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Short Communications

Measuring the roughness of knitted fabrics by analysis of surface signals obtained from image processing

Hossein Hasani[a] & Sanaz Behtaz
Textile Engineering Department,
Isfahan University of Technology, Isfahan, 84166-83111, Iran

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The present study focuses on the evaluation of weft knitted fabric roughness using image processing. Various knitted fabric samples have been produced using flat and circular knitting machines. The SMD value of fabrics which refers to surface roughness has been measured by Kawabata surface tester. Images of samples have been taken by a high resolution scanner, converted to grayscale image and then been processed by Matlab; a signal is obtained from each sample. Six different features have been extracted from the signals. The results of correlation test reveal that there is a good correlation between the wave lengths of obtained signal extracted from fabric images and the measured roughness by KES surface tester.

Keywords: Image processing, Kawabata method, Knitted fabric, Roughness

The roughness of fabrics is important for garments which touch the human skin. It influences the handle of fabric and plays an important role in end-use of fabrics. For many years, subjective methods such as real human fingertips or the back of the hand has been used to determine the fabric roughness.

Many instruments such as Kawabata evaluation system (KES-FB) have been developed to measure fabric surface properties objectively[1]. Because KES is time-consuming method and the translation of the output data is difficult, simpler methods such as the extraction and sled method[2-5] have been applied. As the contact-type measurements are more easily affected by environmental conditions such as moisture and need more measurement time than non-contact methods, they are not suitable for an online, real-time detection system in the manufacturing process. Thus, a considerable amount of work has been done[6-9] by many researchers to precisely evaluate fabric surface roughness by image processing.

Kim and Kang[10] extracted the fractal dimension to describe the degree of fabric surface roughness from three-dimensional (3-D) surface data using a laser scanning method or stereo vision technique. Sul ***et al*** [6] measured surface profile data of nonwovens using a 3-D scanning camera and evaluated the surface roughness with fractal dimensions. Kang ***et al***.[7] proposed a wavelet-fractal method to calculate the fractal dimension to objectively evaluate the surface roughness of fabric wrinkle, smoothness appearance and seam pucker. In the previous investigation[11], we evaluated the knitted fabrics roughness by obtaining the surface profile of the fabrics. The scanned surfaces were compared to the ideal surface, and the differences between the ideal and actual surfaces were measured.

In present work, the fabric roughness is evaluated by a new method. Images captured from fabric surface have been processed by Matlab and a signal was obtained from each sample. Six different features were extracted from the signals and the correlation between extracted features and roughness index measured by Kawabata method was studied.

Cotton yarns (Nm 70/3) were used to knit three structures, namely rib 1×1, full-cardigan and milano-rib on an E 12 electronic flat knitting machine (Stoll CMS 330.6). The fabrics from the knitting machine were air dried for 48 h under the standard conditions (20°C, 60 % RH), and then treated to seven cycles of mechanical relaxation using repeated washing and tumble dryings. The fabric was washed for 75 min at 60°C in a revolving drum washing machine (Mile Co.) with 1% detergent (Persil). After the final spin cycle, the samples were tumbling dried for 57 min.

Cotton yarns (Nm 50) spun with 750 tpm by a conventional ring-spinning machine were used to knit a plain single jersey, a double cross tucks and a double cross miss, using a single jersey circular knitting machine (Mayer & Cie, E 28, 30 inch diameter). Then the fabrics were bleached and dried.

Cotton and viscose yarns with different linear densities spun with a conventional ring-spinning machine were used to knit rib 1×1 and interlock fabric, using a single jersey circular knitting machine (Mayer & Cie, E 18, 30 inch diameter). The fabrics

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[a] Corresponding author.
E-mail: h_hasani@cc.iut.ac.ir

were bleached and dried. The specifications of the knitted fabrics are shown in Table 1.

The SMD values of the fabric samples were measured by KES-FB4 instruments. The measurement was made twice for each of the three separate samples cut from the centre of the knitted fabrics, and finally six resulting values were averaged. Standard size samples of 200 mm × 200 mm were tested in the wale and course directions. Because anisotropy is a consideration in knitted fabrics, the surface roughness was measured in both the course and wale directions. Averages of the wale and course measurements were calculated for further analysis. The specimen preparation, pre-conditioning and testing involve standard atmospheric conditions, of 20 ± 2 °C temperature and 65 ± 2% relative humidity.

Geometry of technical face and technical back of some fabrics, especially single jersey knitted fabrics, is not the same. Therefore, for single jersey structures and Milano-rib the SMD values of both technical back and face were measured.

Knitted fabrics were scanned at a resolution of 600 DPI using a scanner, and a black layer was pasted on the scanner as a background of the images. The image area captured was constrained to a size of 10 cm × 10 cm and saved as jpeg format. The back layer is white for dark specimens; therefore those images should be converted to a reverse image before further image processing. The RGB images are transferred into grey level images. The intensity of an image refers to a two-dimensional light intensity function, denoted by f(x,y). The elements in the intensity matrix present various intensities, or gray levels, where the intensity 0 represents black and the intensity 255 represents white. Figure 1 shows the original image and converted grey image. In these images, the bright zones show sparse parts of the fabric layer, and dark zones show dense parts of the layer. In order to simplify the mathematical operations, the grey images were converted to double precision.

For analysis of images, a program in MATLAB has been created. The aim of this program is to find a relationship between brightness of each point on the images and roghness of the fabric surface. The width of mechanical sensor applied to sense the fabric surface in Kawabata surface tester is 1 cm, which has been simulated from skin of a human finger.

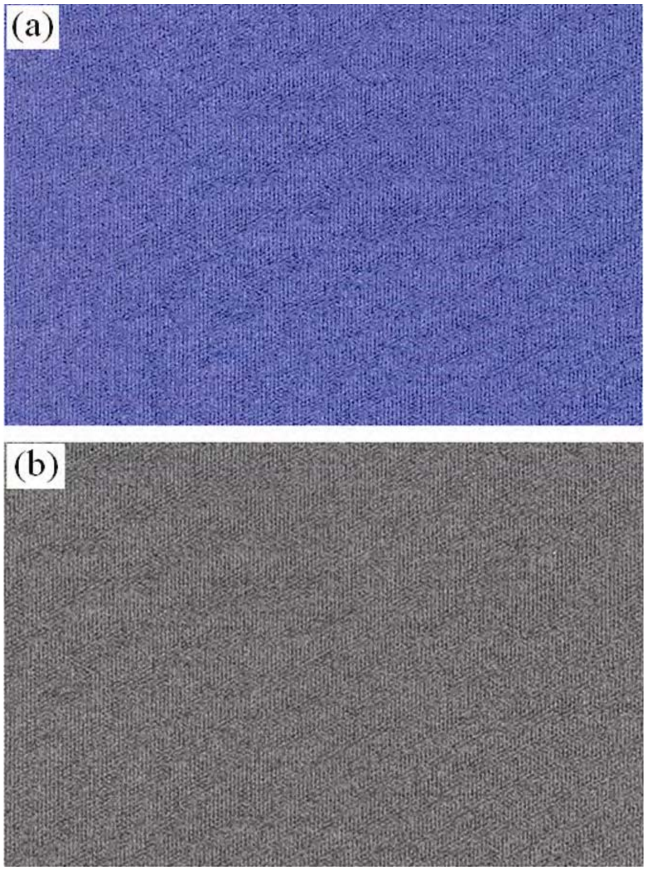

Fig. 1—(a) Original image and (b) processed image

Table 1—Knitted fabrics and their specifications

Sample code	Yarn property	Fabric structure	Loop /cm^2	Weight, g/m^2
DCM	Cotton, Ring, Nm50	Double cross miss	145	141
DCT	Cotton, Ring, Nm50	Double cross tuck	208	196
PSJ-1	Cotton, Ring, Nm50	Plain single jersey	285	168
PSJ-2	Cotton, Ring, Nm50	Plain single jersey	195	149
PRV	Viscose, Ring, Nm 68	Plain rib	60	161
INT-1	Cotton, Ring, Ne30	Interlock	268	175
INT-2	Cotton, Ring, Ne24	Interlock	254	220
FC-F	Cotton, Compact, Nm 70/3	Full cardigan	314	284
MR-F	Cotton, Ring, Nm 70/3	Milano rib	312	450
PR-F	Cotton, Open-end, Nm 70/3	Plain rib	314	241.8

Therefore, the images were divided into different slices with 1 cm width in course and wale direction. The program calculated the sum of brightness data of each cut slice.

If the brightness data of each cut slice is a matrix, sum of each column of this matrix returns a row vector, which forms a signal. In this way, the signals of each slice will be obtained. Figure 2 shows two samples of obtained signal which have been resulted from two different fabric structures. Averaging these signals results the mean signal of each slice. This signal is called as standard signal. Six features were extracted from the standard signal, as shown below:

(i) P_1 — Mean of standard signal data;

(ii) P_2 — Standard deviation of each signal;

(iii) P_3 — Distance between maximum and minimum of standard signal data;

(iv) P_4 — Signal energy which is defined as sum of square of standard signal data;

(v) P_5 — This parameter can be calculated by following formula:

$$\boldsymbol{P}_5 = \frac{\sum |\boldsymbol{r} - \boldsymbol{m}|}{\boldsymbol{l}}$$

where $\boldsymbol{r}$ is the standard signal data; $\boldsymbol{m}$, the mean of standard signal data; and $\boldsymbol{l}$, the standard signal length;

(vi) P_6 — In order to calculate this feature, length of each standard signal was divided to 5 sections. In each section, the mean of distance between sequential peaks and valleys of signal was calculated, where a peak is defined as a point at which domain is higher than those of its neighbourhood points, and valley is a point at which domain is lower than those of its neighbourhood points. The feature is the mean of distance calculated from all sections.

The roughness of knitted fabric depends on many factors which can be clustered into material and structural factors groups. The effect of the material

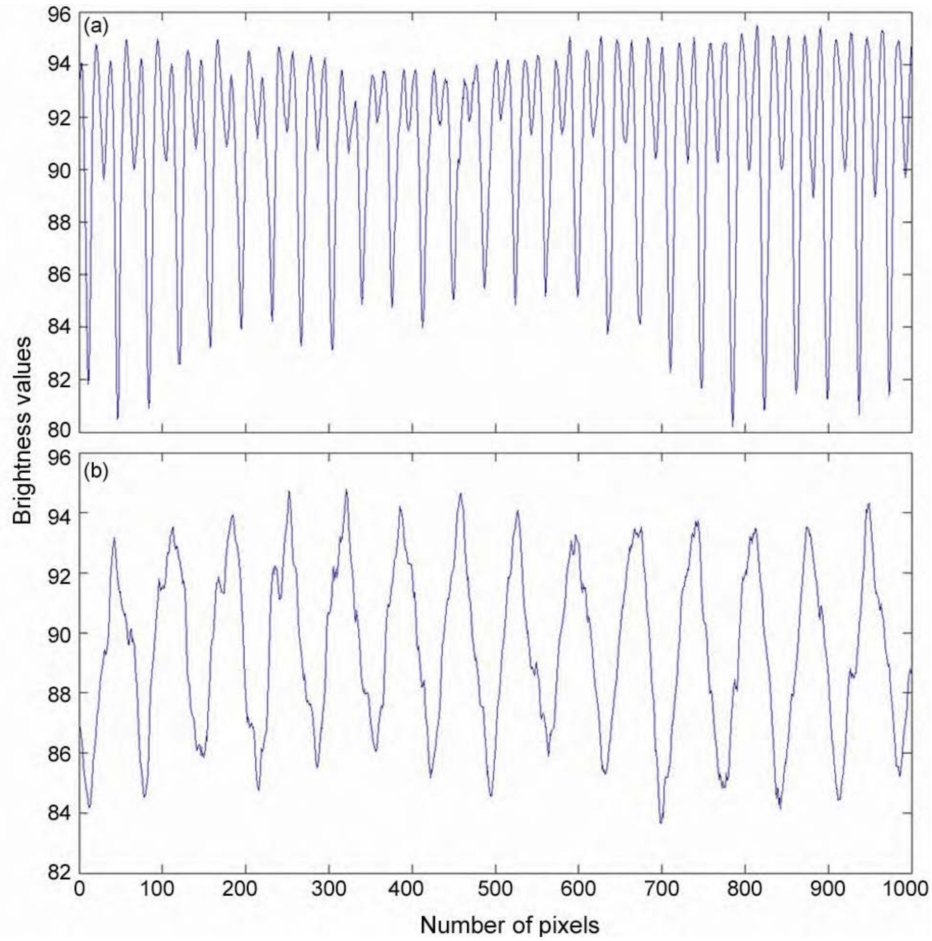

Fig. 2—Signal obtained from a slice of image captured form two different knitted fabrics (a) sample PSJ-1 (b) sample FC-F

Table 2—Six features extracted from the signal

Sample	P_1	P_2	P_3	P_4	P_5	P_6
DCM-Back	89.41	2.76	12.00	6.36	7.99	1.90
DCM-Face	82.89	1.44	7.76	6.18	6.87	1.12
DCT-Back	89.33	0.66	18.57	1.85	7.98	0.56
DCT-Face	84.86	1.60	6.25	4.28	7.82	1.25
FC- Face	89.49	2.69	37.20	5.57	8.01	2.45
MR- Face	94.57	1.85	13.91	3.62	8.94	1.24
P13-Face	89.27	1.09	10.23	3.41	7.97	0.86
P13-Back	87.41	1.20	9.23	3.58	7.64	0.96
P15-Back	91.09	0.67	12.76	1.65	8.29	0.56
P15-Face	88.88	0.83	5.76	2.40	7.89	0.64
RIB-F	90.91	3.36	9.04	7.61	8.27	2.82
RV	45.40	1.33	11.81	3.91	2.06	1.05
INT-2	74.96	0.69	2.04	2.13	5.62	0.54
INT-1	91.92	1.00	5.38	2.89	8.45	0.81

Table 3—Correlation coefficients of different parameters

Parameter	SMD value
P_1	
Pearson Correlation	0.303
Sig. (2-tailed)	0.293
P_2	
Pearson Correlation	0.515
Sig. (2-tailed)	0.060
P_3	
Pearson Correlation	0.843^{**}
Sig. (2-tailed)	0.000
P_4	
Pearson Correlation	0.288
Sig. (2-tailed)	0.319
P_5	
Pearson Correlation	0.310
Sig. (2-tailed)	0.281
P_6	
Pearson Correlation	0.600^{*}
Sig. (2-tailed)	0.023

* Significant at 0.05 level (2-tailed).

** Significant at 0.01 level (2-tailed).

Table 4—Output of roughness algorithm after ten repeated scans and calculations

No. of scans	Sample FC-F	Sample INT-2	Sample MR-F
1	37.2	2.0480	13.9167
2	37.2	3.3747	13.5143
3	38.7	3.5803	14.8000
4	39.2	2.2647	13.2714
5	38.4	3.7117	12.1400
6	37.7	1.9891	11.6500
7	34.8	2.1765	13.8765
8	37.6	2.0639	13.6113
9	36.8	2.0950	14.0167
10	37.9	2.6481	13.7210

on surface features is mainly due to the yarn type, which includes yarn count, fibre formation, yarn twist and fibre migration. The structural effect can be considered with certain dimensional parameters of fabric, such as stitch density, loop length and thickness of fabric. Table 2 shows the six features extracted from the signal.

In order to investigate the correlation between the six features extracted by image processing and SMD values measured by the Kawabata method, a regression analysis was carried out using SPSS statistical software. The correlation coefficients calculated in accordance to Pearson analysis are shown in Table 3. The findings show that there is a high correlation (0.843) at the 95% confidence level between SMD values measured by Kawabata method and P_3 value calculated by image processing. The positive correlation between these two parameters means that the more the P_3 values, the more is SMD value as well as roughness of fabric. Also, there is significant correlation between P_6 and SMD values.

Ten pictures of full-cardigan (FC-F), interlock (INT-2) and Milano-rib (MR-F) were evaluated using the t-test hypothesis to ensure the reality and repeatability of the image processing method. The t-value is calculated from Table 4. The SPSS statistical software was applied to the data measured. Results of the statistical analysis are shown in Table 5. This Table shows that the image processing method results the same output for three selected sample and there is no significant difference between outputs resulted after repeating the calculation.

Table 5—Results of statistical t-test for three different samples

Sample code	Statistical outputs				95% Confidence interval of the difference	
	t	Df	Sig. (2-tailed)	Mean difference	Lower	Upper
FC-F	97.735	9	.000	37.55000	36.6809	38.4191
INT2	11.857	9	.000	2.59520	2.1001	3.0903
MR-F	46.185	9	.000	13.45179	12.7929	14.1107

Hence, it can be concluded that the image processing method can measure the roughness index of different knitted fabrics correctly.

A high resolution scanner was used to evaluate the surface roughness of weft knitted fabrics. Six features were extracted from the mean signal obtained from image analysis. These parameters were compared with SMD values measured by the Kawabata method. Among these parameters, features P_3 which is named as the distance between maximum and minimum of standard signal data has a high correlation with SMD values. Therefore, the proposed method is an effective way to evaluate the fabric roughness. Finally, the non-contact measurement of fabric roughness using a high resolution scanner is useful for the description of fabric roughness.

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