Study of Fabric Movement and Influenced of Drape Measurement Based on Image Processing Using MATLAB

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Abstract. Generally, Drape meter for assessment of fabric drape is used in textile industry. In this paper, Image processing technique for measuring drape profile of apparel fabric has been studied and developed using MATLAB as well as modeled the fabric movement influenced of the fabric strength for a certain mass. A modified method based on conventional drape meter was researched to determine drape parameter. Drape coefficient was selected to compare the conventional result (a standard device used in industry based on SNI ISO 08-1511-2004) and image processing result. In this research, a very good correlation has been found both conventional and image processing technique.

1. Introduction

In textile industry, yarn properties and fabric characteristics are some interested topics researched and studied by some researchers both experimentally and theoretically [1—11]. In textile, specially in fabric characteristic, drape is an important factor affecting the dynamic functionality and aesthetic of fabric characteristic. According to Kenkare and Plumlee [9], drape can be well-defined as the degree to which a fabric can bend when it is permitted to hang under its weight and without the influence of external forces. Commonly, drape ability can be defined as a phenomena of fabric deformation which is caused by the influence of fabric’s force or weight of fabric caused by the gravitation force, when the fabric is suspended down without the influence of external forces.

In the study performed by Lojen and Jevsnik[10], fabric drape is not an independent fabric property. It depends on fabric parameter such as structure, yarn type, fibre content and also its finishing treatment. The drape ability of a fabric can be tested objectively and subjectively. Subjective evaluation has a lot of weakness. Drape of fabric was tested subjectively by panel of judges. Some disagreements in the test result by the panel of judges resulted in development of quantitative methods for evaluating drape. Quantitative methods to measure the drape coefficient has been developed and studied by many researchers[9-10], as subjective evaluation by panel of judges depends on the person evaluating, whereas objective evaluation of a fabric can be tested by drape coefficient which is formulated and calculated as shown below:

\[
DC = \frac{S_p - \pi l^2}{\pi R^2 - \pi l^2} \times 100\% = \frac{\pi l^2 \sin^2 \theta - \pi l^2}{\pi R^2 - \pi l^2} \times 100\% 
\]

(1)

Where \(DC\) is defined as drape coefficient; \(S_p\) the area under drape sample \((S_p = \pi l^2 \sin^2 \theta)\); \(\theta\) the angle of fabric drape; \(\pi l^2\) the area of horizontal disc; \(\pi R^2\) the area of sample before draping. Using Eq. (1), it can be calculated drape coefficient of fabric. Drape coefficient is still used for explaining drape and valid as the primary attribute for explaining the extent to which a fabric deformation under its own weight.
In this research, we developed and designed by applying image processing technique and Eq. (1) for measuring drape coefficient. In this study, the area under drape sample can be calculated by using MATLAB as image processing software. In this process, an image of each drape sample was captured by the WebCam then MATLAB software as image processing software was used to measure the area under drape sample automatically based on our listing program. In this study we also derive the equation to determine the relationship of area of drape and also the fabric strength.

2 Measuring Drape Using Image Processing

Recently, some computer vision techniques for analyzing drape sample have been made and introduced by some researcher. In this research we used MATLAB to analyze the drape area for an arbitrary area of drape. Generally, it is difficult to measure an exact area of an arbitrary area (area of drape) as shown in Figure. 1. According to Solomon7, image processing can be used to measure an arbitrary area and it provides us to overcome the problem.

![Figure 1. Arbitrary area (area under drape sample)](image)

In this research, we have designed and developed a method to measure an arbitrary area as well as to determine the fabric strength. For first investigation of our aims to measure an arbitrary area, we compared a certain area (known area) to our result using image processing by MATLAB. The comparison of evaluation the certain area in pixel square both experimentally and image processing technique can be shown in Table-1. In this evaluation, we have made four images with difference area but having same shape.

| No. | Object | Area by image processing (px²) | Area by experimental (px²) |
|-----|--------|--------------------------------|---------------------------|
| 1   | 1080   | 1074,2±10,29                  |                           |
| 2   | 1560   | 1589,62±12,52                 |                           |
| 3   | 2110   | 2205,06±14,74                 |                           |
| 4   | 2770   | 2826±16,69                    |                           |

Table-1 presents the comparison of certain area both experimentally and image processing technique. In this result, the measured area, both experimentally and image processing technique, has a close relation of value. We also investigated the correlation both experimentally and image processing technique using regression test, Figure.2 shows the program to measure the arbitrary area of the drape fabric.
Based on our first investigation measuring the arbitrary area by our program, we can use and implement our program to measure the drape with arbitrary area using image processing technique. In this method, a circular fabric is allowed to drape put on the circular disk with certain diameter (based on SNI ISO 08-1511-2004). In this modified process, the drape measurement (Figure 3) consists of two circular disks with different shape, a digital camera to capture the drape image of fabric and a computer to analyze the image and to measure drape coefficient. The camera was hung with a certain distance of height from the fabric and it captured the fabric image.

In this research, we have tested some sample of fabrics (with same characteristic) both conventional method (a standard device used in industry based on SNI ISO 08-1511-2004) and image processing method using MATLAB. After placed the sample of fabrics to fall inside the box (Figure 4), the image of the draped fabric was captured using digital camera run by the user and transferred to the computer to be analyzed and to be measured drape coefficient (DC). In this image processing technique, the picture was measured into a binary image after being processing. The threshold value can be controlled by the user to convert grey color into binary image (black and white). Using black and white image, the arbitrary area of drape can be measured using our listing program in MATLAB.
Figure 4. Placing the sample of fabrics to fall

The system of image processing can be shown in Figure 5 below:

```
INPUT COLOR IMAGE
↓
GRAY IMAGE CONVERSION
↓
NOISE REMOVAL & FILTERING
↓
BINARY IMAGE CONVERSION
↓
THRESHOLDING
```

Figure 5. The system of image processing

3 Modeling of Fabric Movement influenced of Drape Measurement

To show the influence of fabric movement to the drape measurement, it can be pretended that the movement of fabric can be shown as Figure 6.
Figure 6. The Movement of Fabric as a function of angle

Taking Cartesian coordinate (x,y) in the vertical plane as shown in Figure 6, we have, for the mass \( M_1 \) can be written as shown below:

\[
Y_1 = -r \cos \theta_1 \\
X_1 = r \sin \theta_1
\]

...(2)

And for Mass \( M_2 \), we have the coordinates as written below

\[
Y_2 = -r \cos \theta_1 - r \cos \theta_2 \\
X_2 = r \sin \theta_1 + r \sin \theta_2
\]

...(3)

If we look for each speed of the masses, hence we can get for Mass \( M_1 \)

\[
\frac{dY_1}{dt} = \frac{d}{dt}(-r \cos \theta_1) = -r \frac{d}{dt}(\cos \theta_1) = -r \frac{d\theta_1}{dt} \frac{d}{dt}(\cos \theta_1) = r \dot{\theta}_1 \sin \theta_1
\]

...(6)

\[
\frac{dX_1}{dt} = \frac{d}{dt}(r \sin \theta_1) = r \frac{d}{dt}(\sin \theta_1) = r \frac{d\theta_1}{dt} \frac{d}{dt}(\sin \theta_1) = r \dot{\theta}_1 \cos \theta_1
\]

...(7)

For mass \( M_2 \), we can get the equation below

\[
\frac{dX_2}{dt} = \frac{d}{dt}(r \sin \theta_1 + r \sin \theta_2) = r \dot{\theta}_1 \cos \theta_1 + r \dot{\theta}_2 \cos \theta_2
\]

...(8)

\[
\frac{dY_2}{dt} = \frac{d}{dt}(-r \cos \theta_1 - r \cos \theta_2) = r \dot{\theta}_1 \sin \theta_1 + r \dot{\theta}_2 \sin \theta_2
\]

...(9)

Hence the total kinetic energy and potential energy both vertical and horizontal force of the system can be written as determined below

\[
T = \frac{1}{2} M_1 (r \dot{\theta}_1 \sin \theta_1)^2 + \frac{1}{2} M_2 (r \dot{\theta}_1 \cos \theta_1)^2 + \frac{1}{2} M_2 (r \dot{\theta}_2 \cos \theta_2)^2 + (r \dot{\theta}_1 \cos \theta_1 + r \dot{\theta}_2 \cos \theta_2)^2 + \frac{1}{2} I_{M_1} \dot{\theta}_1^2 + \frac{1}{2} I_{M_2} \dot{\theta}_2^2
\]

...(10)

\[
V = -M_1 g r \cos \theta_1 - M_2 g (r \cos \theta_1 + r \cos \theta_2)
\]

...(11)

and the Lagrangian is
\[ L = \frac{1}{2} M_1 \{(r \dot{\theta}_1 \sin \theta_1)^2 + (r \dot{\theta}_1 \cos \theta_1)^2 \} + \frac{1}{2} M_2 \{(r \dot{\theta}_2 \cos \theta_2)^2 + 2 r \dot{\theta}_2 \dot{\theta}_1 \cos \theta_1 \cos \theta_2 + (r \dot{\theta}_2 \sin \theta_2)^2 \} + (r \dot{\theta}_1 \cos \theta_1 + r \dot{\theta}_2 \cos \theta_2)^2 + 2 r \dot{\theta}_1 \dot{\theta}_2 \sin \theta_1 \sin \theta_2 + \frac{1}{2} I_{M_1} \dot{\theta}_1^2 + \frac{1}{2} I_{M_2} \dot{\theta}_2^2 + M_1 g r \cos \theta_1 + M_2 g (r \cos \theta_1 + r \cos \theta_2) \]  

\[(\text{12})\]

\[ L = \frac{1}{2} M_1 (r \dot{\theta}_1)^2 + \frac{1}{2} M_2 \{(r \dot{\theta}_1)^2 + 2 r \dot{\theta}_1 \dot{\theta}_2 (\cos \theta_1 \cos \theta_2 + \sin \theta_1 \sin \theta_2) + (r \dot{\theta}_2)^2 \} + \frac{1}{2} I_{M_1} \dot{\theta}_1^2 + \frac{1}{2} I_{M_2} \dot{\theta}_2^2 + M_1 g r \cos \theta_1 + M_2 g (r \cos \theta_1 + r \cos \theta_2) \]  

\[(\text{13})\]

\[ L = \frac{1}{2} M_1 (r \dot{\theta}_1)^2 + \frac{1}{2} M_2 \{(r \dot{\theta}_1)^2 + 2 r \dot{\theta}_1 \dot{\theta}_2 \cos \theta_1 \theta_2 + (r \dot{\theta}_2)^2 \} + \frac{1}{2} I_{M_1} \dot{\theta}_1^2 + \frac{1}{2} I_{M_2} \dot{\theta}_2^2 + M_1 g r \cos \theta_1 + M_2 g (r \cos \theta_1 + r \cos \theta_2) \]  

\[(\text{14})\]

Consider Lagrange’s equation \( \frac{d}{dt} \left( \frac{dL}{d\theta_1} \right) = \frac{dL}{d\theta_1} + F_{\text{ext}} \) therefore we have the motion for \( \theta_1 \)

\[ \frac{d}{dt} \left( \frac{dL}{d\dot{\theta}_1} \right) = \frac{dL}{d\theta_1} + F_{\text{ext}} \]  

\[(\text{16})\]

\[ \frac{d}{dt} \left\{ M_1 r^2 \dot{\theta}_1 + M_2 \left[ (r^2 \dot{\theta}_1 + r \dot{\theta}_2 \cos (\theta_1 - \theta_2)) + I_{M_1} \dot{\theta}_1 \right] \right\} = -M_1 g r \sin \theta_1 - M_2 g r \sin \theta_2 + F_1 r \]  

\[(\text{17})\]

And the motion for \( \theta_2 \), we have

\[ \frac{d}{dt} \left( \frac{dL}{d\dot{\theta}_2} \right) = \frac{dL}{d\theta_2} \]  

\[(\text{18})\]

\[ \frac{d}{dt} \left\{ M_2 (r^2 \dot{\theta}_2 \cos (\theta_1 - \theta_2) + r \dot{\theta}_2 \dot{\theta}_1) + I_{M_2} \dot{\theta}_2 \right\} = -M_2 g r \sin \theta_2 + F_2 r \]  

\[(\text{19})\]

For a special case when the acceleration and the speed of the fabric are kept constant, therefore we get from Eq.(20) the force of the fabric which can be concluded as:

\[ -M_2 g r \sin \theta_2 + F_2 r = 0 \]  

\[(\text{20})\]

\[ M_2 g r \sin \theta_2 = F_2 r \]  

\[(\text{21})\]

\[ \sin \theta_2 = \tan \theta_2 = \frac{F_2}{M_2 g} \]  

\[(\text{22})\]

and for mass \( M_1 \), we get

\[ M_1 g \sin \theta_1 + M_2 g \sin \theta_1 = F_1 \]  

\[(\text{23})\]
\[ \sin \theta_1 \approx \tan \theta_1 = \frac{F_1}{(M_2 + M_1)g} \]  \hspace{1cm} \text{...(24)}

For a small angle both \( \theta_1 \) and \( \theta_2 \), hence we can get

\[ \tan \theta_2 = \theta_2 \approx \frac{F_2}{M_2g} \]  \hspace{1cm} \text{...(25)}

\[ \tan \theta_1 = \theta_1 \approx \frac{F_1}{(M_2 + M_1)g} = \frac{F_1}{M_1 \left( \frac{M_2}{M_1} + 1 \right) g} \]  \hspace{1cm} \text{...(26)}

For a special case, when the mass of \( M_2 \) is lower than \( M_1 \), hence we get

\[ \theta_1 \approx \frac{F_1}{M_1 \left( 1 + \frac{M_2}{M_1} \right) g} \approx \frac{F_1}{M_1 g} \]  \hspace{1cm} \text{...(27)}

\[ DC = \frac{\pi l^2 \sin^2 \theta - \pi l^2}{\pi R^2 - \pi l^2} \times 100\% \approx \frac{\pi l^2 \left( \frac{F_1}{M_1 g} \right)^2 - \pi l^2}{\pi R^2 - \pi l^2} \times 100\% \]  \hspace{1cm} \text{...(28)}

As shown in Eq. (29) we can look that drape is defined as the amount to which a fabric will deform when it is allowed to hang under its own weight and without the influence of external forces. Commonly, drape ability can be defined as a phenomena of fabric deformation which is caused by the influence of fabric’s force or weight of fabric caused by the gravitation force, when the fabric is suspended down without the influence of external forces. Based on the calculation of the fabric motion it can be determined that the higher the angle of fabric, the higher is the area under drape sample as well as the drape coefficient DC.

4 Results and Discussions

Based on the calculation of the fabric motion, we can analyze from Eq.(23) and Eq.(25) that the value of the angle of drape is influenced by the mass of fabric and also the yarn strength \( F \), the higher the angle of fabric, the higher is the strength of the fabric for a constant mass as well as drape coefficient, DC. It has been found that the drape coefficient can be related with Eq.(1), Eq.(26) and Eq.(28). Based on theoretically approach, we can show the formula to show the relationship of angle of fabric, drape coefficient as well as the strength of fabric as stated in Eq.(29). Based on the Eq.(29) we can assume that drape ability can be defined as a phenomena of fabric deformation which is caused by the influence of fabric’s force, \( F_1 \), or weight of fabric, \( M_1g \). Based on the validation of the experiment, we can show the drape coefficient both using image processing and also drape tester. Comparison the average of drape coefficient both conventional and image processing method can be shown in Table-2

| Table 2-Drape Coefficient of some fabrics |
|------------------------------------------|
| Sample | Drape By Image Processing | Drape By Conventional Drape Tester |
| 1      | 35.44                     | 34.18                              |
| 2      | 34.18                     | 36.13                              |
| 3      | 34.41                     | 35.09                              |
| 4      | 34.87                     | 34.39                              |
| 5      | 34.77                     | 35.57                              |
The face, back and overall average drape coefficient of five samples, with same characteristic, tested with conventional and image processing method can be shown in Figure 6

![Figure 6](image)

**Figure 6.** Average drape coefficient of five samples tested using conventional and image processing

The difference of drape measurement of two methods can be shown in Figure 6 using homogeneity analysis, the sig value has been found more than 0.05. It was found by t-test that there’s no difference both standard drape tester and drape measurement using image processing technique. Both methods can be used to measure drape coefficient of fabric. We also conclude that from Eq. (26) and Eq. (28) the angle of $\theta_1$ and $\theta_2$ are influenced by the fabric strength ($F_1$) for a special case when the mass of $M_2$ is lower than mass $M_1$. Based on our calculation and also looked Eq. (1) and Eq. (29) it can be assumed that the more the angle, the higher is the length as well as the higher the fabric strength, the higher the area of the drape or the lower is the drape coefficient.

**Conclusions**

We have found the new equation to determine the drape coefficient related by the angle and fabric strength and we also have used Image processing technique for measuring drape profile of apparel fabric which has been studied and developed using MATLAB as an image processing software. In this research, a very good correlation has been found both conventional and image processing technique to determine the drape coefficient.

**References**

[1] Putra VGV, Maruto, G & Rosyid, M.F., 2017, *Indian Journal of Fibre and Textile Research*, 42. pp. 359-363.

[2] Putra, V G V, Rosyid M F and Maruto, G., 2016, . *Global Journal of Pure and Applied Mathematics*, 12.,No.1 pp. 405-412.

[3] Herawati RM, Fauzi I. and Putra V G V., 2015, *Applied Mechanics and Materials*, 780, pp. 69-74.

[4] Lawrence, 2003, *Fundamentals of Spun Yarn Technology*, (New York: CRC Press)

[5] Backer, Hearle & Grosberg, 1969, *Structural Mechanics of Fibres, Yarns and Fabrics*, (New York: Wiley-Interscience)

[6] Hearle, J.W.S. & Gupta, B.S., 1965, *Textile Research Journal*, 35 pp. 788-795.

[7] Kenkare N & Plumlee T, 2005, *J Textile Apparel Tech Management*, 4, pp 1.

[8] Lojen DZ & Jevsnik S, 2007, *FIBRES & TEXTILES Eastern Europe*, 15, pp 39.

[9] Trommer, G., 1995, *Rotor Spinning*, (Frankfurt.: Deutscherfachverlag.)

[10] Zeidman, Shawney and Herington, 2003, *Indian Journal of Fibre and Textile Research*, 28., pp. 123-133.

[11] Putra, V G V, Rosyid, M F. & Maruto, G., 2016, *Global Journal of Pure and Applied Mathematics*, 12. pp. 405-412.