# Determination of Crimp Indexes of False Twist and Knit de Knit Textured Yarns Using Computer Vision

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*ABSTRACT*

Measurement and monitoring of product characteristics during of production is very important to achieve improvement in product qualities. According to increased rate of machinery speed this issue becomes more important, especially in case of yarn texturing because of high demand of textured textiles. In this investigation, new methods introduced for determination of crimp indices in false twist and knit de knit textured yarns. In false twist textured yarns the box counting and distance fractal dimension used in addition to crimp percentage to achieve good correlation with crimp contraction. The filament's structure at knit de knit textured yarns were very regular and flat, so in this case the crimp percentage can explain the total crimp contraction of this type of yarn. Finally, utilization of fast Fourier Transforms on images of this type of yarns, successfully predicts the frequency and length of crimp waves.

*KEYWORDS*

Textured yarn, false twist, knit de knit, computer vision, crimp contraction

## 1. Introduction

Characterizing of the textured yarn's structure depends on filaments properties and the texturing processing. Some characteristics of yarn such as twist, bulkiness, crimps, strength, and density ... are different in different type of yarns. Finding an accurate method for determination of any type of yarn's characteristic is very important. Textured yarns behave different structures and characteristics depend on texturing processes. In false twist and knit de knit textured yarns the yarns have a three-dimensional and crimped structure. In this case, determinations of crimp characteristics are very important, because of its effect on end usages products characteristics. Some usual and standard test methods [1], [2], [3] and [4] can be used for determination of these properties, but they are very time consuming and very users' accuracy dependant. In the resent years, many researches and projects tried to achieve more accurate methods for determination of crimp characteristic and especially crimp contraction in textured yarns. The appearance of new digital computers and programming tools, the researchers were going to have more consideration on using computer vision systems as a new method for testing and controlling the quality of products. One of these researches was conducted in 1992 in Maryland University of USA [5]. In this study, they obtained a new method for quantization of crimp morphology of a single filament. The structure of false twist and knit de knit textured yarns are similar to fractal shapes so some researchers encouraged using the concept of fractal dimension for quantification of the yarn characteristics [6], [7] and [8]. In this investigation, some new and efficient methods were achieved, that showed a very good correlation with the empirical testing methods.

## 2. Fractal Geometry and Dimension

In 1623, Galileo expressed that the book of nature was

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written in mathematic languages and the alphabets of this language is triangles, circles and other geometrical shapes, that human being could not understand it carefully [9]. The Euclidean geometry is the axiomatic study of lines, circles and triangles that shaped form an ideal, therefore approximate basis for understanding geography, mechanics and every real thing. From this perspective, nature is like noisy mathematics and crumpled slightly out of focus. Fractal create an alternative to Euclidean geometry whose elements are not lines and circles but iterations and self-similarities, whose surface are not smooth but jogged, whose feature are not perfect but broken. Fractal is a new geometry that enables us to understand formerly inexplicable real world phenomena. Fractal provides insight into the distribution of galaxies, the shape of coastlines and growth of crystals [10]. In nature, we can see more fractal object such as fern, cauliflower, clouds, trees and so on. The fractal objects have distinctive boundaries that occupied the constant volume or space. Fractal dimension can define any changing in the details of object. Until now, many fractal dimensions were introduced with special applications [11]. The fractal dimension is changed ranged between 0 to 3 and takes a real amount. For curve, this varies between one up to two and for surface changes from two to three. The fractal dimension shows freedom's degree of object. From the perspective of some application and also the concept that is used in present research, fractal dimensions can be used instead of human vision in some systems. So using this concept, it is very useful for object's pattern investigation. Some of the most important and useful of fractal dimensions are box counting, compass and self-similar dimension.

### *A. Box counting Dimension*

Box counting dimension used in many applications in different systems. It is related to self-similarity structures, but it can be applied even to a random structure without a conspicuous self-similar unit, like a coastline. For determining box counting dimension ( $D_B$ ) it is assumed that the object is covered by a square mesh of various sizes " $s$ " and then number of boxes ( $N(s)$ ) contain part of the image (containing the object) is counted. Because $N$ is the function of the mesh size, $N(s)$ increases as s decreases. The box counting dimension ( $D_B$ ) is given by the slope of the linear portion of a $\log(N(s))$ vs $\log(1/s)$ graph [12] as expressed by Equation 1.

$$\log N(s) = D_B \log(1/s) \tag{1}$$

### *B. Compass Dimension*

The compass dimension is a relationship between the compass divider setting and measured length. To measure the length of a random fractal curve, a compass divider must divide by a compass divider or ruler with certain ruler setting. If multiplying the ruler length by the number of rulers that is needed to cover the object's image length, the approximate length of a curve can be expressed as Equation 2:

$$L = N \times l \tag{2}$$

By decreasing the length of rulers, the more accurate length of the curve can be obtained, because of the closer measurement to the path of the curve. So if we plot $\ln(L)$ against $\ln(l)$ for a range of value of $l$, the slope will be an estimation for the compass dimension ( $D_C$ ) [12].

$$\ln(L) = \ln(l)^{1-D_C} + c' \tag{3}$$

## 3. Experimental

### *A. Image Capturing And Processing*

The digital image of texture yarn was obtained with a monochrome non-color CCD camera and for eliminating the environment's light and minimizing image's noises. Image capturing was done in a closed cabinet. Two fluorescent lamps (18W) above the sample are used for illuminating. The camera was equipped with a 0.75X lens. This system could capture only 13mm of yarn's length. Image data were transferred to A/D intermediate card (Matrox Intellicam) and so the image is shown on Intellicam software. The images have a CCIR format with 576(H) × 768(V) pixels. Two samples of yarn images are shown in Figure 1 and 2.

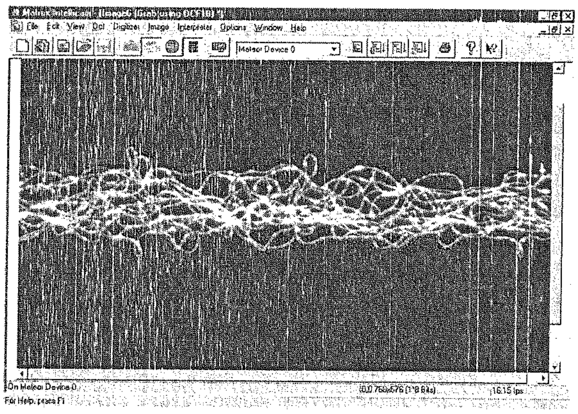

Figure 1: False Twist textured yarn's image in Intellicam software

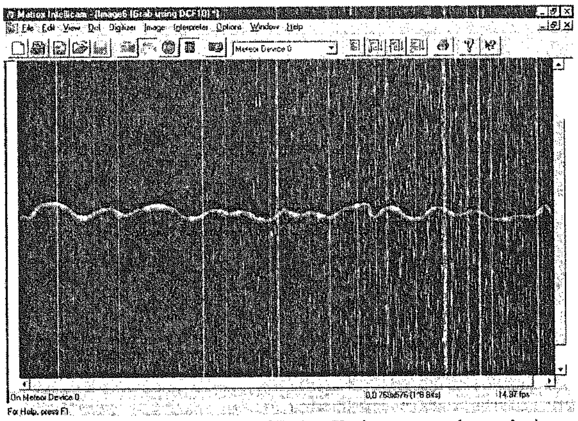

Figure 2: A single filament of False Twist textured yarn's image in Intellicam software

First of all, it is very important to unify all of images. So dependent on each image histogram, the proper value of threshold was obtained for converting the raw grayscale images to black and white format. After making binary images, erodition is further unify for identification of patterns. Using erodation algorithms, we eliminated all of image's noises. So we can have a skeleton of source image (usually with one pixel width on yarn line) that has a topological characteristic of source image. For achieving this goal a program was written that is able to change the width of object according to the user input value. A sample of single filament of false twist textured yarn before and after applying the above algorithm is shown in Figure 3.

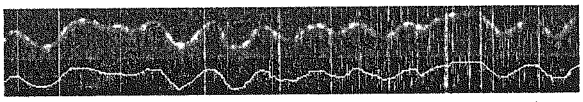

Figure 3: A single filament of false twist textured yarn's image before and after applying erodation algorithm.

*B. Sampling*

Sample preparation step is very important to achieve the reliable results. The sample must have the same characteristic similar to main society. The most important reasons for substituting samples instead of large society are reducing the cost of testing, making the test to be done more rapidly and obtaining high accuracy even in case of distractive tests. Another important factor that must be considered in sampling is the size of samples. This comes into account when we want to distinguish between two alternative indexes for the same characteristic. For example, when a new method for determination of a special characteristic goes to replace the previous method, it is very important that the results of new method have less error than the old one. In the absence of standard samples from source society, the results obtained in the conventional test method become a comparative basis. There are two ways for determining the proper size of the samples. First, it could use the same sample size in two different test methods and in other way it could take the different size of sample, but the size of sample in new method must be conducive to the same variation value or less than old testing method [13]. The results of new method that are introduced in present research were compared with the crimp contraction of textured yarn in standard test method [4]. The standard crimp contraction of textured yarn was taken as basis in this research and the mean of this factor in five skeins with one-meter length and 2500dtex used for this purpose. The total length of skein is obtained by taking into consideration the yarn density and in this research, it was 75 meter of yarn. The sample size in new method is only 13 millimeters.

According to central limited theory in statistical science, for obtaining the best solution to get a sample from the main group, first we have taken 100 samples from different paces of bobbin as a base and the average of crimp percentage and standard deviation were calculated. It is expected that by increasing the size of sample the standard deviation and errors decrease. So the samples were divided to different groups and were classified with different subgroups that the total of each them were 100. The results are shown in Figure 4.

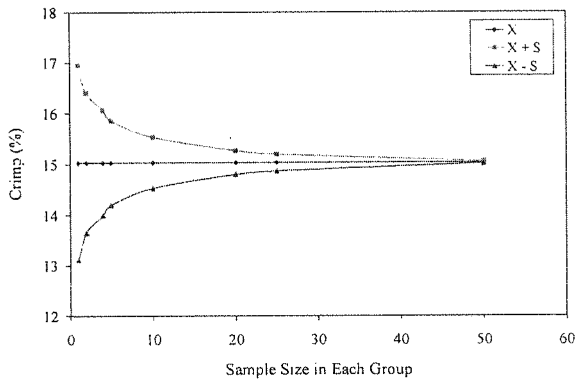


Figure 4: The results of crimp% when getting the various sample size

As Figure 3 shows, the total average is independent from the classification but decreasing the number of subgroups and increasing the amount of samples in them make results with low standard deviation (Figure 5). In conventional test method, the standard deviation of crimp contraction that is obtained for one bobbin was 1.35 and its CV% was 2.11% so we choose the classes that have the less value than these values. The 6th classes were chosen because its standard deviation was further smaller than this value in standard testing method (1.35).

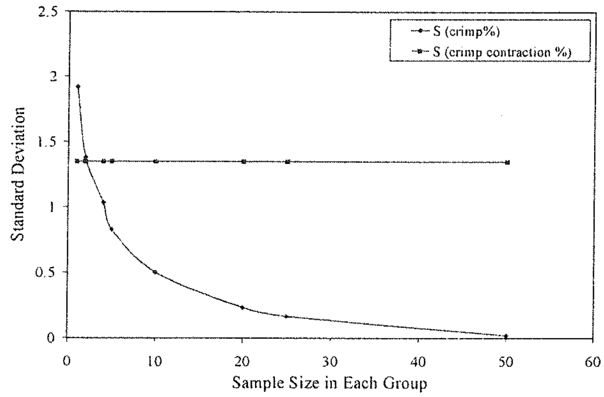


Figure 5: The variation of standard deviation in different classifications.

The results by this classification are the best estimation for the real value of yarn with small error. As equation 4 shows, the errors have two sources. First is inherent error in the samples $(\varepsilon_{ij})$ and the other comes from the measuring method system or the error between groups and classes $(\alpha_j)$.

$$\overline{X} = \mu + \alpha_j + \varepsilon_{ij} \tag{4}$$

In equation 4, $j$ is the number of groups and $i$ represents the number of element in each groups.

So from the later discussion for choosing the samples, we have taken 5 part of the yarn from bobbin with 50 centimeters length randomly. Since the shape and the structure of a single filament in false twist textured yarn are approximately similar to others so one of the filaments in each group was chosen and with applying the minimum tension on its ends a started point was selected randomly as ($x_1$) and its image was taken. 9 other images also were captured sequencelly one after another from the started point.

$$x_{(i+1)} = x_i + 1.3 \quad (i = 1,2,...,9) \tag{5}$$

As mentioned before, the length of image using the lens 0.75× that is observed in these images was 1.3 centimeters. Under this condition, we get 13 centimeters of filament for measurement. In case of wider angle of camera lens the number of captured images will be reduced accordingly.

### *C. Conventional Test Methods And Their Results*

In this attempt, the polyester multifilaments yarn with 70/17 dtex density (F1) and 70/24 density (F2) were used for texturing in false twist process. The amount of twist was varied during texturing because of its large effect on crimp contraction value in textured yarn. Five different groups of false twist textured yarns with different twist value were textured and produced. The crimp characteristics of producing yarns were measured according to standard test method DIN 53840-PART 1 [4]. Iran standard test method number 931-1 also can be used [2].

In Figure 6, the variation of crimp contraction vs twist per meter of textured yarn is shown. By increasing the amount of twist per meter, the crimp contraction values also increase.

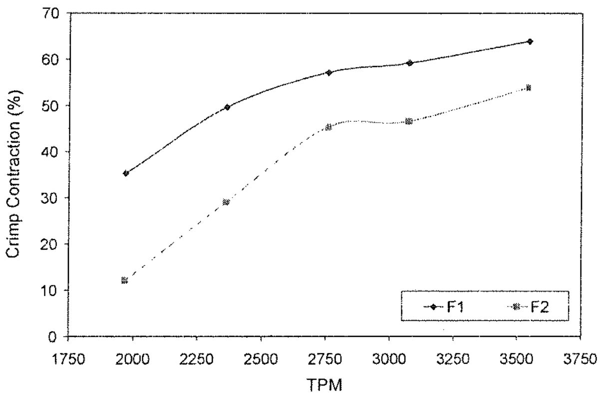


Figure 6: The graph of crimp contraction vs twist per meter in false twist textured yarn for two different yarn's density.

For determining the crimp value of textured yarn, we also produced two different knit de knit texture yarn. Their specifications are presented in Table 1.

TABLE 2
THE CHARACTERISTIC OF KNIT DE KNIT TEXTURE YARN

| Yarn code | Type | Density [dtex] | Number of Filament | Crimp percentage(%) |
|---|---|---|---|---|
| K1 | nylon | 244 | 72 | 9.62 (3.11) |
| K2 | nylon | 100 | 24 | 53.78 (3.78) |

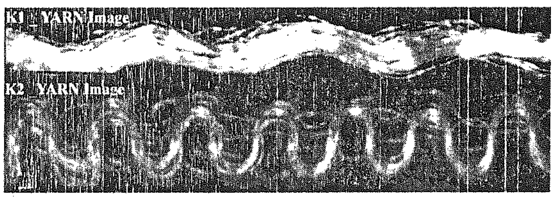


Figure 7: The images of two different knit de knit textured yarn

## 4. Applying And Using The Theories

Fractal dimension is able to characterize the complexity of the image's structure. If the source image has complex and uneven structure, the value of fractal dimension increases more from 1 to 2. Textured yarns have a very complicated and chaotic structure. So using the concept of fractal geometry and fractal dimension could characterize their structure. In addition, using this method could determine the amount of crimp percentage in the yarn.

After doing many investigations, it was observed that it could not be possible to determine the fractal dimension of false twist textured yarns directly and it should be defined using their structure's unit. Therefore, applying the algorithms on single filament of this type of yarn, it could be possible to define yarn's crimp characteristics and this is because of the strong relationship between single filaments and textured yarns characteristics. Both fractal dimensions, i.e. box counting and compass dimension were calculated for all of samples and their results are given by Figure 8.

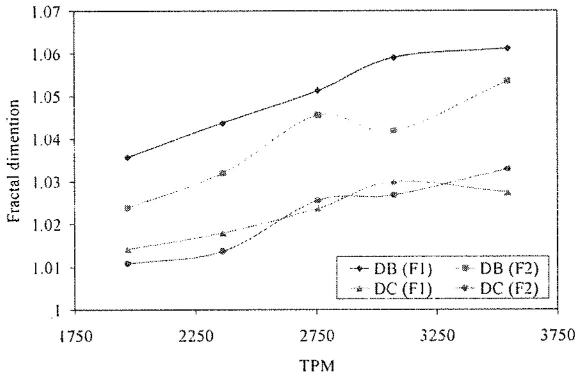


Figure 8: The relation between fractal dimension and twist per meter in single crimped filament of false twist textured yarns.

Considering the relation between fractal dimension and twist per meter in textured yarns in Figure 8, it is observed that increasing TPM results in higher value for fractal dimensions.

In these attempts, using the concept of fractal dimension, the crimp percentage of single filament was calculated according to equation 6 (Figure 9):

$$crimp = \frac{L - L'}{L} \times 100 \qquad (6)$$

In equation 6, $L$ is the total length and $L'$ is the longitude length of crimped filament.

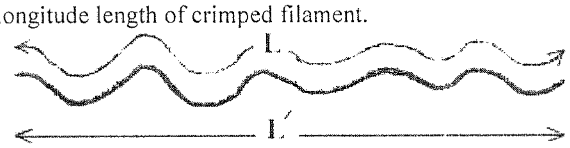


Figure 9: The schematic of single crimped filament of textured yarn

When comparing the $L$ value with the one that is calculated from compass dimension algorithm, it is very clear that these two values are similar to each other when the rulers get a unit size in compass dimension's algorithm. In Figure 10, the behavior of crimp percentage variation against twist per meter for two different groups of false twist textured yarns is given. It can be noticed that the crimp percentage goes to higher value by increasing the amount of twist per meter.

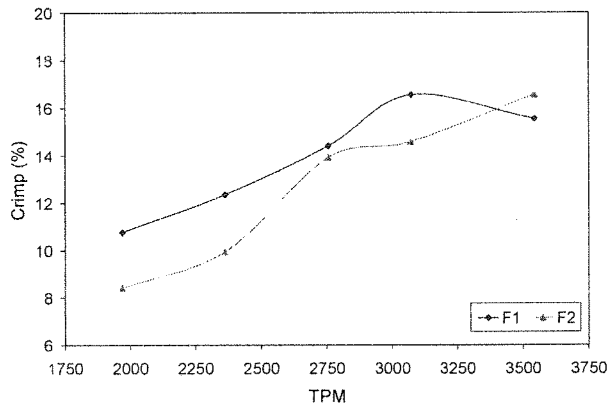


Figure 10: The crimp percentage value of false twist textured yarn vs twist per meter

In this research, it was observed that the new indexes for determining crimp in textured yarn have a very good correlation with the crimp contraction values that is calculated according to conventional test methods. For example, the correlative index between box counting dimension and crimp contraction value of yarn (F2) is 0.9917 and they have a linear relation. So having the relationship formula, one can define the amount of crimp contraction of yarns by applying fractal dimension values of single filaments of textured yarns.

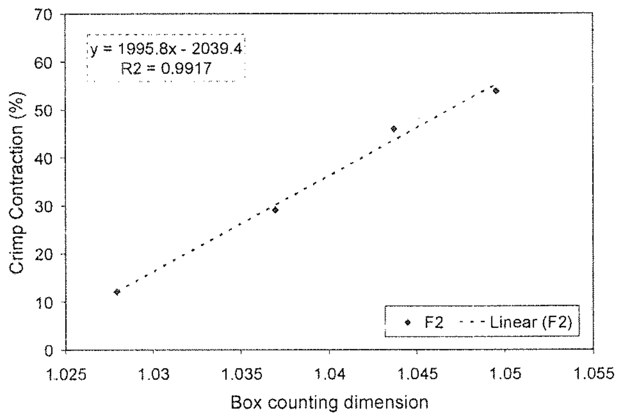


Figure 11: The relation between crimp contraction values and box counting dimensions in F2 yarn.

In the next steps, knit de knit textured yarns are going to be discussed. The crimp percentage values were calculated for K1 and K2 groups and were 9.56% and 55.65%. Consequently these values in conventional test method were 9.62% and 53.78% and the statistical test did not show any meaningful differences between them. On knit de knit textured yarns all of the new techniques were applied on yarn's image because of its regular structure. As one considers the results, it is very clear that the value that was obtained from new indexes is the same with that in conventional test methods. Because of their smooth and regular's shape applying Fast Fourier Transform on their image could show the frequency of crimps and predicts the length of crimp waves in this type of textured yarns. The power spectrum diagram for K2 yarn is shown in Figure 12. The maximum point of this diagram shows the value of crimp frequency in knit de knit textured yarn.

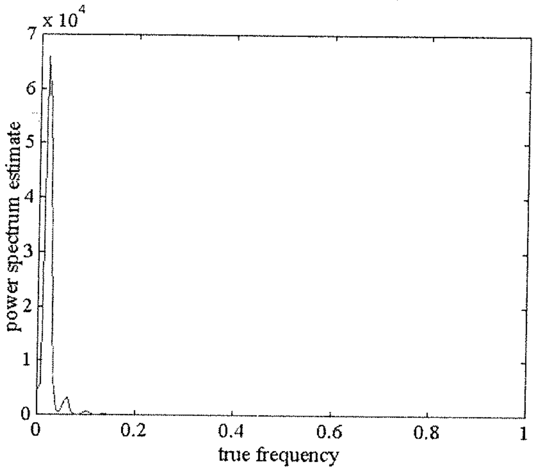


Figure 12: The power spectrum of knit de knit textured yarn (K2)

*A. Crimp development*

In most of the test methods for characterizing and determining the crimp contraction value for textured yarns, they have the step for crimp developing on the yarn. By having this step, we can extend the crimps of yarn after opening from bobbins [2],[4]. This important fact comes into consideration and the results for one of testing yarn's groups are given in Table 2. In this table, the crimp percentage value as one of the new indexes was calculated before and after crimp development in heater with 120°C for false twist textured yarn with the same characteristic with F1 groups (F3).

TABLE 2

CRIMP PERCENTAGE VALUES FOR SINGLE FILAMENT OF F3 GROUPS

| Yarn code | Crimp percentage (before crimp developing) | Crimp percentage (after crimp developing) |
|---|---|---|
| F31 | 11.89 | 12.13 |
| F32 | 13.20 | 12.87 |
| F33 | 13.21 | 14.98 |
| F34 | 14.09 | 16.15 |
| F35 | 14.87 | 15.73 |

As can be seen from the results, there are no meaningful differences between the results before and after crimp development in textured yarns expect on F33, F34 and F35. The reason for this fact may be because of yarn's raw materials characteristics. As the type of these tested yarns were nylon and considering that those types of yarns get their final crimp value under mechanical tension, so it could not seen any differences between the crimp percentage before and after of crimp developing. If the tested yarns are polyester, it may result in more differences before and after crimp development in hot air[14].

## 5. CONCLUSION

Using the concept of fractal dimensions and applying their algorithms on textured yarn's images, the new indexes for quantifying of crimp were found.

The fractal dimensions of false twist textured yarns with different density and twist per meter, have shown very good correlation with the results that be obtained in conventional test methods. These correlated values in all of results are more than 95%. So having their relation function, it is very easy to calculate the crimp contraction by having the fractal dimensions value.

In knit de knit textured yarns, all of the algorithms were applied on yarn's image and the crimp percentage results were the same with the results that were obtained in conventional test method.

Using these new technique and indexes, the crimp contraction (as the most important factor that affects textured yarns characteristics) can be defined more rapidly and with high accuracy.


## 6. ACKNOWLEDGMENT

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## 7. REFERENCES


[1] *Iran Standard*, "Determination of yarn's bulkiness", No. 6973, Azar 1382.

[2] *Iran Standard*, "Crimp measuring methods-textured yarns with density up to 500 dtex", No. 931-1, Esfand 1380.

[3] *Annual Book of ASTM standards: Textile-Fiber*, American Society of Testing and Materials, D6774-02، Vol. 7، 2003.

[4] *DeutschesInstitut für Normung e.V.* , DIN 53840-part 2.

[5] B. Xu; Pourdeyhimi B.; "Characterizing Fiber Crimp by Image Analysis, Definition, Algorithms & Techniques", *Textile Res. J.*, vol. 62, no. 2, p.p. 53-73, 1992.

[6] T.J. Kang; J.Y. Lee; K. Chung; S.G. Lee; "Evaluating Yarn Crimp with Fractal Geometry", *Textile Res. J.*, vol. 69, no. 7, p.p. 527-534, 1999.

[7] T.J. Kang; J.Y. Lee; "Filament Crimp in Three Dimension Measured by Image Analysis and Fractal Geometry", *Textile Res. J.*, vol. 71, no. 2, p.p. 112-116, 2001.

[8] Y. Muraka.; K. Inoue; H. Tagaya; K. Nishizawa; "Fiber Crimp Analysis by Fractal Dimension", *Textile Res. J.*, vol. 65, no. 8, p.p. 454-460, 1995.

[9] H.O. Peitgen; P.H. Richter; The Beauty of Fractals, Images of Complex Dynamical System, Springer-Verlag, 1986.

[10] M. Frame; Mandelbrot B.B.; *Fractal, Graphics & Mathematics Education*, The Mathematical Association of America, 2002.

[11] B.B. Mandelbort; *The Fractal Geometry of Nature*, W.H. Freeman and Company, NewYork, 1983.

[12] P. Bourke, "Fractal Dimension Calculator User Manual", http://astronomy.swin.edu.ac, February 1993.

[13] D. C. Montgomery; *Design and Experiment*, 3 nd edition, John Wiley, NewYork, 1991.

[14] M. Yousefzadeh, *Determination of crimp indexes in textured yarns using computer vision* , M.Sc. Theses, textile department, Amirkabir University of Technology, 1383.