A Novel Computer Vision Method for Evaluating Deformations of Fibers Cross Section in False Twist Textured Yarns

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***Abstract*—**In recent five decades, textured yarns of polyester fiber produced by false twist method are the most important and mass-produced manmade fibers. There are many parameters of cross section which affect the physical and mechanical properties of textured yarns. These parameters are surface area, perimeter, equivalent diameter, large diameter, small diameter, convexity, stiffness, eccentricity, and hydraulic diameter. These parameters were evaluated by digital image processing techniques. To find trends between production criteria and evaluated parameters of cross section, three criteria of production line have been adjusted and different types of yarns were produced. These criteria are temperature, drafting ratio, and D/Y ratio. Finally the relations between production criteria and cross section parameters were considered. The results showed that the presented technique can recognize and measure the parameters of fiber cross section in acceptable accuracy. Also, the optimum condition of adjustments has been estimated from results of image analysis evaluation.

***Keywords*—**Computer Vision, Cross Section Analysis, Fibers Deformation, Textured Yarn

I. INTRODUCTION

THE fast dynamic pace in computer technologies, founded a broad opportunities in other aspects of engineering. Nowadays, Image processing techniques become a widespread mean for identifying, monitoring and measuring. In textile engineering, image processing techniques have been used in many aspects of this field. In this research image processing techniques applied to the cross-sectional areas of yarn and fibers. Since cross-sectional size and shape have a significant impact on physical and mechanical properties of fibers, and also geometrically cross section of fibers are very small and it is hard to inspect them by naked eye. Many researches had been dedicated to measuring and identifying different characteristic of fibers cross section. The first studies in this field were determining cotton fiber maturity by images of cross section of fibers [1- 3]. Also some researches were measuring cross sectional parameters of cotton[4 and 5]. There are different approaches to analyze cross section of fibers. Cross-sectional shapes are characterized with the aid of geometric and Fourier descriptors. Geometric descriptors measure attributes such as area, roundness, and ellipticity. Fourier descriptors are derived from the Fourier series for the cumulative angular function of the cross- sectional boundary and are used to characterize shape complexity and other geometric attributes [6]. Moreover, image processing based methods have been used for identifying different types of fibers in cross section. To recognize fibers, some shape features of them were measured and variances in these features for different types of fibers results in identifying them [7 and 8]. In textured yarns, cross section has a dominant role in physical and mechanical properties of yarn such as strength, luster, friction, etc. Evaluating the fibers cross section in yarn, we can determine those properties of yarn and also we can find the best adjustment of machine in order to obtain best cross-sectional features of fibers. To evaluate cross section of a fiber, first its shape must be assessed. The shape of an object is defined by its boundary. In order to analyze the shape, the object boundaries must be segmented. The outcome of segmentation operation depends on the amount of noise, the degree of object-background contrast, and the amount of separation between cross sections. Noise may be removed or suppressed by a filter that replaces each pixel value with a grey level based on the mean or median value of its immediate neighborhood. Contrast between objects and back ground may be enhanced by filtering techniques that emphasize rapid change in gray level gradients or by histogram modification.

The next step is to extract boundaries from objects and morphological operations in order to modify binary objects in a controlled and automated fashion. The resulting object outlines are then thinned by using an iterative morphological procedure, which produced boundaries consisting of a single line of corner-connected or edge-connected pixels [9].

II. MATERIALS AND METHODS

In this research, images of cross section of textured yarn acquired by a CCD camera embedded on a compound microscope with a magnification of x40 and resolution of 72 DPI. Fig.1

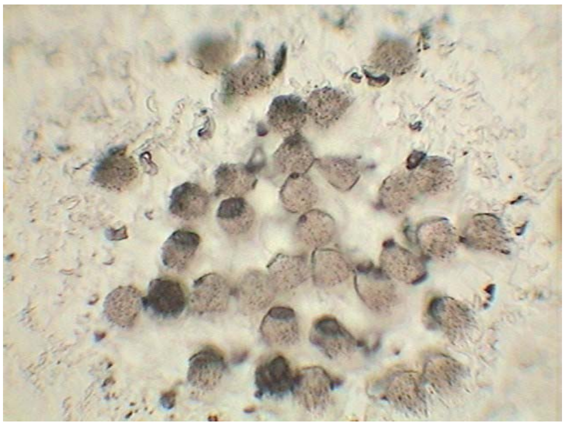

Fig.1 captured image by compound microscope with x40 magnification

The images are in RGB format which must be converted to the gray scale images. After converting the images, the sobel filter was used to recognize edge of objects in image. In the second level of process, the images converted to the binary format, and then it was reversed for easier detection of cross section of each fiber Fig.2.

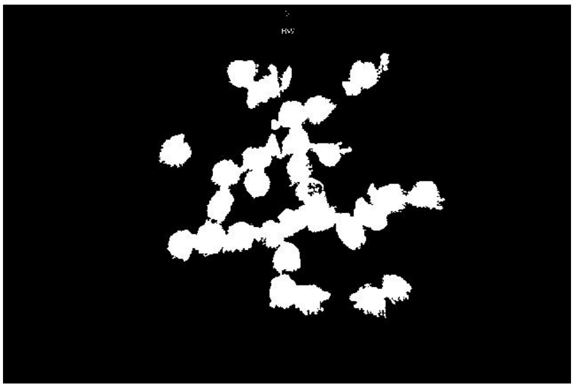

Fig.2 binary image

The reversed image was used, to evaluate cross section of fibers and measuring their physical properties. First, every fiber segmented from the others then its properties was measured. The method for segmenting the cross sections of fibers in yarn is using labeling procedure for binary object in image. After segmenting fibers from each other, different properties of them were measured by MatLab image processing toolbox. Fig.3 is showing cross section of a segmented fiber from the cross section of yarn.

To determine the best adjustments to produce a yarn with optimum physical properties, the effect of different adjustments of machine on the various parameters of cross section were assessed individually. For this purpose different kinds of yarns were produced with different adjustments in temperate, drafting ratio and D/Y ratio according to Table I.

Fig.3 a separated cross section of a fiber

TABLE I
DIFFERENT CONDITIONS OF YARN PRODUCTION

Sample	Temperature	D/Y Ratio	Drafting Ratio
I*	200	2.14	1.718
II	200	2.14	1.745
III	200	2.14	1.69
IV	200	2.08	1.718
V	200	2.21	1.718
VI	190	2.14	1.718
VII	210	2.14	1.718

* Sample I is the basic adjustment which had been obtained experimentally in the factory

The yarns were produced by RIETER SDS8300 texturizing machine; 100-denier yarns with 36 filaments were produced in this machine. The basic adjustments had been obtained experimentally in the factory, but to acquire the optimum conditions of production with better features in the cross section of yarn, the adjustments had been altered and different types of yarn were produced. The alternations in each adjustment were 5 percent more and 5 percent less than the basic adjustment in every adjustment. Afterwards, the images of cross section of all samples were acquired using the microscope. Then the algorithm was applied to the images and different parameters of them were measured. To measure and estimate the parameters following approaches used for every parameter.

Surface Area: to estimate surface area in the discrete space Formula 1 was used

$$A(x) = \sum_{i,j} g(x_i, y_i) \qquad (1)$$

Where the $g(x_i, y_i)$ is a white element of object in the binary image.

Perimeter: to measure perimeter of cross section in a discrete space Formula 2 was used

$$P = \sum_k \sqrt{(x_k - x_{k-1})^2 + (y_k - y_{k-1})^2} \qquad (2)$$

Where (x_{k-1}, y_{k-1}) and (x_k, y_k) are the consecutive points at the edge of the cross section.

Equivalent Diameter: This criterion demonstrate the diameter of a circle whose surface area is the same with the surface area of cross section and was calculated by Formula 3

$$Equivalent - Diameter(x) = \sqrt{\frac{4.S(x)}{\pi}} \qquad (3)$$

Large Diameter: This parameter demonstrates the diameter of smallest circle which can fully contain the area.

Small Diameter: Shows the diameter of largest circle which completely surrounded by the cross section area.

Hydraulic diameter: Generally, the hydraulic diameter is important in hydrodynamic of flow in a pipe. The mean value of diameters of porosity is related to the hydraulic diameter. Hydraulic diameter was calculated by the Formula 4.

$$Hydraulic - Diameter = \frac{4.A_i}{P_i} \qquad (4)$$

Where A_i is the area of the object and P_i is its perimeter.

Eccentricity: originally this parameter shows the ellipticity of an oval-shaped area. In other words, a circle has zero eccentricity and this parameter is 1 for a fully elongated oval; this parameter was calculated according to the Formula 5.

$$e = \sqrt{1 - \frac{b^2}{a^2}} \qquad (5)$$

Where b is the small diameter and a is the large diameter of an oval.

Solidity (Stiffness): this parameter is the ratio of surface of smallest convex area which surrounds the cross section to the surface area of cross section. The smallest convex area obtained by dilation and erosion processing on the image of cross section. Then, the surface of convex area was calculated according to Formula 1. To illustrate, there is an inverse relationship between Solidity factor and eccentricity. Calculation of Solidity factor was mentioned in Formula 6.

$$Solidity = \frac{S_i}{S_c} \times 100 \qquad (6)$$

Where the S_i is the surface area of cross section and S_c is the surface area of the surrounding convex shape.

III. Results

Measuring cross section parameters, it is possible to assess deformations in the cross section. The results of measuring became here in figures.

Fig 4.a shows the relation between surface area and drafting ratio, this shows that increase in drafting ratio first results in increasing of area, but the more increase lead to decrease in surface area. Fig 4.b shows that increase in D/Y ratio caused to decrease of area surface; this is due to increase in the speed of disks in machine which caused to more abrading and thinner yarn. Fig 4.c shows that the hotter chamber in machine caused to production of thinner yarn. This is because of easier movement and migration of polymers in hotter atmospheres.

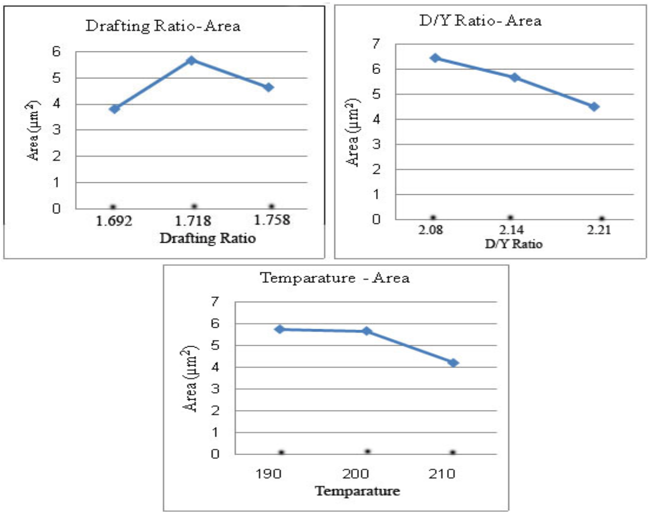

Fig 4. Relations of area with different adjustments of machine

Relations of adjustments on perimeter of cross section had been showed in the Fig.5. According to Fig 5.a and 5.c increase in drafting ratio and temperature lead to increase in perimeter of cross section.

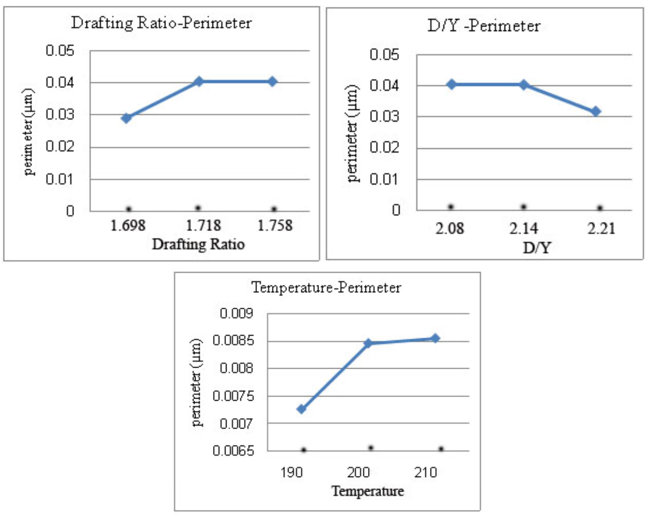

Fig 5. Relations of perimeter with different adjustments of machine

Also it was shown that increase in D/Y ratio results in decrease of perimeter.

In Fig. 6 relation of machine adjustments with equivalent diameter were shown. Since equivalent diameter is associated with surface area, trends in these two parameters are similar.

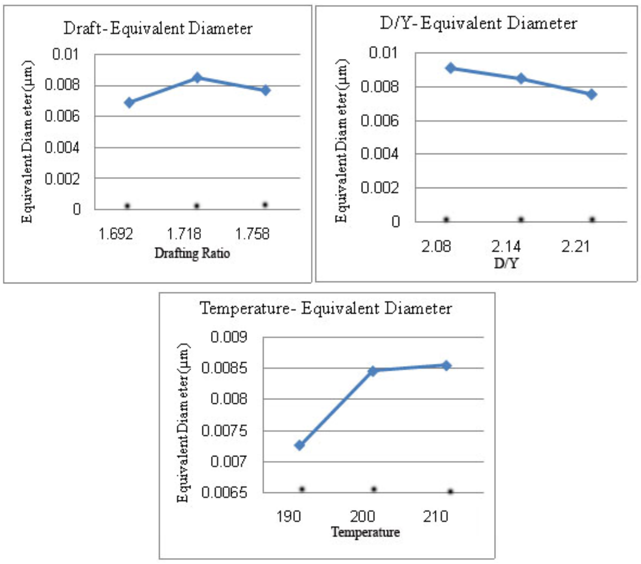

Fig. 6 Relations of Equivalent Diamater with adjustments of machine

In Fig. 7 the relations of large diameter of cross section of fiber were assessed. As it was shown, with rise on draft and temperature the large diameter increases Fig 7.a and Fig 7.b. This is due to easier movements of polymers which results in to a more oval shaped cross section Fig 7.c. But with increase in D/Y ratio the large diameter will decrease because of more abrading forces.

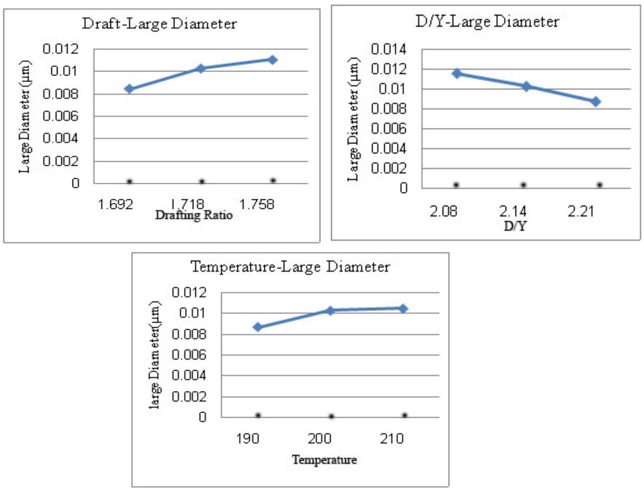

Fig. 7 Relations of Large Diamater with adjustments of machine

With increase in draft and D/Y initially the small diameter grows but in second level the small diameter was reduced, especially for D/Y which this reduction is much more Fig 8.a and 8.b. But increase in temperature in draft results in thinner cross section and lower small diameter Fig 8.c.

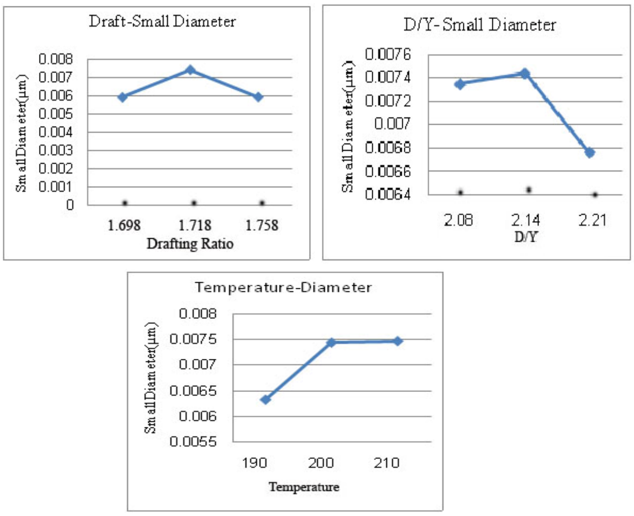

Fig. 8 Relations of Small Diamater with adjustments of machine

As hydraulic diameter is related with surface area the trends are alike as they were shown in Fig, 9.

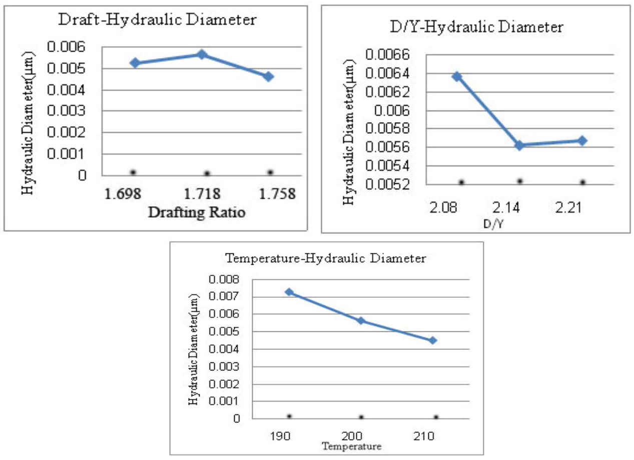

Fig. 9 Relations of Hydraulic Diamater with adjustments of machine

For eccentricity, measurements show that with raise in draft and temperature substantially it will increase. This means that with increase in these parameters the initially circular cross section changes into a more oval shaped area Fig. 10.a and 10.c. Yet with increase in D/Y ratio, the cross section becomes more circular area. Since more D/Y ratio results in more torque and torsion on the yarn and fibers, it is better for fibers to become more circular to reach their relaxation mood Fig 10.b.

For stiffness, more draft results in less of it Fig 11.a. And more D/Y and temperature will cause to initially decrease of it but following that they will grow as it is shown in Fig 11.b and 11.c.

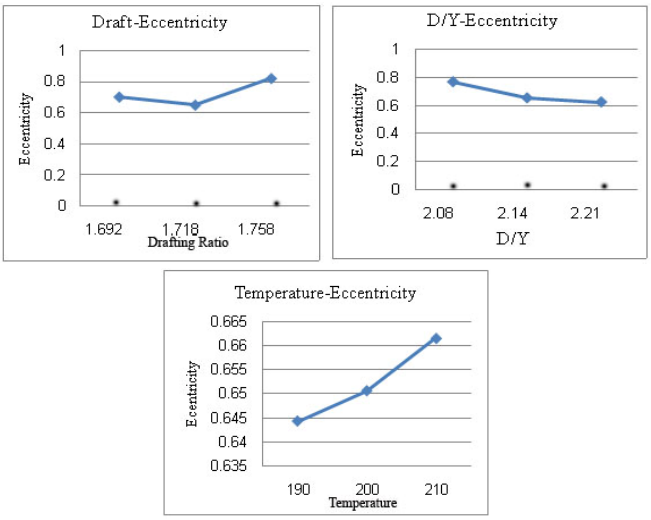

Fig. 10 Relations of Eccentricity with adjustments of machine

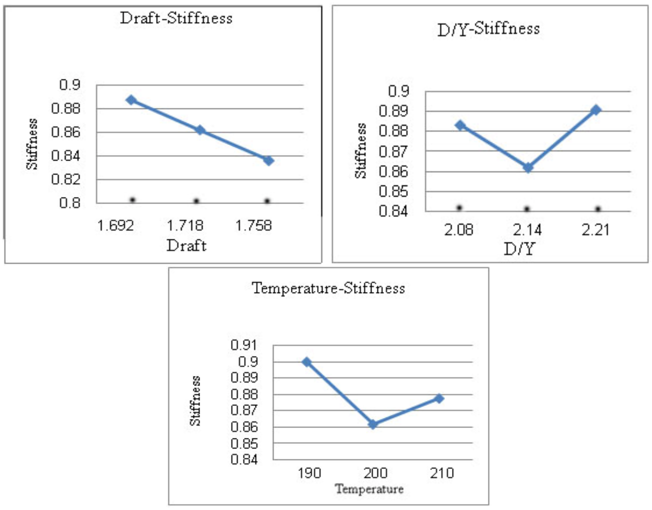

Fig. 11 Relations of Eccentricity with adjustments of machine

IV. Discussion

With evaluating cross section of fibers we can assess some important properties of yarn such as, friction, luster, tensile strength, bending rigidity, dyeing affinity, etc. This research was an attempt to find relations between adjustments of texturizing machine and different parameters of cross section. Considering these relations between machine and production might lead to a more accurate control of production line. The image analysis method has been applied to recognize fibers in cross section of yarn; then the geometrical features of fibers have been measured. The results showed that by increasing the twist rate and setting temperature lead to more deformation of fibers cross section from circular shape to deformed random shapes while increasing the tension lead to decrease of fibers deformation. The situation of more random shapes of fibers is suitable in texturing process. The optimum condition is occurred at draft ratio 1.692, temperature 210 ^{o}C and twist rate 2.08.

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