take photos of texturized yarn, digital microscopic Dino (AU-351) was used with a resolution of 640×480 VGA, which was connected to a PC. Digital microscopy was equipped with a lens (×10), (×100-200), and (×400-600). For lighting, LED can be used to set front lighting and behind lighting. The best image was obtained by a lens of (×100-200). The sample length in these images was 1.54 mm.

To get images of texture yarn with false twist, the yarn without any additional twist was opened, and then fixed from one side; from another side it was placed under appropriate weight so that it did not cause its crimp to open. Also no more stretch was applied on it, being straight under Lenz to photography. To reach this goal, 50 mg clamps were used. In this study, from every yarn package, 30 samples with a length of 11 cm were prepared and from each sample 5 photos were taken.

2.2.2 Image Processing

In the image processing tool of Matlab Software, by im2bw method all images in black and white format were obtained and by Otsu method the threshold to separate filaments from the background was defined. In evaluated images, the lighting point in white indicatesthe existence of the filament and the black lighting point is representing the background[5].

After obtaining binary images, it is time to make them thinner. Thinning is an importantstep in preprocessing in detecting the pattern. In some cases, it is necessary to have a simple candidate of the image that has numeral properties of the initial image.False-twist texture yarn and its image skeleton are illustrated in Fig.1.

2.2.3 Corrective Methods

In the image skeleton, hair branches occur at the end of the fibres that should be omitted before the
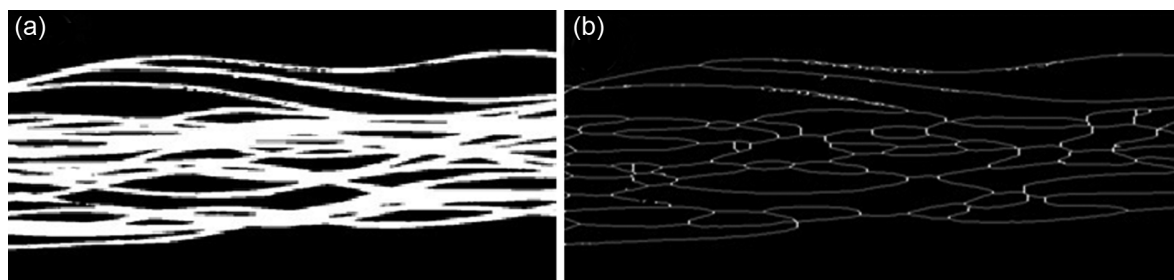

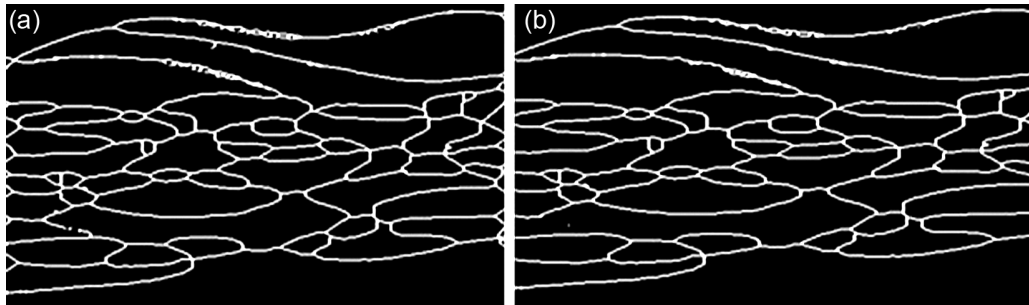Fig. 1—Schematic diagram of false-twist texture yarn (a), and its skeleton (b)

Fig. 2— Schematic diagram of false-twist texture yarn (a) before, and (b) after corrective procedure

next operation. Thus, corrective algorithm should be used. It is supposed that branches must not exceed a certain number. Hence, the branches lengths that exceed from a certain number are omitted by the spur operation. Multifilament false-twist texture yarns are shown before and after corrective procedures (Fig.2).

2.2.4 Assigned Connection Points

P-point in coordinate (x,y) has two horizontal neighbors and two vertical neighbors that are called the four neighboring. If four diagonal neighbors are also considered, it is called eight neighboring. The coordinate of these neighbors is shown in Fig.3.

White points indicate the fibre existence. So, at first find these points and then points with more than 3 neighbors are introduced as connection points. To determine the angles of the filaments aligned in multifilament texture yarn, the improved algorithm was used, considering the direct tracking method. Direct tracking algorithm is long and for intersection points, should be single definition based on minimum deviations from the initial direction, that itself makes the complexity, high computational volume and low speed of algorithm. So, in improved algorithm, at first, filaments connections points are evaluated and then omitted from image[6].

2.2.5 Remove Connections

Removing the connection points reduces the complexity of the algorithm without affecting the result.As a result, the connection points are removed from the image and then all filaments can be directly traced. In fact, the filaments are considered as separated pieces in the connection points (Fig. 4).

2.2.6 Determination of Orientation Angle

By removing the connection points of the image, the filaments will not have continuity and can be labeled as single piece of filament. In the images of false twist texture, filaments yarns are not straight.
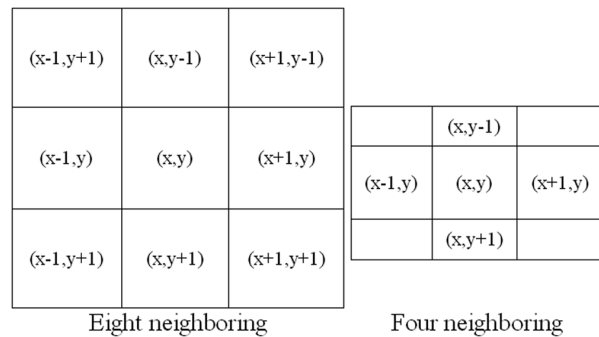

Eight neighboring   Four neighboring

Fig.3— Neighboring points coordinates of the main point (x,y)

Thus, after labeling each piece, the length is considered as a tracing piece. For example, if 10 points of filament are considered as a tracing length, the angle between the first and the eleventh point, and the angle between the eleventh and the twenty first points are determined with the x axis. The average filament position angle is determined as the index to crimp concentration.

2.2.7 Orientation Index

Orientation index (F) is definedas the ratio of double refraction of filament to ideal double refraction that shows the position of macromolecules completely parallel to the fibre axis. This index is related to average slope angle Ø, as shown below:

$$F = (n_1 - n_2)/(n_1'' - n_2'') \qquad \ldots (4)$$

$$F = 1 \left(\frac{3}{2} \right) \sin^2 Ø \qquad \ldots (5)$$

For a fibre in ideal conditions of which macromolecules are oriented, align its axis to F=1 and Ø = 0° and for homogeneous fibre, F=0 and Ø = 55°, where Ø is the angle of filament with yarn axis.

2.2.8 Performance Evaluation of Algorithms

In order to measure the accuracy of the proposed methods before running the program on the texture

sample yarn, at first accurate performance on simulated samples iscontrolled. Angles from the X axis are measured and compared with the results of the algorithm. Some simulated images are shown in Table 2. The relative error rate in calculation of the angle in the axis with defined algorithm is 1.15%, which is calculated using the following equation:

$$e = \frac{a_r - a_i}{a_i} \qquad \dots (6)$$

where e is relative error; a_r, the mean angle obtained from the sample; and a_i, the mean angle obtained from the image processing method. Low relative error obtained from this method show high accuracy. After ensuring the correctness of the program, an investigation is also initiated on the false twist texture yarn (Table 2) .

3 Results and Discussion

3.1 Effect of Twist on Mean Angle of Aligned Filaments

After preparation by image processing, the orientation angle of the filament aligned index is evaluated. The mean of the orientation index and the aligned filament angles in texture yarn are presented in Table 3.

By increasing twist, mean angle increases and orientation index decreases. In other words, deviation from straight of filament increases. Hence, bending and torsional moments are applied to the yarn. Filament bending and torsion caused their deviation from yarn axis and orientation parallel with yarn axis decreases. The statistical tests with 95% confidence show that these five samples have different

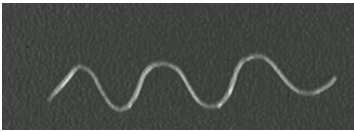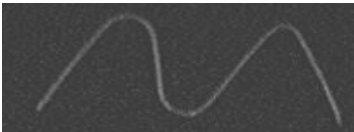Table 2— Calculated mean angle from samples and by image processing method for simulated samples
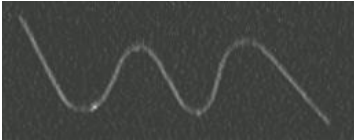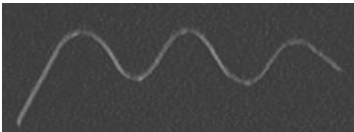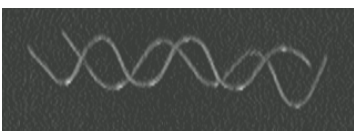
Image of simulated model	Measured angle from sample deg	Measured angle by algorithm deg
	55.92	56.42
	44.68	45.89
	61.41	61.97
	49.82	50.11
	63.44	63.17
	44.15	45.10

Table 3— Algorithm results for samples with different mean twist per meter

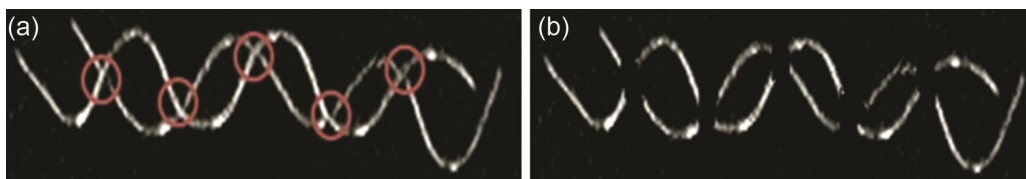| Sample number	Mean of twist per meter	Density %	Mean angle of orientation, deg	CV of filament alignment angles	Orientation factor	Crimp concentration, %
1	2165	1.55	29.70	27.34	0.55	46.8
2	2559	1.82	31.40	26.87	0.53	51.2
3	2954	1.8	32.77	27.03	0.5	55.2
4	3189	1.87	32.97	26.94	0.5	56.4
5	3544	1.98	32.68	26.85	0.51	56.4

Fig.4— (a) Simulated image with connection points, and (b) omitting connection points

meanings in their level. Figure 5 shows the relationship between crimp contraction percentage and orientation angle for yarn.

Considering that the explanation of linear relations are easier than polynomial, and linear fittings have the correlation coefficient (CC) of more than 95%. Yarn concentration is calculated using the following relationship:

$$CC\% = a \times a_m + b \qquad \dots (7)$$

where a_m is the crimp contraction; b, the oreintation angle when crimp contraction is zero; and a, the ratio of orientation angle to crimp contraction.

3.2 Effect of Heater Temperature on Mean Angle of Aligned Filaments

Table 4 shows the variation in filaments placement in texture yarn for different heater temperature. After image evaluation by image processing, the mean
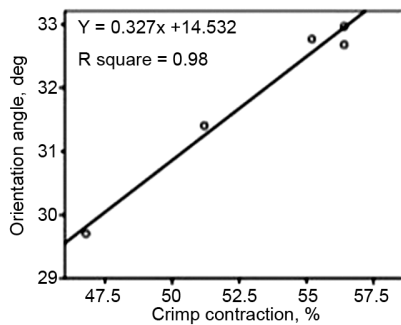

Fig.5—Relationship between crimp concentration and mean angle of orientation

angle of filaments and the mean index orientation are calculated (Table 4).

In Fig. 6, the variation in mean angle of aligned filaments and index orientation with changes of heater temperature are illustrated.

The results show that by increasing heater temperature, mean angle increases and the orientation index decreases. The deviation from the straight position of filaments in comparison with yarn axis increases. It is caused by better fixing of crimp at higher temperatures. Based on the Duncan test, although increasing heater temperature from 160 °C to 170 °C or from 180°C to 190°C causes a decrease in mean angle orientation, the difference between mean angle of orientation and orientation index does not have meaning from a statistical view.

3.3 Effect of Texturizing Speed on Mean Angle of Aligned Filaments

To evaluate the effect of texturizing on filament placement, samples in different texturizing speed are presented in Table 5.

With the texturizing speed, the mean angle of aligned filaments decreases and the orientation index increases. At high speed, the staying duration of yarn in the heater decreases and hence there is no chance for the yarn to move and filament deviation from the straight line decreased. Likewise, the Duncan test (Table 6) shows that there is a significant difference between the sample groups.

The relationship between crimp concentration and mean angle of orientation has a linear correlation coefficient of more than 95%.
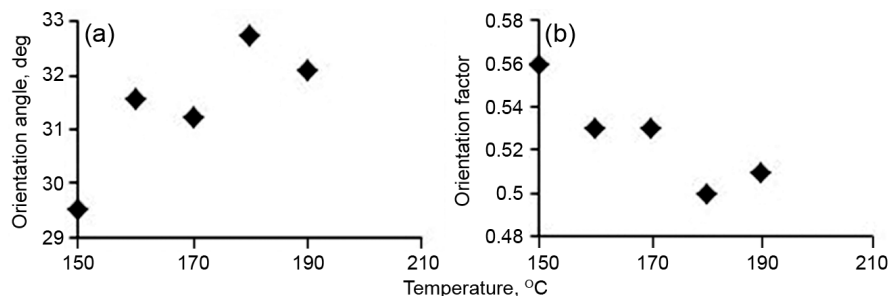

Fig.6— Variation in (a) mean angle of aligned filaments, and (b) orientation factor versus heater temperature

Table 4— Algorithm results for samples—effect of heater temperature

Sample number	Heater temperature,°C	Figure density, %	Mean angle orientation	CV of align filament angle	Orientation index	Crimp concentration, %
1	150	2.31	29.54	24.91	0.56	52.4
2	160	2.24	31.56	25.81	0.53	55.8
3	170	2.01	31.23	26.77	0.53	55.9
4	180	2.07	32.76	26.60	0.5	57.6
5	190	2.12	32.12	26.38	0.51	56.7

Table 5—Algorithm results for samples effect of texturizing speed

Sample number	Texturizing speed, m/min	Density %	Mean angle of orientation	CV of aligned filament angle	Orientation index	Crimp concentration, %
1	40	2.02	31.20	26.04	0.53	58.3
2	60	1.86	30.78	26.73	0.54	57.9
3	80	1.98	29.93	26.03	0.55	56
4	100	1.95	29.21	26.05	0.57	53.2
5	120	2.15	29.04	25.82	0.57	53.2

Table 6—Duncan test for evaluation of texturizing speed on variation of mean orientation angle

Velocity	N	Subset for alpha = 0.05		
		1	2	3
120	150	29.0351	-	-
100	150	29.2099	-	-
80	150	-	29.9270	-
60	150	-	-	30.7812
40	150	-	-	31.2031
Sig.	-	0.617	1.000	0.228

4 Conclusion

This study is a novel approach using computer vision to determine the percentage of crimp concentration in false twist texture yarn so that the test results with accuracy are achieved more quickly than other existing methods. Also, the study of placing the filaments in the false twist texture yarn is considered as the aim of this research. Experiments performed on images on false twist texture yarn includes determination of orientation index and mean angle filament alignment index. In the mean angle of orientation, with a correlation coefficient of more than 95%, the yarn is found to have a linear relationship with the amount of crimp concentration. The effect of production variables (twisting, temperature and speed of texturizing) on the arrangement of the filaments in the false twist texture yarn in this new method is also studied. It is observed that (i) increasing texturizing twist causes a decrease in orientation along the yarn axis, (ii) increasing heater temperature results in deviation of filaments from the yarn axis and (iii)increment of texturizing speed has high orientation as a result.

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