

Evaluation of Fabric Pilling Using Hybrid Imaging Methods

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Abstract: A study has been made on the quantification and evaluation of fabric pilling using two-dimensional and three-dimensional hybrid imaging methods. Two-dimensional imaging method was good for some samples while three-dimensional measurement method for others, according to the properties of their base fabric. Various image processing techniques as well as three-dimensional data processing algorithms were applied for the extraction of pills from measured data and a series of shape parameters have been defined for the objective evaluation of fabric pilling. An evaluation criterion that is compatible with the conventional evaluation method has been proposed by applying the new evaluation method to the current photographic standards.

Keywords: Objective pilling evaluation, Pill extraction, Two-dimensional imaging, Three-dimensional measurement, Pilling shape parameter

Introduction

The pilling phenomenon has been one of the most serious visual imperfections of textile fabric because it causes not only a bad appearance but also a bad touch especially when fabric is used for clothing. The pill growth mechanism is affected by many factors such as the physical properties of fiber and the finishing processes for fabric. As is already known, pills are likely to grow easily on the fabric composed of high tenacity synthetic fiber that the prevention and evaluation of pilling phenomenon is becoming more and more important. So far, the evaluation of pilling property has been a subjective process, in which trained experts compare the pilling specimen with some photographic standards to grade the fabric [1,2]. Recently, many researchers tried to make an objective evaluation method for pilling using various image processing techniques [3-6]. However, each of those methods had a common intrinsic difficulty when applied to the fabric with complex colorful patterns. Other researchers tried to use three-dimensional measurement methods to evaluate fabric pilling. Laser point sensors were used to detect pills regardless of the color and pattern of the fabric but it was not so practical as it took too much time in measuring relatively a small area of the specimen [7-9]. In this paper, we used the two-dimensional as well as the three-dimensional measurement methods to characterize the pilling phenomenon. It was observed that, the two-dimensional method was good for the fabric with thin and smooth yarn while the three-dimensional method for the fabrics with thick and hairy yarn. A series of image processing algorithms were applied to analyze the images of pilling specimen. Also the laser scanner that was developed in our previous study was used to measure the three-dimensional geometry of the specimen [10]. However, the software system for the scanner has been completely

renewed for the optimum performance. A series of shape parameters were defined to characterize the pilling and a new evaluation criterion that is compatible with the conventional one has been developed based on those parameters by applying the new measurement technique to the conventional photographic standards.

Experimental

Preparation of Specimen

In this study, six pilling specimens were used prepared by the ASTM-D3512 random tumble pilling test method. As shown in Figure 1, each specimen is in single tone without any pattern. Three of them consist of relatively thick and hairy yarn, while others thin and smooth yarn. As the main topic of this study was not the analysis on the pill growth mechanism but the quantitative measurement of fabric pilling phenomena, the chemical and physical properties of fabric were not considered while selecting the specimen.

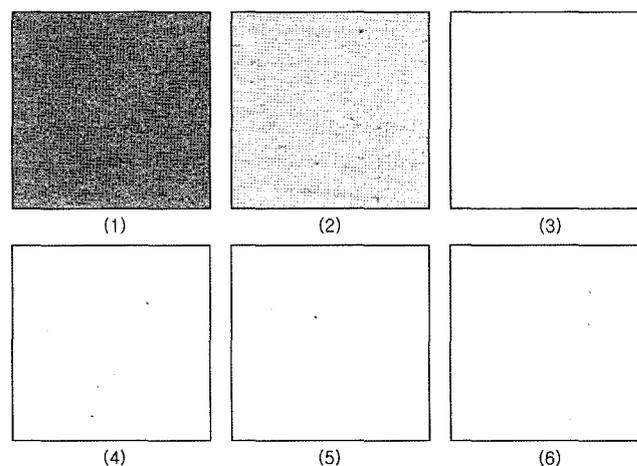


Figure 1. Fabric specimens used in this study.

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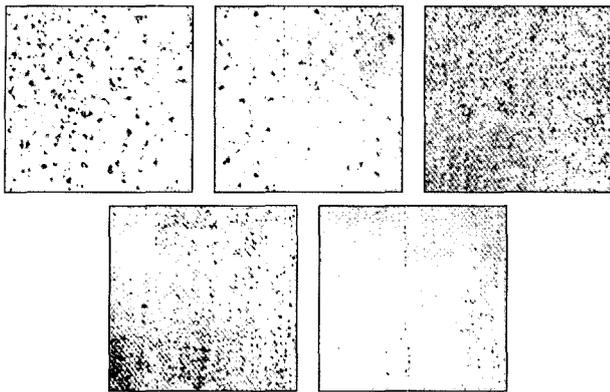


Figure 2. Conventional photographic standards for pilling evaluation.

To suggest a new evaluation criterion that is compatible with the conventional pilling evaluation method, the images of ASTM 3512 photographic standards for pilling test were prepared as shown in Figure 2.

Measurement Methods

The two-dimensional image acquisition system used in this study is shown in Figure 3. The CCD camera can capture color images sizing 640×480 pixels. The direction and intensity of illumination can be adjusted to enhance the contrast between pills and background fabric. In this study, a square area of 50 mm for both sides was captured in each specimen for subsequent image analysis.

The schematic diagram of three-dimensional measurement system used in this study is shown in Figure 4. Three-dimensional measurement is done based on the laser trigonometry where a laser line is projected onto the object to be measured and a CCD camera captures the image of that line to reconstruct the surface shape of the object. The laser projector and CCD move together to measure a wide range

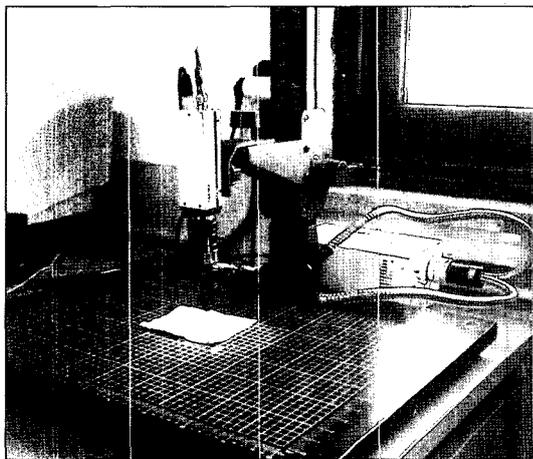


Figure 3. 2-D image acquisition system.

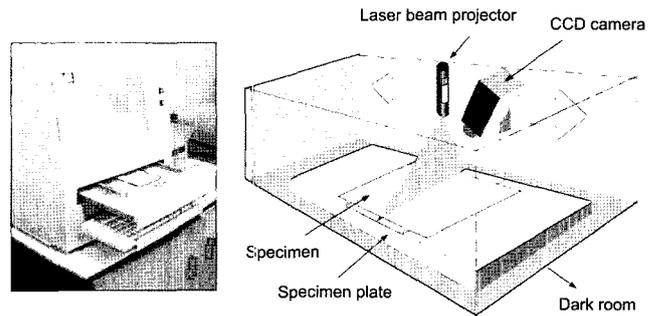


Figure 4. Schematic diagram of the 3-D measurement system.

of area. The system software has been renewed to move them by 1 mm at a step to enhance the accuracy of measurement. The measurement system can measure a square area of 50 mm for both sides just like in the two-dimensional measurement system. It took about 30 seconds to measure a specimen.

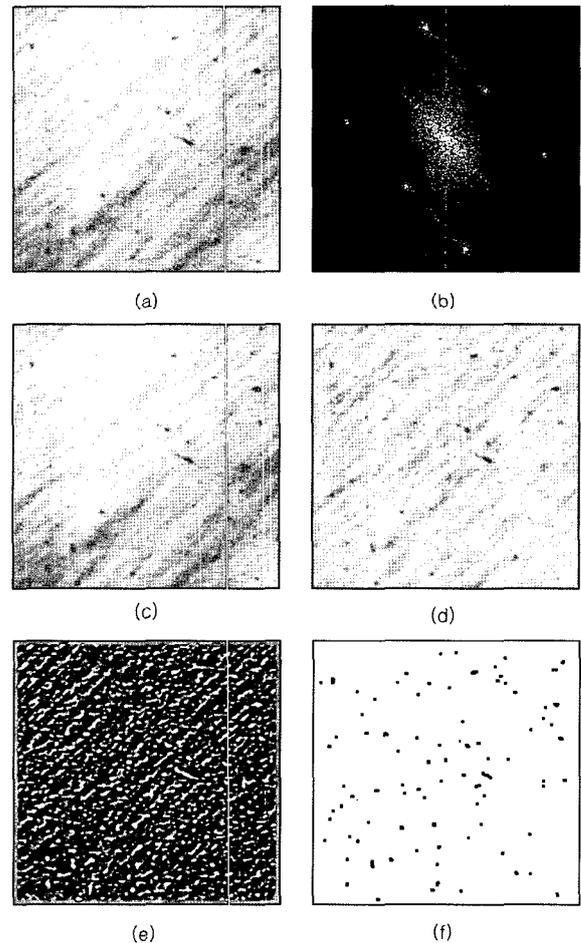


Figure 5. Schematic diagram of image processing: (a) original image, (b) FFT image, (c) inverse FFT after noise removal, (d) after flatten filtering, (e) after laplacian and median filtering, (f) after thresholding.

Extraction of Pills

The schematic diagram of pill extraction procedure for a 2-D image is shown in Figure 5 and each step can be explained in detail as follows. First, fast Fourier transformation (FFT) is performed to remove the periodic noise in the image such as twill lines. The noises appear as some distinctive high-frequency peaks in the transformed image and it can be removed by the inverse transformation after deleting such peaks from the spectrum lies behind the image. Flatten filter can reduce the partial irregular shades on the image resulted from either the irregular illumination or the global surface curvature of the specimen. Large artifacts in the image such as the irregular shades can be reduced by the subtraction operation between the original image and the pretreated image where small objects were deleted by a series of erosion and dilation operation. Finally, the Laplacian filter and median filter are applied to extract all the edges in the image to separate the pills from background fabric image.

Once the pills are extracted form background fabric image, the number, positions, and areal occupancy of them can be calculated to characterize the pilling property of the specimen. It could be observed through the preparatory experiments that fabric with thick and hairy yarn was unsuitable for two-dimensional imaging method because it was difficult to separate the pills from background even after the application of FFT and flatten filter due to its irregular background pattern. While the specimen with thin and smooth yarn seemed suitable for two-dimensional measurement method due to its regular background pattern and relatively conspicuous pills.

Schematic diagram of three-dimensional pill extraction method is shown in Figure 6. There are some noises in the three-dimensional data just like those in the two-dimensional images and they can be removed by the similar noise reduction techniques used in 2-D image processing. For example, a three-dimensionally extended flatten filter can be applied to reduce the noise resulted from the global deformation of the specimen. Pills can be separated from the background surface by applying a three-dimensional separation algorithm using a certain height value as the threshold. Fabric with thick and hairy yarn seemed suitable for three-dimensional measurement because the sizes of pills were rather large. But fabric with thin and smooth yarn seemed unsuitable for this method because the size of pills sometimes went below the intrinsic

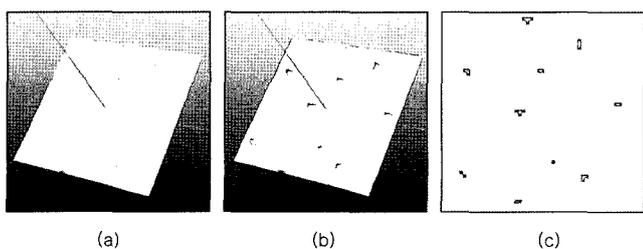


Figure 6. Schematic diagram of three-dimensional data processing.

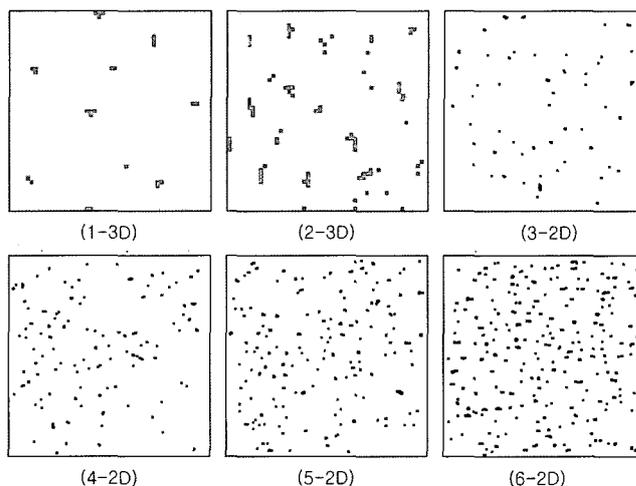


Figure 7. Measurement results of pilling specimen.

measurement error of the system and therefore it was impossible to separate pills from the globally curved background surface.

Results and Discussion

Measurement Results

Example images of extracted pills are shown in Figure 7.

Definition of Evaluation Criterion

Some shape parameters that can characterize the fabric pilling phenomena was defined from the quantitative information of extracted pills including the density, areal occupancy, and dispersion of pills. Parameters extracted from each specimen and the photographic standards are listed in Table 1.

Dispersion coefficient was obtained by calculating the

Table 1. Extracted shape parameters for each specimen and photographic standards

Fabric	Number of pills	Areal occupancy (%)	Density (pill/cm ²)	Dispersion coefficient
Specimen 1	14	1.32	0.56	2.88
Specimen 2	60	3.65	2.40	0.31
Specimen 3	120	3.09	4.80	0.11
Specimen 4	44	0.72	1.76	0.47
Specimen 5	66	1.21	2.64	0.28
Specimen 6	54	1.01	2.16	0.36
Standard 1	107	1.37	4.18	0.12
Standard 2	47	0.76	1.88	0.46
Standard 3	14	0.31	0.56	2.54
Standard 4	7	0.07	0.28	8.08
Standard 5	2	0.01	0.06	86.06
Average of standards	35.4	0.504	1.392	19.452

Table 2. Intermediate calculation for the grade evaluation of specimen #1

Standard grade	Number of pills	Areal occupancy	Density	Dispersion coefficient	
1	$\frac{(14-107)^2}{35.4} = 244.32$	$\frac{(1.32-1.37)^2}{0.504} = 0.005$	$\frac{(0.56-4.18)^2}{1.392} = 9.41$	$\frac{(2.88-0.12)^2}{19.452} = 0.39$	
2	$\frac{(14-47)^2}{35.4} = 30.73$	$\frac{(1.32-0.76)^2}{0.504} = 0.62$	$\frac{(0.56-1.88)^2}{1.392} = 1.25$	$\frac{(2.88-0.46)^2}{19.452} = 0.30$	
3	$\frac{(14-14)^2}{35.4} = 0$	$\frac{(1.32-0.31)^2}{0.504} = 2.02$	$\frac{(0.56-0.56)^2}{1.392} = 0$	$\frac{(2.88-2.54)^2}{19.452} = 0.006$	
4	$\frac{(14-7)^2}{35.4} = 4.07$	$\frac{(1.32-0.07)^2}{0.504} = 3.11$	$\frac{(0.56-0.28)^2}{1.392} = 0.056$	$\frac{(2.88-8.08)^2}{19.452} = 1.39$	
5	$\frac{(14-2)^2}{35.4} = 4.07$	$\frac{(1.32-0.01)^2}{0.504} = 3.40$	$\frac{(0.56-0.06)^2}{1.392} = 0.18$	$\frac{(2.88-86.06)^2}{19.452} = 14.12$	Resulting grade
Minimum value at	3	1	3	3	2.5

Table 3. Evaluated pilling grades using the newly proposed criterion

Specimen	1	2	3	4	5	6
Grade	2.5	1.75	1.0	2.0	1.5	2.0

weighted average distance between pills as shown in equation 1. A new pilling evaluation criterion has been defined from the relationship between the parameters listed in Table 1.

$$C_{disp} = \frac{\sqrt{\frac{\sum_{i=1}^n \sum_{j=1, j \neq i}^n (P_i P_j)^2}{n-1}}}{n^2} \tag{1}$$

where, n = the number of pills, P = the position of a pill

For example, intermediate calculation results can be obtained for specimen 1 as shown in Table 2. In this study, the pilling grade of a specimen is determined by the average value of the grades where each parameter gets the minimum value so that the new method can show the similar trend with the traditional evaluation method.

The evaluated pilling grade for each specimen is listed in Table 3.

Conclusion

An objective evaluation method for pilling has been developed. In this method, two-dimensional as well as three-dimensional measurement methods are used to characterize pills on fabric surface according to its base material and

structure. Two-dimensional imaging method seemed to be suitable for fabrics with thin and solid yarn while three-dimensional method for fabrics with thick and hairy yarn. A series of shape parameters were extracted from the measured data and a new pilling evaluation criterion has been defined by applying the new method to the conventional photographic standards. Although this method seemed to be suitable for some kinds of fabric, it turned out to be somewhat difficult to apply this method to all kinds of fabric especially for the fabric with complex colorful patterns due to the intrinsic limitations in the measurement techniques as with previously developed methods. As explained in this paper, it would be necessary to develop more efficient measurement methods that can provide accurate and reproducible results regardless of the color and pattern of the specimen by combining the two and three-dimensional methods together to overcome such problems.

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