Using Linear Mean and Variance Technique to Evaluate the Patterning in Random Winding Process

Rasoul Mahdi, Mohammad Sheikhzadeh, Dariush Semnani and Sayyed Mahdi Hejazi

***Abstract*—In random cone winding system, the patterning concept results in many problems in further processes, e.g. yarn breakage and/or early take off of the package. In current winding machines, there is no system to detect the patterning and consequently the anti-patterning system is working continuously. In this research, an online-computer-vision system is used to detect the concept of patterning through the linear mean and variance technique. In fact, photographs of bobbin surface are continuously taken with specified time interval. In this way, the mean or variance is calculated from columns within the image matrix, and a vector is obtained. Then again, the variance or the mean of the vector is calculated, thus a number is obtained for each matrix. Therefore, there are four methods including mean of mean (MOM), mean of variance (MOV), variance of mean (VOM) and variance of variance (VOV) to give the index number. Accordingly, a diagram of image number versus index value is plotted for each method, and a peak is perceived in place of patterning defect. By finding this peak, the moment of occurrence of defect is diagnosed, and the "patterning" can be recognized. The results show that among the four methods, the MOV is more accurate. Finally, this outcome is mathematically analyzed.**

Keywords: Random winding, patterning, image processing, linear mean and variance technique

I. INTRODUCTION

Textile yarns are usually wound into a package form that is convenient for use in a variety of processes such as weaving and knitting. Most such packages are produced by winding many thousand meters of a single yarn on to a cylindrical and/or conical tube by a yarn winding machine, as shown in Fig. 1. In this way, patterning is mainly occurred as the threads are wound in the same positions at each layer, and consequently, a ribbon-shaped yarn bobbin is formed.

In random cone winding system, the patterning concept results in many problems in further processes, e.g. yarn breakage and/or early take-off of the package [1,2]. Mainly, in current winding machines, a system for detecting the patterning has not been planned and the anti-patterning system is arranged and working continuously to prevent further problem. However, it seems that, determination of linear speed of yarn winding is not very costly by using the anti-patterning systems. So, yarn clearing unit, which is the process of removing yarn faults at winding, does not work properly. To solve the problem, using machine vision technique, i.e. image processing method, could be a novel idea.

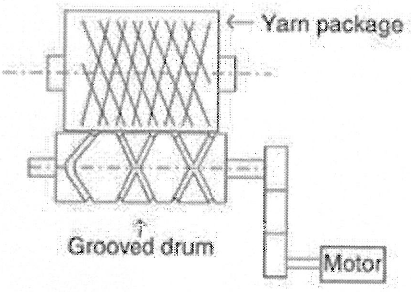

Fig. 1. Schematic of a head of a yarn bobbin winder machine.

Principally, it has been accepted that using image analysis techniques in textile industry could enhance the quality of products through the efficient use of metrology and control [3-5]. Digital analysis of two-dimensional images is based on processing the image acquirement, with the use of a computer. The image is described by a two-dimensional matrix of real or imaginary numbers presented by a definite number of bytes [6]. Such technique also enables the estimation of other characteristics features of the external structure of linear textile products, for instance twist parameter and/or linear density coefficient [7].

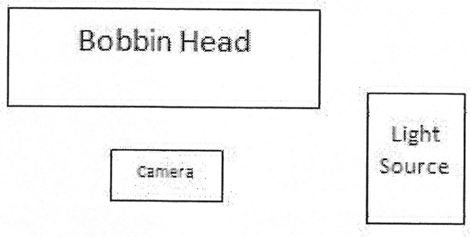

Fig. 2. Schematic of the lightening system used in this study.

Therefore, nowadays, online machine vision and image processing method are widely used in different fields of textile industry. This technique can be used as a substitute of standard tests and/or as a new method to test some specifications in textile engineering. For instant, the image analysis method is used in pore distribution determination of nonwoven geotextiles due to the lack of a proven procedure [8]. Palmer and Wang proposed a new method of frequency domain image analysis based on the two-dimensional discrete wavelet transform to objectively measure the pilling intensity in sample images of knitted

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fabrics [9]. Recently, a mathematical model has been developed to predict the fabric quality based on yarn quality determination. Evaluation of yarn quality in fabric could be possible by using image processing method [10]. Patel *et al.* found the location of defects in fabrics by using feature extraction technique [11].

In addition, online machine vision and image processing methods can be used to improve the quality of textile products. For example, the phenomenon of fly generation during cone-winding has been investigated by using the image processing technique [12]. Shiekhzadeh *et al.* reported that determination of yarn position on cone surface of random cone winding system is possible by using image processing technique [13]. This concept would be useful to find optimum yarn winding conditions.

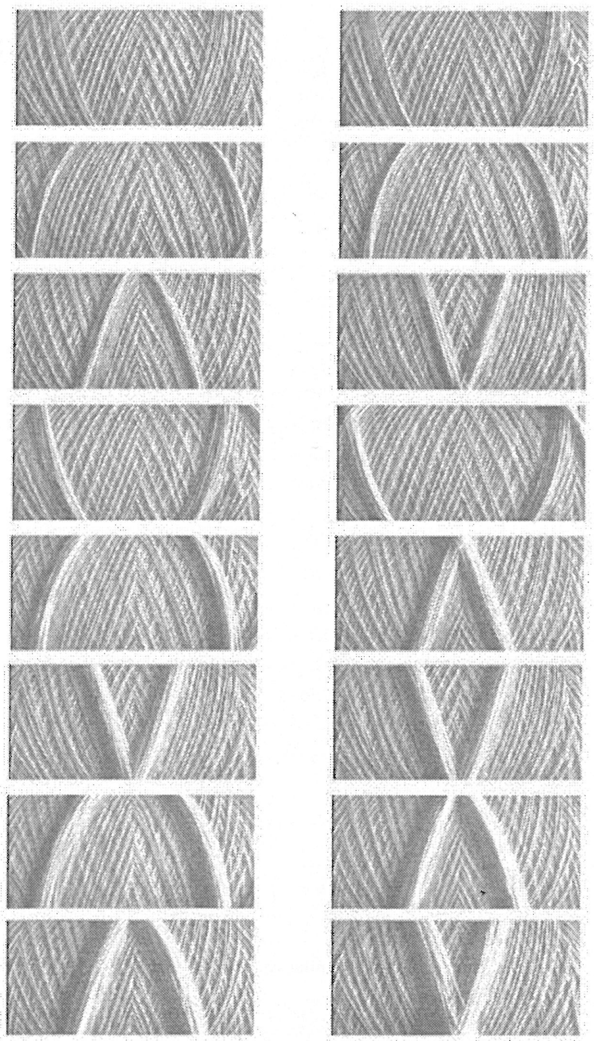

Fig. 3. Set of images taken in which the pattering concept can be observed.

In summary, it could be claimed that image processing methods have been used by many researchers in the field of textile engineering. However, using these methods to improve the quality of bobbin winding would be considered as an important pasture. So, this paper is going to introduce a novel method to detect the concept of pattering by using a simple technique, i.e. the linear mean and variance. It will be illustrated that just before and after the occurrence of pattering, a regular orientation of wound yarns, similar to the precision winding, appears on the bobbin. This concept can be considered as a sign of patterning when the machine vision system is working. So, the concepts of complete patterning and deviation from patterning could be easily determined.

II. Experimental Work

In this work, an experimental bobbin winder machine was used with the specifications of; motor power: 1.5 H.P, constant drum (k) = 5, drum diameter (D) = 8.2 cm; and drum track angle = 79 0. The bobbin rotational speed was set on 900 rpm. The anti-patterning system of the machine was manually abandoned to produce yarn bobbins with the fault of patterning. Cylindrical bobbins with the initial diameter of 5.9 cm and winding-length of 17 cm were employed to wind conventional cotton-polyester yarn (35%-65%, respectively) of 10/1 Ne (virgin color), 20/1 Ne (virgin color) and 30/1 Ne (virgin color); and 20/1 Ne (red color) on packages.

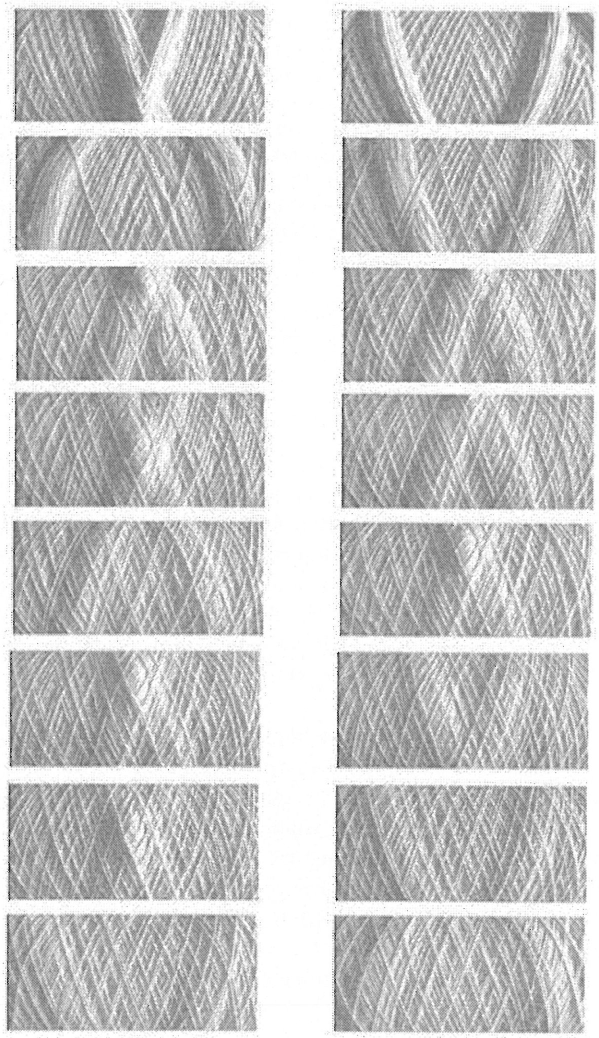

Fig. 4. Set of images taken in which the pattering concept can be observed (images 256 to 271)

A digital camera (Model CCD: Komoto Co., Ltd., Japan with clarity of 6 M. Pixel) was used for imaging. The camera transferred the images to a PC equipment through a DVR card. The DVR card included four internal terminals with transformation rate of 30 frames/second. A wide lenz (Tokina Ltd, Japan) was coupled with the camera to capture the images close to camera.

Four halogen lamps (220 volt, 50 Watt) were installed on a wooden board to illuminate the winding zoon. While the concept of imaging was performed from the face, the lightening process was done through the right-side. The configuration was derived by a set of try and error experiments, since, the best contrast of images were obtained in this case. The schematic of the lightening system has been shown in Fig. 2.

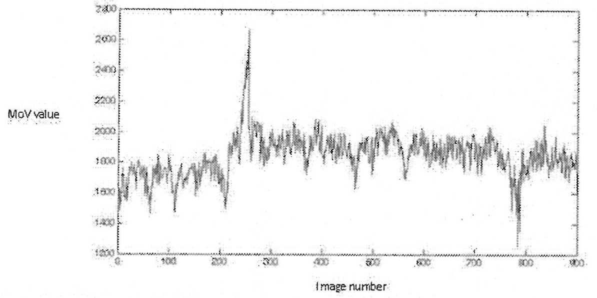

Fig. 5. MOM values calculated for sample 20/1 Ne (virgin color).

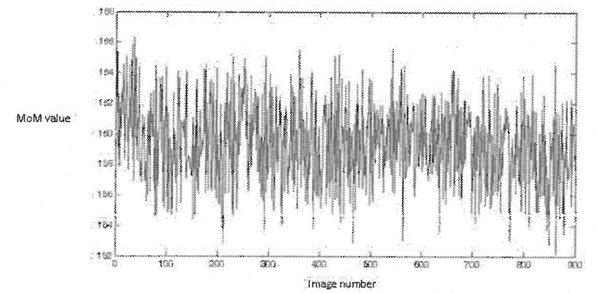

Fig. 6. MOV values calculated for sample 20/1 Ne (virgin color).

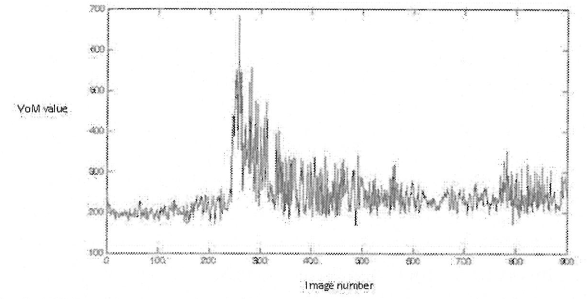

Fig. 7. VOM values calculated for sample 20/1 Ne (virgin color).

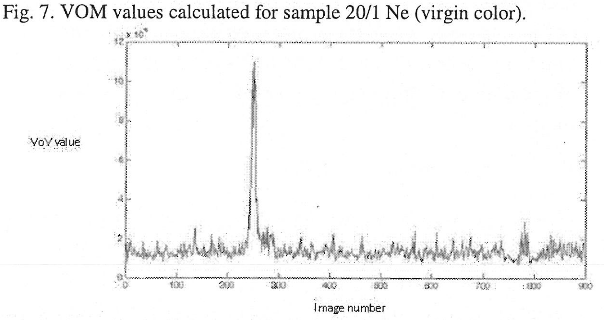

Fig. 8. VOV values calculated for sample 20/1 Ne (virgin color).

The image acquisition process was programmed with the rate of 12 photo/minute by using Matlab software. The winding process continued till 75 minutes. Therefore, during this period, 900 images were taken and consequently, 13050 meters of yarn were wound on the bobbin. Thus, a complete patterning fault occurred for the duration of image acquisition process. Next, each photo was converted into a digitalized image through Matlab software including 480 pixel rows and 640 pixel columns. In the winding process, the patterning fault occurred through the images 240 to 271. Figures 3 and 4 illustrate the set of images with different patterning.

III. Results and Discussion

A. Mathematical Modeling

At first, assume a digitalized image-matrix including n rows and m columns, $I_{n\times m}$. Consequently, $I_{n\times m}$ comprises of $n \times m$ components of image intensity values such as:

$$I_{n\times m} = \begin{bmatrix} x_{11} & \cdots & x_{1m} \\ \vdots & \cdots & \vdots \\ x_{n1} & \cdots & x_{nm} \end{bmatrix}_{n\times m} \quad (1)$$

It is clear that at ordinary conditions, i.e. during the winding process exclusion of pattering concept, the components of the matrix are approximately similar to each other. Therefore, for simplification, the $I_{n\times m}$ at ordinary condition can be rewritten as:

$$I_{n\times m} = \begin{bmatrix} x = x_{11} & \cdots & x = x_{1m} \\ \vdots & \cdots & \vdots \\ x = x_{n1} & \cdots & x = x_{nm} \end{bmatrix}_{n\times m} \quad (2)$$

At this moment, consider the $I_{n\times m}$ at and/or near the patterning concept. Clearly, an improvement in some components will occur at each column. This improvement, on the other words clarification, will repeat at all columns. For more simplification, assume that for the duration of the patterning, x will change into $\acute{x}$ only in one array of each column. The relationship between x and $\acute{x}$ can be easily formulated as:

$$\acute{x} = a \times x \quad (3)$$

Where, a is the amplification coefficient determining the contrast between patterned array and ordinary arrays at each column in the image matrix $I_{n\times m}$. Therefore, the image matrix $I_{n\times m}$ deforms into:

$$I_{n\times m} = \begin{bmatrix} x = x_{11} & \cdots & \cdots & \cdots & x = x_{1m} \\ \vdots & \cdots & \cdots & \cdots & \vdots \\ \acute{x} = a \times x & \cdots & \vdots & \vdots & \acute{x} = a \times x \\ \vdots & \cdots & \acute{x} = a \times x & \cdots & \vdots \\ & \cdots & \vdots & & \\ x = x_{n1} & \cdots & \cdots & & x = x_{nm} \end{bmatrix}_{n\times m} \quad (4)$$

So, the mean value of k'th column $\overline{x}ck$ in this case can be calculated through:

$$\overline{x}ck = \sum_{i=1}^{n} x_{ik} = \frac{(n+a-1)x}{n} \quad (5)$$

It is clear that all columns have the same mean value $\overline{x}ck$, so, the mean of mean (MOM) procedure gives the value of:

$$MOM = (\textstyle\sum_{k=1}^{m} \overline{x}ck) / m = \frac{(n+a-1)x}{n} \quad (6)$$

The variance of mean (VOM) procedure is obviously zero at this certain conditions, since:

$$VOM = var(\bar{x}ck) = var(MMC) = \left(\sum_{k=1}^{m} (MMC - \bar{x}_{ck})^2\right) / m = 0 \quad (7)$$

In matrix $I_{n\times m}$, the variance of k'th column vck can be calculated though:

$$vck = \left(\sum_{i=1}^{n} (x_{ik} - \bar{x}_{ck})^2\right) / n = \left(\sum_{i=1}^{n} \left(x_{ik} - \frac{(n+a-1)x}{n}\right)^2\right) / n \quad (8)$$

Equation (8) can be rewritten

$$vck = \frac{\left(\frac{(n+a-1)x}{n} - x\right)^2}{n} \times (n-1) + \frac{\left(\frac{(n+a-1)x}{n} - ax\right)^2}{n} \quad (9)$$

Therefore, vck will be:

$$vck = \frac{((a-1)(n-1)(n+a-na-1)x)^2}{n^3} \quad (10)$$

So, the mean of variance vector of columns can be calculated as:

$$MOV = \sum_{k=1}^{m} v_{ck} = \frac{((a-1)(n-1)(n+a-na-1)x)^2}{n^3} \quad (11)$$

Once more, it is clear that the variance of variance vector of columns (VOV) equals with zero, because:

$$VOV = var(vck) = \left(\sum_{k=1}^{m} \left(\frac{((a-1)(n-1)(n+a-na-1)x)^2}{n^3} - v_{ck}\right)^2\right) / m = 0 \quad (12)$$

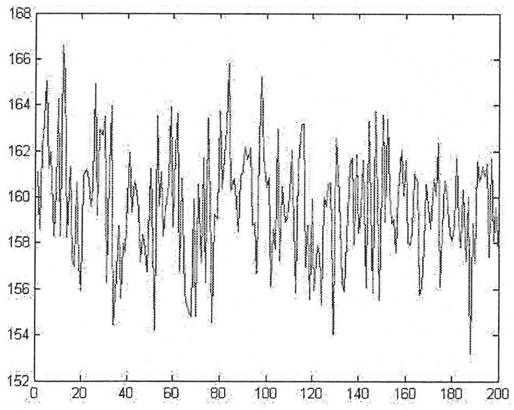

Fig. 9. MOM values calculated for sample 10/1 Ne (virgin color).

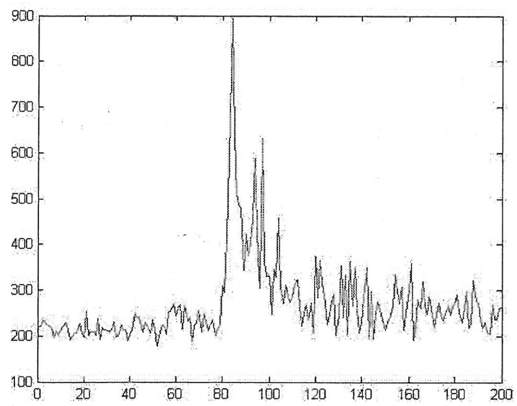

Fig. 10. MOV values calculated for sample 10/1 Ne (virgin color).

Currently, one can conclude that only MOV and MOM methods reflect considerable values from image matrix $I_{n\times m}$ compared to VOV and VOM. Accordingly, the main question is that which method, MOV and/or MOM, does theoretically perform superior? To answer this question, MOV and MOM parametric values should be evaluated against each other. Further calculations illustrate that MVC value will be greater than MMC value if:

$$a > \frac{\frac{2(n-1)x}{n} + 1 + \sqrt{4(n-1)\frac{(n-1)x}{n} + 4\frac{(n-1)x}{n} + 1}}{\frac{2(n-1)x}{n}} \quad (13)$$

As a result, Equation (13) gives a minimum parametric value for the amplification coefficient "a". The above equation states that MOV method can perform superior than MOM procedure whereas the amplification coefficient "a" improves to a certain value of "$\frac{\frac{2(n-1)x}{n} + 1 + \sqrt{4(n-1)\frac{(n-1)x}{n} + 4\frac{(n-1)x}{n} + 1}}{\frac{2(n-1)x}{n}}$". It is clear that in the case of random winding, the amplification coefficient "a" improves considerably during the winding process and exceeds to the maximum value at the beginning of the patterning. Obviously, this improvement occurs at all image columns, but in certain arrays at each column. Matrix "I" presents an example of image matrix I during the patterning:

$$I_{6\times 6} = \begin{bmatrix} x & x & x & x & x & a.x \\ x & x & x & x & a.x & x \\ x & x & x & a.x & x & x \\ x & x & a.x & x & x & x \\ x & a.x & x & x & x & x \\ a.x & x & x & x & x & x \end{bmatrix}_{6\times 6}$$

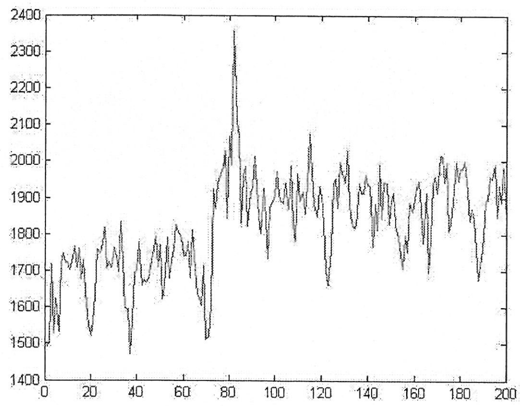

Fig. 11. VOM values calculated for sample 10/1 Ne (virgin color).

The arrays comprised of "a.x" value represent the points in which pattering has occurred on the bobbin. Therefore, the MOV method performs better compared to other introduced methods, i.e. MOM, VOV and VOM to recognize patterning. So, everybody can understand that defects repeat regularly at each column of any image, like pattering concept, should be recognized through the mean of variance technique compared to the three mentioned methods.

B. Fitness Evaluation of Results

Figures 5 to 8 show the results of different analyzing techniques including mean of variance (MOV), mean of mean (MOM), variance of mean; (VOM) and variance of variance (VOV) applied on the images taken from sample 20/1 Ne (virgin color). As it can be seen, the results show that among the four methods, the mean of variance (MOV) is more accurate. Since, a peak can be perceived in the place of patterning defect. By finding this peak, the moment of occurrence of defect may be diagnosed, and consequently, the "patterning" will be recognized. In the following, this outcome is mathematically analyzed.

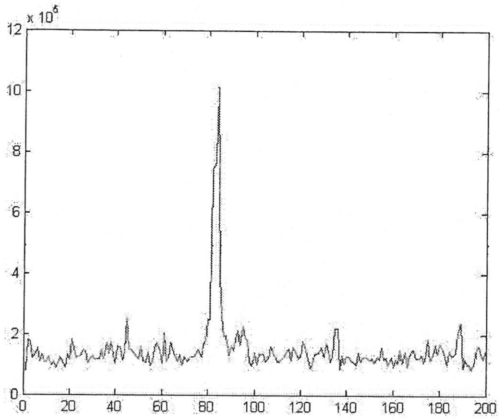

Fig. 12. VOV values calculated for sample 10/1 Ne (virgin color).

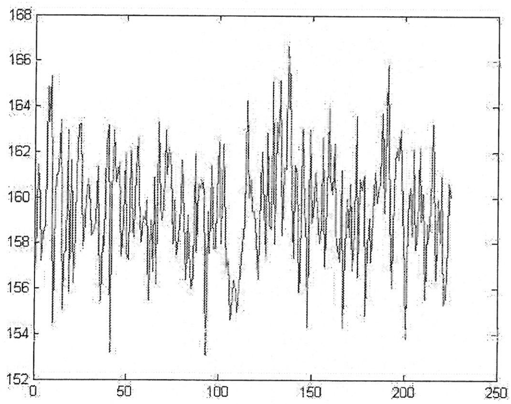

Fig. 13. MOM values calculated for sample 20/1 Ne (red color).

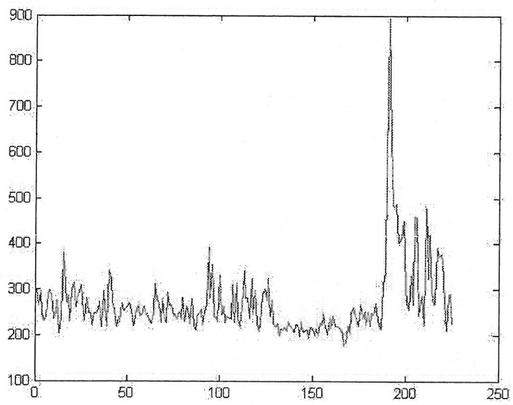

Fig. 14. MOV values calculated for sample 20/1 Ne (red color).

In addition, Figs. 9 to 20 illustrate the results of MOV, MOM, VOM and VOV techniques performed on samples 10/1 Ne (virgin color), 20/1 Ne (red color) and 30/1 Ne (virgin color). It is also clear that the MOV method dedicates the best identifying peak results.

It is important to know that when patterning occurs, the light intensity will increase in image matrix. However, the shadow made by patterning causes to decrease light intensity in other part of image matrix. So, the whole intensity may not change within the image matrix. In this way, Otsu algorithm [14] was used in pre-processing operations based on local filter. Therefore non homogeneity of lighting through width of image was solved easily.

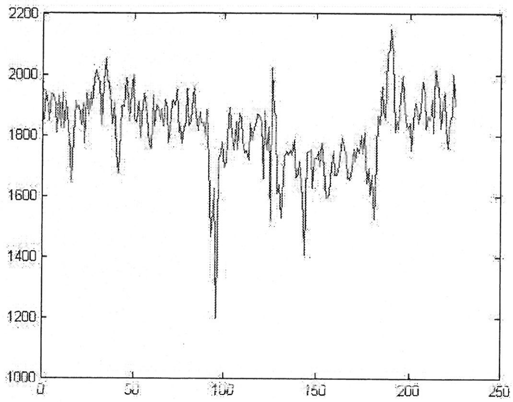

Fig. 15. VOM values calculated for sample 20/1 Ne (red color).

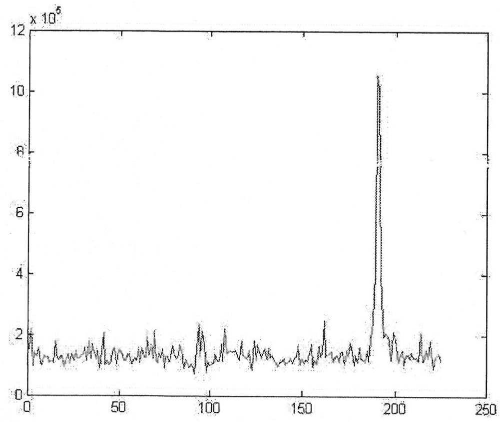

Fig. 16. VOV values calculated for sample 20/1 Ne (red color).

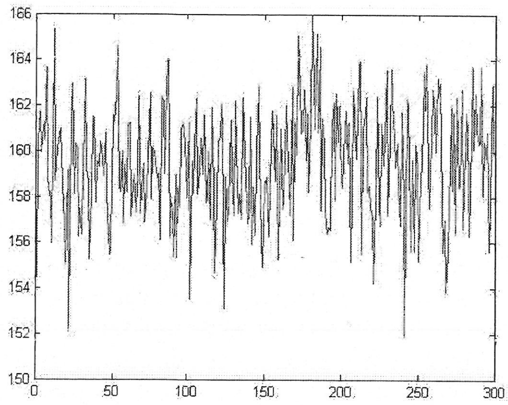

Fig. 17. MOM values calculated for sample 30/1 Ne (white color).

IV. Conclusion

The main aim of this research was using online-computer-vision technique to recognize the concept of patterning during random cone winding system. Consequently, photographs of bobbin surface were continuously taken with specified time interval. After that, a bi-dimensional matrix was obtained for any picture by digitalization process. The simple linear mean and variance technique was chosen for image processing. So, four simple algorithms including Mean of Mean (MOM), Variance of Mean (VOM), Mean of Variance (MOV) and Variance of Mean (VOM) were employed to recognize the patterning concept and consequently to active the anti-patterning system. At final, through the experimental investigations and running the four algorithms, it was illustrated that the MOV method performs more accurately compared to the three mentioned methods. The correctness of this concept was mathematically analyzed.

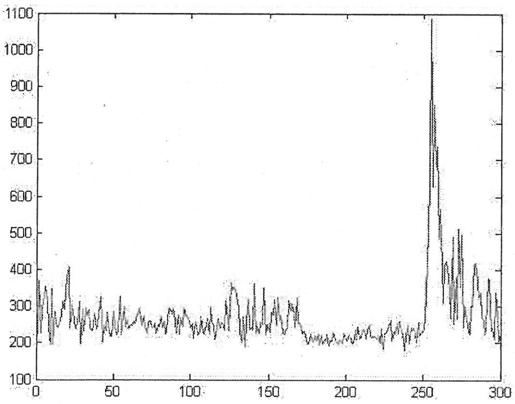

Fig. 18. MOV values calculated for sample 30/1 Ne (virgin color).

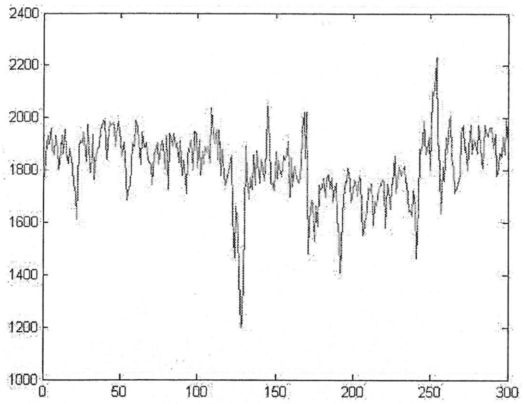

Fig. 19. VOM values calculated for sample 30/1 Ne (virgin color).

Consequently, as the patterning occurs, the system will alarm. By this technique, the anti-patterning system does not necessarily need to work sequentially and it should become active just at the time the system alarms. Therefore, the yarn clearing unit works appropriately all the time.

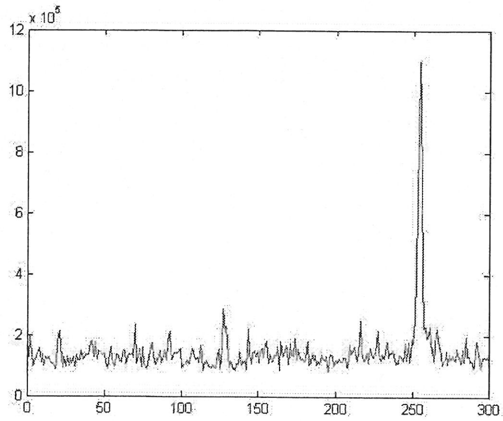

Fig. 20. VOV values calculated for sample 30/1 Ne (virgin color).

References

[1] G. Durur and P. Bandara, "Active ribbon breaking in random winding of yarn packages", *Mechatronics*, vol. 12, no. 9-10, pp. 1225-1238, 2002.

[2] G. Osawa and T. Koyama, "On the slippage between yarn-package and grooved drum during winding", *J. Text. Mach. Soc. Japan*, vol. 25, pp. 113-123, 1972.

[3] C. Castellini, F. Francini, G. Longebardi, B. Tribilli and P. Sansoni, "On-line textile quality control using optical Fourier transforms", *Opt. Lasers Eng.*, vol. 24, no. 1, pp. 19-32, 1966.

[4] A. Cay, S. Vassiliadis, M. Rangoussi and I. Tarakçoghlu, "On the use of image processing techniques for the estimation of the porosity of textile fabrics", *World Acad. Sci. Eng. Tech.*, vol. 1, no. 2, pp. 76-79, 2007.

[5] M. Cybulska, "Assessing yarn structure with image analysis methods1", *Text. Res. J.*, vol. 69, no. 5, pp. 369-373, 1999.

[6] R. Drobina and S. Machnio, "Application of the image analysis technique for textile identification", *AUTEX Res. J.*, vol. 6, no. 1, pp. 40-48, 2006.

[7] J. Masajtis, "Thread image processing in the estimation of repetition of yarn structure", *Fibres Text. East. Eur.*, vol. 10, no. 3, pp. 68-72, 1997.

[8] H. Aydilek, H. Oguz and B. Edil, "Digital image analysis to determine pore opening size distribution of nonwoven geotextiles", *J. Comput. Civ. Eng.*, vol. 16, no. 4, pp. 280-290, 2002.

[9] S. R. Palmer and X. Wang, "Objective Assessment of Pilling of Knitted and Nonwoven Fabrics Using the Two Dimensional Discrete Wavelet Ttransform", in *Studies in Computational Intelligence*, vol. 55, J. Kacprzyk Ed. Springer, 2007, pp. 23–37.

[10] K. Bahl and S. Kainth, "Evaluation of yarn quality in fabric using image processing techniques", *Int. J. Sci. Res.*, vol. 3, pp. 558-561, 2014.

[11] J. Patel, M. Jain and P. Dutta, "Location of defects in fabrics using feature extraction technique", *Int. J. Res. Manage.*, vol. 5, no. 3, pp. 128-135, 2013.

[12] M. Ghane, M. Karbalaei, D. Semnani and M. Sheikhzadeh, "Investigation of fly generation during cone-winding using the image processing technique", *Fibres Text. East. Eur.*, vol. 20, no. 6, pp. 58-62, 2012.

[13] M. Sheikhzadeh, D. Semnani, Z. Eslamian and M. Darvishzadeh, "Determination of yarn position on cone surface of random cone winding system", *Indian J. Fib. Tex. Res.*, vol. 33, pp. 181-184, 2008.

[14] J. Vala and A. Baxi, "A Review on Otsu image segmentation algorithm", *Int. J. Adv. Res. Comp. Eng. Tech.*, vol. 2, no. 2, pp. 387-389, 2013.