Seyed Abbas Mirjalili, Esfandiar Ekhtiyari

Textile Engineering Department
Yazd University,
Yazd, Iran,
E-mail: amirjalili@yazduni.ac.ir

Wrinkle Assessment of Fabric Using Image Processing

Abstract
The light profile method using image processing is a suitable technique for the assessment and analysis of fabric wrinkle. In this method the colour and fabric pattern have no effects on the results. The heights of the light profiles created by fabric wrinkles are considered as the most important factor in this study. The standard deviation, mean deviations and mean heights of the light profile on the fabric surface are other factors used in this work. The results indicated that mean deviations is the most accurate method of assessing fabric wrinkle. At the same time the results showed good agreement with the assessments of experts in the field.

Key words: *fabric wrinkle, image processing.*

Introduction

The appearance of a garment and its care characteristics during wearing or after frequent washing will produce an uneven surface on the cloth, which is not desired. This uneven area on the garment surface is known as wrinkle, which is extremely important for people and customers. Wrinkle assessment can be traditionally made by experts who sometimes have different assessments, which are affected by their own judgment, vision ability, etc. In this method the wrinkle of the fabric is compared with a specific standard of people individually. Therefore the results are mainly dependent on personal views [1 - 4].

A lot of works concerning the drape behaviour of fabrics, seam puckering, wrinkles and pilling have been carried out by image processing systems [5].

In the recent years, some new methods of assessment have been introduced. The advantage of these methods is their nondependency on the vision ability of the people assessing the wrinkle [6 - 7]. In fact, fabric wrinkle is assessed by image and signal processing based on the Fast Fourier Transform (FFT). However, FFT is used for static, not dynamic, signals. Another method is the evaluation of the picture of the fabric surface under light reflection. However, this method is not useful for colourful and printed fabrics since analysis in this way is dependent on the light source, the colour and pattern of the print used on the fabric surface, and on the reflection properties of the fabrics [8].

The method involving a 3D-projecting grid technique based on image processing was applied by Kang et al. to evaluate fabric wrinkles [9]. They calculated the roughness ratio of the fabric samples using the root mean square method.
Yeung, Li, Zhang and Yao [10] developed a method to evaluate fabric bagging from captured images of bagged fabrics using image processing and abstracting the criteria to recognize the bagging magnitude. To characterise the image features: the bagging heights, volume, shape and fabric surface pattern on the bagging image, they extracted eight criteria on the basis of intensity images.

Abril et al. proposed a method of fabric surface imaging and processing so that information about wrinkles can be extracted and evaluated [11]. Two images of the sample obtained under orthogonal lateral illumination were considered, and a joint Canny edge detector was applied to integrate the information about the wrinkles of both images. The smoothed and scaled perception of wrinkle edges from the viewing distance and its influence on the evaluation of the fabric appearance were simulated, analysed and a more realistic assessment of a fabric was proposed.

In his research work, Naujokaitytė et al. [12] used an image analysis method in combination with a bias extension test for characterisation of the specimen's buckling point and surface irregularity changes during uni-axial extension. Buckling point dependence on the stiffener concentration was recorded. Shear angle values were obtained by an optical method dependent on the load and extension.

Recently a novel method has been introduced to quantify geomembrane wrinkles using low-altitude aerial digital photography and image processing techniques. The results of the analysis indicate that at the date and time the aerial image was captured, the geomembrane contained 100 major wrinkles covering 13.9% of the total area of the geomembrane exposed. More importantly, from a potential leakage perspective, over 90% of those wrinkles were found to be hydraulically connected over the entire field of vision of the geomembrane exposed. The hydraulically connected wrinkle was found to have an aggregate length of 520 m [13].

Some research workers have used the fractal method for laser measurment [14]. In this method a laser scan is used to scan the surface of the fabric in 3-D. In order to determine the fractal dimension, the method of cubic counting is applied.

As regards the problems mentioned, we used a new method for the wrinkle assessment of fabric based on image processing and wrinkle grade.

Methods and equipment

Measurement of fabric wrinkle

Projecting a thin light ray on the fabric is a suitable and accurate method to make

Mirjalili S. A., Ekhtiyari E.; Wrinkle Assessment of Fabric Using Image Processing.
FIBRES & TEXTILES in Eastern Europe 2010, Vol. 18, No. 5 (82) pp. 60-63.

possible the taking of a clear picture of the sample. The equipment used for this assessment is illustrated in ***Figure 1***. As can be seen, the set-up consists of a PC, light source, CCD camera (model TM 9701) and a moving platform to move the fabric sample under the light source. The illumination of the light was 1:19, provided by a lighting unit with a DC tungsten-halogen lamp with a zoom lens. The resolution of the camera used in this work is 280 × 300 pixels. The movement of the sample and its speed can be controlled through the software of the equipment. The width of the light slit is about 0.7 mm, and its length is bigger than the width of the fabric sample. The moving platform moves the sample in one direction, 2 mm for each picture taken from the light profile. The light is projected on the sample, placed in a dark chamber, and a picture is taken of the surface of the fabric. The number of pictures can be adjusted through the software. The angles of the light source and camera relative to the sample are adjustable, although the angles desired for these are 50 and 40 degrees, respectively, as applied by previous researchers [15].

Before the sample fabric is wrinkled, its light profile is a direct line, but when it is subject to wrinkling, its light profile will consist of a series of curved lines, as can be seen from ***Figure 2***. The difference between the two lines determines the degree of wrinkling. ***Table 1*** gives the specifications of the fabrics used.

The height of a point on the sample, Z_i, is calculated from the digital picture. The light profile is converted into a binary in the next stage, and a line is passed in the middle of the profile so that we will have a thinner profile, as seen in ***Figure 3***. These operations are a part of image processing, which will be explained in the next section. Scanning the length of the sample, the number of profiles for each sample is 52. The software was written in VC++, which processes and evaluates the wrinkle of the fabric as a grade [16].

In order to compare the results with visual assessment results from experts and find a relationship between the two methods, eight different samples of 280mm×150mm were prepared according to the AATCC standard. The samples were put in the wrinkle device for 2 hours. Then the degree of wrinkle of the samples was determined manually and using the computerised equipment.

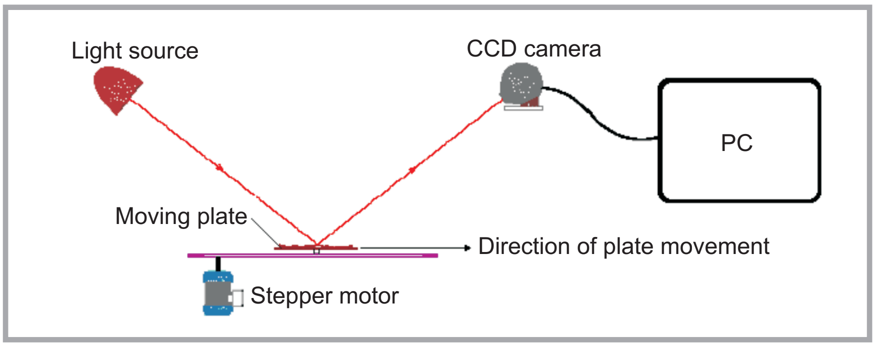

Figure 1. *Set-up of measuring fabric wrinkle.*

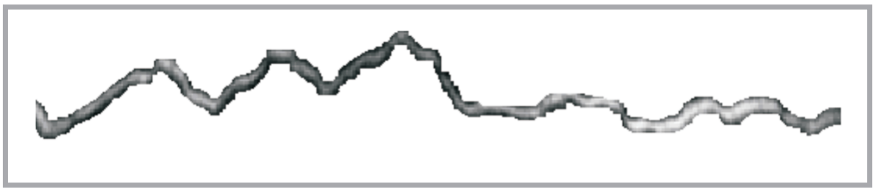

Figure 2. *Picture of a light profile taken from the surface of wrinkled fabric.*

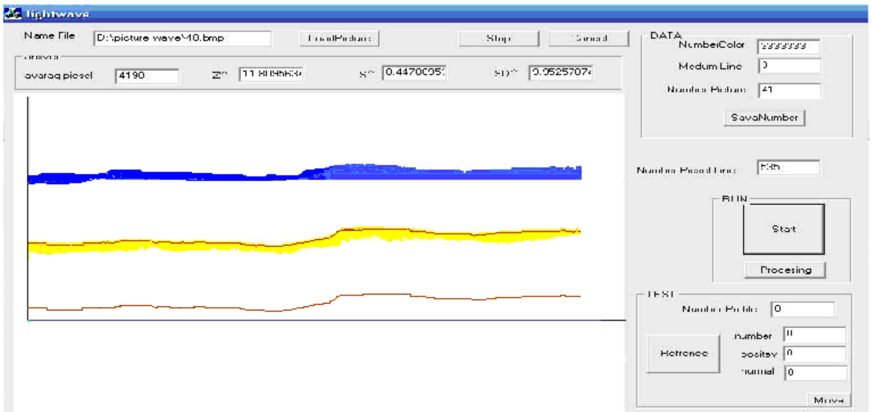

Figure 3. *Process of binary, filtration and passing the line in the middle of the light profile.*

Table 1. *Specifications of fabrics used.*

Sample No.	1	2	3	4	5	6	7	8
Material	PET	C/PET	C	Nylon	Jean	W/Trevira	Jean	Viscose
Pattern	Plain	Plain	Plain	Plain	Twill	Plain	Plain	Plain
w.p.c	24	32	29	29	44	23	20	28
p.p.c	20	23	28	29	22	20	17	28
Colour	White	Brown	White	White	White	Brown	Black	White

Filtering

Due to some noises in the pictures taken, it is necessary to eliminate them from the digital images. This can be done in two methods using software and hardware (special filters). As can be observed from ***Figure 2*** and the top of ***Figure 3***, the light profile is not a thin line and should be filtered to obtain a clear and thin line. Therefore the profile is filtered using software.

Wrinkle quantization

As mentioned earlier, the wrinkle of a fabric is expressed as a grade, which is the quality factor of the fabric or garment. In this study, we determine and evaluate the fabric wrinkle using three factors: standard deviation, mean deviation and the mean heights of the points on the profiles.

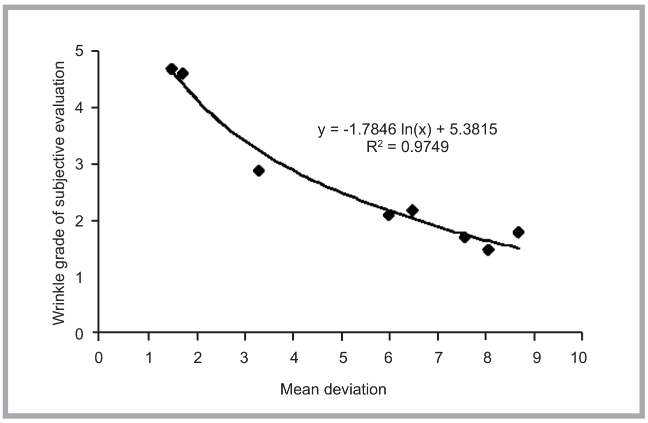

Figure 4. *Regression graph of the mean deviation and degree of wrinkle evaluated by experts.*

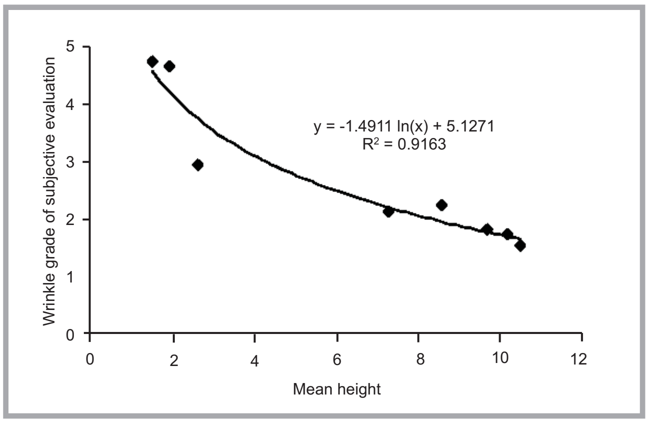

Figure 5. *Regression graph of the mean height degree of wrinkle evaluated by experts.*

Mean height

To determine this factor, a light profile is considered. The function of the height at different locations of the profile is defined as $Z = f(x,y)$. Where $f(x,y)$ is a function determining the intensity of the light at each position (x,y) on the image. Its average for absolute values, $|\overline{Z}|$, can be calculated from (1):

$$|\overline{Z}| = \frac{\left|\sum_{j=1}^{m}\sum_{i=1}^{n} z_{i,j}\right|}{m \times n} \quad (1)$$

Where $|\overline{Z}|$, is the mean of heights for each light profile, $z_{i,j}$ the height of each point, n the number of pictures taken and m is the number of pixels on the Y axis relevant to the curve of the light slit. For a fabric with less wrinkle or smooth surface, the amount of $|\overline{Z}|$ is small; it is larger for fabrics with more wrinkle.

Standard deviation

To investigate this quantity, a curve of the light profile on a fabric surface is considered. As mentioned earlier, the function of the height of different points on the profile is defined as $Z = f(x,y)$, and the amount of standard deviation, Z_{sd}, is obtained from Equation 2.

Where the first term of this equation is relevant to the values of the wrinkled fabric, whereas the second term of this equation is for the original fabric, which has not been wrinkled. Fabrics with a lower amount of wrinkle have a lower amount of standard deviation and vice versa.

Mean deviation

This value, denoted as Z_{md}, is the average of low and high points at different locations on the fabric surface, which is calculated from Equation 3.

Where the first term of this formula is relevant to the mean deviations of optical profiles reflected on the wrinkled fabric, whereas the second term of the formula is related to the original fabric before becoming wrinkled.

This value is low for fabrics with less wrinkle and higher for fabrics with more wrinkle.

Results and discussions

The results obtained from the mean deviation indicate that this function is not entirely suitable for the wrinkle assessment of fabric, since this function does not follow a normal trend. When the unevenness of the fabric is considered visually, the heights and distances are quadratic. Therefore this function cannot be a reasonable method for wrinkle assessment. ***Figure 4*** shows a comparison of the mean deviation of 8 samples, the results of which were obtained from the judgment of experts .

As can be observed from this curve, the correlation between the two methods is about 97%; the correlation is higher for larger mean deviations.

Figure 5 also illustrates a comparison of the function of mean heights from the judgment of experts for this purpose. However, the correlation between these values is less than in the previous case, being about 92%.

It was attempted to find out if there is a relationship between the judgment results of the experts (J) and the mean deviation (Z_{md}). The number of experts for the judgment was determined as suggested in the relevant standards [7]. For this purpose, as the correlation coefficient between these functions is quite large, we tried to enter function $f(Z_{md})$. This relation can be written as (4):

$$J_v = -1.784 \ln(Z_{md}) + 5.38 + f(Z_{mh}) \quad (4)$$

Where J_v is the result visually obtained from the judgment of experts. Z_{md}, is the mean deviation, and $f(Z_{mh})$ is the function of mean heights, indicating the difference between the results obtained from the two methods. To determine the difference between the amounts of these methods, ΔJ is introduced as written in (5):

$$\Delta J = J_v - J_t \quad (5)$$

$$J_v = \Delta J + J_t \quad (6)$$

$$Z_{sd} = \frac{\sqrt{\sum_{j=1}^{m}\sum_{i=1}^{n}(z'_{i,j} - \overline{z'})^2}}{m \times n} - \frac{\sqrt{\sum_{j=1}^{m}\sum_{i=1}^{n}(z_{i,j} - \overline{z})^2}}{m \times n} \quad (2)$$

$$Z_{md} = \frac{\sum_{j=1}^{m}\sum_{i=1}^{n}\left|z'_{i,j} - \overline{z'}\right|}{m \times n} - \frac{\sum_{j=1}^{m}\sum_{i=1}^{n}\left|z_{i,j} - \overline{z}\right|}{m \times n} \quad (3)$$

Equations 2 and 3.

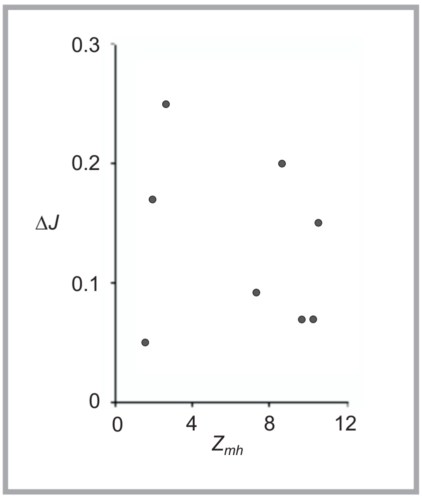

Figure 6. Theoretical and empirical degree of wrinkle for 8 samples.

Where J_v is visual judgment made by experts, and J_t is the amount of wrinkle obtained theoretically.

From (4) we have:

$$J_t = -1.784 \ln(Z_{mh}) + 5.38 \qquad (7)$$

On the other hand, we may consider ΔJ proportional to the mean heights, which can be expressed as (8):

$$\Delta J \; \alpha \; Z_{mh} \qquad (8)$$

or

$$\Delta J = f(Z_{mh}) = \alpha + \beta \cdot Z_{mh} \qquad (9)$$

In order to study the validity of relationship (9), we plotted Z_{mh} against ΔJ for 8 fabric specimens, shown in ***Figure 6***.

As can be seen from ***Figure 6***, there is no significant relationship between ΔJ and Z_{mh}. Therefore equation (9) is not valid, but we can apply the following equation:

$$J = -1.784 \ln(Z_{md}) + 5.38 \qquad (10)$$

Conclusion

The results show that among the three factors applied in this study, the mean deviation of the light profile heights is the best and most accurate method for the determination and evaluation of fabric wrinkle. This claim was confirmed by the judges who visually graded the samples. In fact, there is good agreement between the theoretical results and the view of judges. Moreover, this method has none of the restrictions of previous methods.
Investigating the effect of taking a picture of samples suggests that the parameters representing wrinkle grade are not affected. Therefore, it is not necessary to consider the direction of sample fabrics when they are put on the moving plate of the equipment, although the samples are usually cut in the main directions.

References

1. Postle R., Carnaby G. A., De-Jong S.; "The Mechanics of Wool Structures", Chapt.14, pp. 369-385, John Wiley & Sons.
2. Weber's New Collegiate dictionary, 1993.
3. Beech S. R., Farnfield C. A.; Textile Terms & Definitions, 1988.
4. Morton W. E., Hearl J. W. S.; "Physical Properties of Textile Fibres", 1973.
5. Mitsuo M., „Fabric Handle and Its Mechanical Properties", Textile Engineering Journal, 2006, Vol. 52, No. 1, pp. 1-8.
6. British Standard: Textile fabric – Determination of the recovery from Creasing of a Horizontally Folded Specimen by Measuring the Angle of Recovery, 1992.
7. AATCC Wrinkle Recovery of Fabrics: Appearance Method, SDL 272, 1998.
8. Xu B., Cuminato D. F.; "Evaluation Fabric Smoothness Appearance with a Laser Profilometer", Textile Res. J., 1998, 68(12), pp. 900-906.
9. Kang T. J., Cho D. H., Whang H. S.; "A New Objective Method of Measuring Fabric Wrinkles Using a 3-D Projecting Grid Technique", Textile Res. J., 1998, 69(4), pp. 261-268.
10. Yeung K. W., Li Y., Zhang X., Yao M.; "Evaluating and Predicting Fabric Bagging with Image Processing", Textile Res. J., 2002, 72(8), pp. 693-700.
11. Abril H. C. et al.; "Influence of the wrinkle perception with distance in the objective evaluation of fabric smoothness", 2008 J. Opt. A: Pure Appl. Opt. 10 104030 (10 pp).
12. Naujokaitytė L., Strazdienė E., Domskienė J.; »Investigation of Fabric Behaviour in Bias Extension at Low Loads«.
13. Take W. A., Chappel M. J., Brachman R. W. I., Rowe R. K.; „Quantifying geomembrane wrinkles using aerial photography and digital image processing"
14. Kang T. J., Lee J. Y.; "A New Objective Evaluation of Fabric Wrinkles and Seam Puckers Using Fractal Geometry", Textile Res. J., 2000, 70(6), p. 462.
15. Xu B., Reed J. A., "Instrumental Evaluation of Fabric Wrinkle. Recovery", the Journal of the Textile Institute, 1995, 86 No. 1.
16. MATSUDAIRA M., HAN J., YANG M., „Objective Evaluation Method for Appearance of Fabric Wrinkling Replica by Image Processing System", Textile Engineering Journal, 2002, Vol. 49, No. 1, pp. 11-16.

Received 01.11.2008 Reviewed 09.02.2010

FIBRATEC 2010
6th Symposium on Natural Fibers: Processing and Application

Part of the 15th Scientific Convention on Engineering and Architecture

29 November – 3 December 2010, Havana, Cuba

President of the Organising Committee:
Tania Carbonell Morales Ph. D., Havana, Cuba

President of honour:
Prof. Ryszard Kozłowski, Ph. D.
Institute of Natural Fibres & Medicinal Plants, Poznań, Poland.

Selected topics:
- Natural fibre diversification
- Fibre treatment and technology
- Economic evaluation and quality in fibre management
- Clean technologies
- Waste treatment
- Alternative energy sources in fibre production.

Contact:
Website: http://www.cciacuba.com/index.php?module=general13
e-mail: taniac@ceter.cujae.cu.