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Noncontact capture of pilling profile on fabric surface - objective assessment method

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Abstract- Pilling is a fabric surface defect caused by regular wear-cleaning cycles. Assessment of the pilling on the fabric surface is done in subjective manner visually by experts. This paper presents a method of objective assessment of pilling on the fabric surface, employing a system designed for non-contact capture of the pilling profile on fabric surface. The results obtained from the proposed method are validated by direct measurement of pill parameters on stereo microscope, as correlation studies indicate correlation coefficient value more than 0.90. Five fabric samples with widely different physical properties were used in the pilling study Statistical analysis proves reliability of the pilling measurement by the new method and supportive role it offers to the subjective assessment by experts.

Index Terms- 2DDWT, Fabric, Pilling, Surface-defect, Textile.

I. Introduction

One of the results of fabric abrasion that mostly affects fabric surface appearance is pilling phenomenon. A pill, colloquially called a bobble, is a spherical or elliptical or spiral structured entangled fibres that forms on a surface of fabric. Pilling refers to formation of such balls.

Pilling happens when washing and wearing of fabrics causes loosening of fibres which then push out from the fabric surface of the garment. In due course of time, abrasion/rubbing action compels such loose fibres to get entangled and develop into spherical bundles, anchored to the surface of the fabric by anchoring fibres that haven't broken. These anchor fibres provide the necessary fibre material for the growth of the pill with more wear and washing. [1]

Pilling mostly occurs in staple fibre fabrics, such as woolen knitted goods made from soft twisted yarns. With the advent of synthetic fibres, the problem has become more acute particularly with the rapidly rising use of polyester-cotton blend [2]. With fibres such as polyester, acrylic, nylon, pills remain keyed to the garment and become more visible. The high strength and flex life of synthetic fibres, particularly polyester fibres, prevent easy wear-off of pills.

The occurrence of pilling is undesired and has no resolution afterwards. It drastically changes appearance of the fabric thereby compromising its acceptance for apparel work. Fuzzing and pilling brings about many changes in the fabric surface property such as its luster, flatness, decorative pattern, feel, surface friction and wear resistance [3]

In the textile industry, severity of pilling is objectively evaluated using five parameters: pill number, the mean area of pilling; the total area of pilling; contrast, and pill-density. There is a need for mechanisms for assessment of degree of pilling on fabric surface as a product quality / process countercheck measure. Prevailing industry practice of assessment is, experts evaluate pilling and assign grade by visual examination. However, this technique is dependent on subjective opinion/skills/availability of an individual and thus, lacks both accuracy as well as reproducibility. Automated Objective assessment in this perspective is an aspect therefore attracting interest of researchers in the textile industry.

Recent technical advances involve architectures which are both complex, expensive to manufacture, operate and maintain, or analysis based on complicated algorithm to derive basic characteristics from pilling profile of surface as reported by researchers.[3] [4] [5] [6] [7] [8]. Algorithms and techniques used for segregation of the pills from the background in digital images of pilled fabrics include pixel-based brightness thresholding [5], Region-based template matching for extracting pills from fabric surface [7] [9], frequency domain image processing- two-dimensional discrete Fourier transform (2DDFT)[10].

II. MATERIAL AND METHODS

Present system (fig.1), generates accurate surface profile of pilled fabric by recording the pilling information in the digital format, from the pilled surface of the fabric without disturbing surface profile. Such unspoiled, untouched surface profile scan, presents most of the details of pilled surface.

Patent for this machine has been applied with India patent office. [11]

The work was carried out in two parts. In the first part, tumbling method is used to generate pills on the specimen fabric using tumble box generator as per the 10971 IS standard. Then scanning of the surface profile of the pilled fabric specimen was carried out using machine developed. Scan of a fabric sample as shown in figure 2, a non-contact capture of the pilled surface of the fabric specimen which preserves the status of the fabric surface generated after tumbling. For matlab analysis, scanned digital image of pilled fabric sample (cotton-2) was divided into six rectangular parts (fig.2) for convenience in analysis. Part-"E"(fig.4a) was selected for measurement of pill parameter like pill area employing matlab code developed for the purpose.

In the second part of the work, direct visual measurement of the prominent pills was acquired using Motic Stereo microscope (fig.3), to validate the measurement of the pilling features undertaken in the first part. The pills were prominently visible, which helped in identifying and labeling them individually.

After measurements, correlation analysis was carried out between two sets of measurements. Correlation coefficient was determined using Karl Pearson method [12].

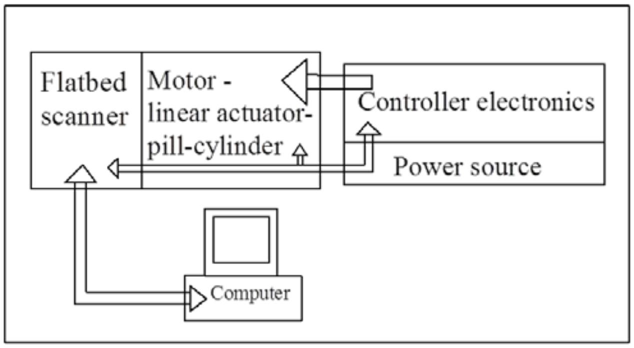
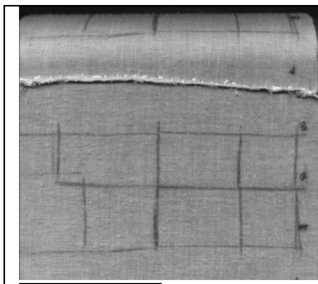


Figure-1: System block diagram



A	B	C
D	E	F

Fig-2:Scan Image of fabric Sample-(cotton-2)

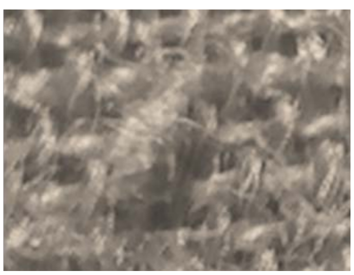


Fig.3: Single pill on fabric surface.

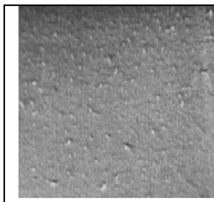
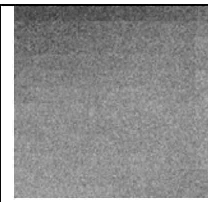
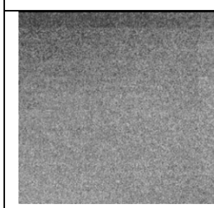
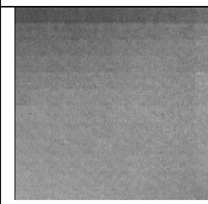
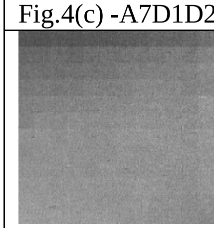
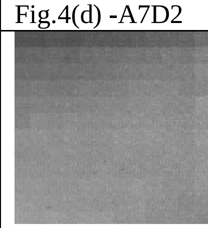
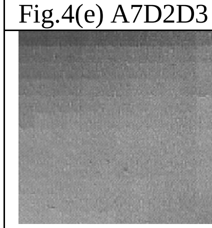
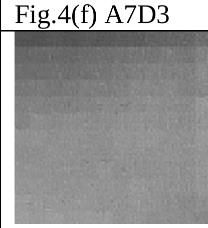
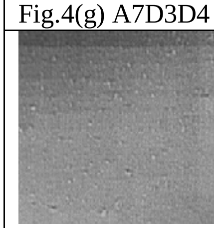
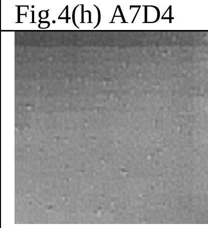
Computational Analysis

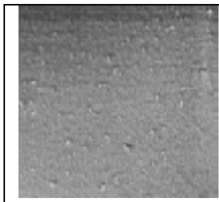
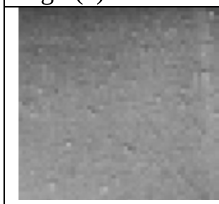
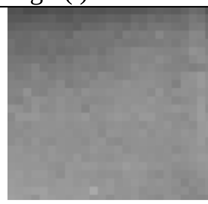
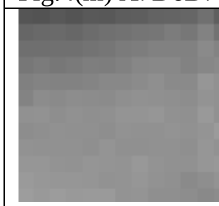
I) Wavelet Analysis

A pilled fabric image consists of multi-scale brightness variation information such as high frequency noise, fibre structure, base texture (woven and knitted fabrics), fuzz and pills, fabric surface unevenness and background illumination variance. This information exists in the image frequency domain at different frequency bands. With the appropriate wavelet and decomposition scale, it is possible to separate the fabric texture, fuzz, pills and background intensity variation into independent sub-images. Wavelet transform analysis is based on wavelets or small waves of limited duration and different frequency. Appropriate wavelet can decompose image into sub images. Each such sub image refers to specific frequency band and supplies information about the fabric surface as present at that frequency band.

The content of a pilled image at different scales can be separated into different reconstructed detail and approximation images. It helps in identifying /detecting localised features in an image by employing frequency domain analysis technique 2DDWT (2-dimensional discrete wavelet transform). The pilling information was identified by inspecting the reconstructed detail images. Pilled fabric gray image (sample-cotton-1) was decomposed by haar-7 wavelet using Matlab wavelet toolbox utility [13].

Scale 5 and 6 together brings out pills prominently as shown in figure 4(k).

 Fig.4(a)Original image	 Fig.4(b)Scale1-A7D1
 Fig.4(c) -A7D1D2	 Fig.4(d) -A7D2
 Fig.4(e) A7D2D3	 Fig.4(f) A7D3
 Fig.4(g) A7D3D4	 Fig.4(h) A7D4
 Fig.4(i) -A7D4D5	 Fig.4(j) A7D5

 Fig.4(k)-A7D5D6	 Fig.4(l) A7D6
 Fig.4(m) A7D6D7	 Fig.4(n) A7D7
 Fig.4(o) -A7	

Wavelet processed reconstructed digital image of part "E" of pilled fabric sample is showed in figure 5b.

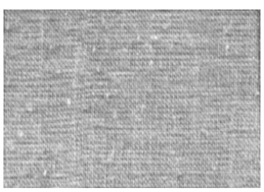


Fig.5a-Part-E of scanned image

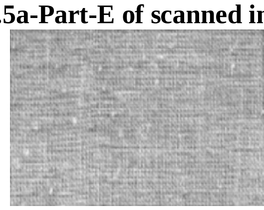


Fig.5b- Haar Wavelet processed image

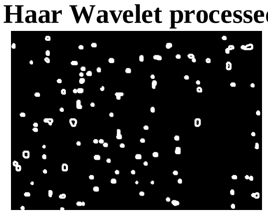


Fig.5c-binary image

II) MATLAB Analysis

Wavelet transform processed image is processed by Matlab code[17] to segregate pills from the underlying fabric structure and display them prominently in binary image (fig.5c).This final binary image could be visually compared to original image to establish positively that entire pill profile has been detected by matlab code processing. This processing also generates pill-area readings with identification number for pills and stores the same in excel file, which are then correlated with the measurement of pill area of same sample obtained from Motic stereo microscope. Correlation graph (fig. 6) and correlation values of five fabric samples are given in table-1.

Pill-profile implies the number, position, area, shape of prominent pills in the final processed image, which are the actual identifiable qualitative and quantitative primary pilling parameters from the final image. Other quantifiable group of parameters includes, the total area of pilling, pilled area percentage, the mean area of pilling, and densities of pills represent secondary parameters derived from image. Together they give complete information about the pilling propensity.

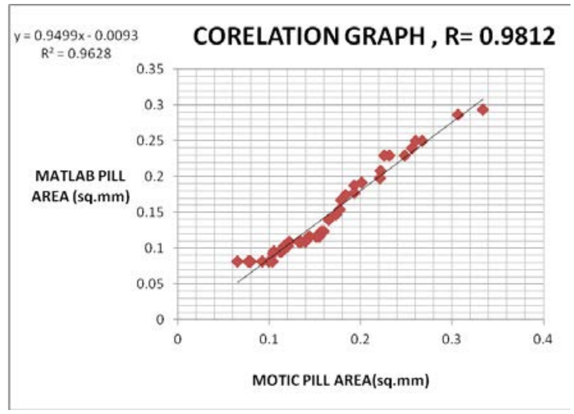


Fig.6- Correlation graph of the sample

Table 1- Correlation coefficient values for five fabric samples.

Pilled fabric Sample	Correlation Coefficient
Cotton-1	0.9660
Cotton-2	0.9812
Polyester-Viscose	0.9706
Knitted Cotton (Hosiery)	0.9314
Knitted wool	0.9829

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For the analysis purpose, three decisive parameters are used in the matlab morphological processing, involved at different stages of processing of image of pilled fabric sample, deriving complete pilling profile of the fabric specimen. These parameters, namely, (1) Number of tiles used for histogram processing-'N', (2) threshold value used for binarization of the image-'t' and (3) size of structural element 'E' for noise filtering, are explained below.

Imaging factors such as uneven illumination can transform perfectly segmentable histogram of the digital image into a histogram that cannot be partitioned effectively by a single global threshold. This problem could be handled by technique of adaptive histogram equalization 'adapthisteq' wherein original image is divided into subimages and the contrast transform function for each of these regions is calculated individually to enhance each tile's contrast. Number of tiles specifies the number of rectangular contextual regions (tiles) into which 'adapthisteq' divide the image. The optimal number of tiles (subimages) depends on the type of the input image, and it is best determined through experimentation. While 'histeq 'works on the

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entire image, adapthisteq operates on small regions in the image, called tiles.

Thresholding used for converting grayscale image to a binary image, replaces all pixels in the input image with luminance greater than specified threshold level with the value 1 (white) and replaces all other pixels with the value 0 (black)[15]. It clearly marks pills as white regions contrasted with black background as showed in figure 5c.

Minimum size of structural element is prescribed and is used to discard very small white regions in the binary image as noise.

In the initial stage, optimum values of the parameters are decided on the basis of trial and error method by visual comparison, giving correlation coefficient values close to 1 between two sets of pill-area, first set obtained from matlab processing of scanned image and second set obtained from visual measurement on stereo microscope. For small variation in values of these parameters near optimum values, correlations are measured, for the statistical analysis.

III) Factorial Analysis

Factorial design of experiment is employed to explore interaction between three parameters (factors) used for in matlab code. For the purpose, MINITAB software [14] helped in generating this analysis. For this analysis fabric sample (cotton-1) measurements are used. Factorial design has several important features. It has great flexibility for exploring the effect of “signal” (treatment) or factors which decide the value of the outcome variable of the studies. It effectively combines independent studies into one study, thereby saving time and resources needed for conducting a series of independent studies and examine interaction effects between factors.

In factorial designs, a **factor** is a major independent variable and a **level** is a subdivision of a factor. In this analysis, there are three factors, each with two levels, a 3 x 2 factorial design. Correlation coefficient values in the last column of table 1 give the response/outcome because of combination of values of these factors.

Factor-1- Window size (number) = N= 64 and 100
Factor-2-Threshold (number) = t = 0.853, and 0.890
Factor3--Noise-Element (pixel) = E = 4 and 9

Table-2-Factor N, t, E -level table with response (correlation coefficient) values

N	t	E	Correlation coefficient
64	0.853	9	0.98234
64	0.853	4	0.99031
64	0.890	4	0.98818
100	0.890	9	0.96783
100	0.853	4	0.99100
100	0.853	9	0.98782
64	0.890	9	0.99287
100	0.890	4	0.98110

A contour plot is a graph that can be used to explore the potential relationship between three variables. Contour plots display the 3-dimensional relationship in two dimensions, with x- and y-factors (predictors) plotted on the x- and y-scales and response values represented by contours. A contour plot is like a topographical map in which x-, y-, and z-values are plotted instead of longitude, latitude, and elevation.

Contour plot brings out Interaction between parameters more strongly, because of the strength in defining the range of optimum values of three parameters so as to obtain higher values of correlation coefficients. Since these ranges are obtained by statistical analysis, there is more reliability, objectivity in the process than decision based on visual observation and comparison between binary image output from matlab analysis and original image.

As given in figure 7, contour plot is drawn for table2.

1st sub-plot- from left bottom corner- for N=64, from t=0.864 move upward for higher t, shows maximum value of correlation coefficient. And for t= 0.853, from N=78 move right shows again maximum value of Corr. Coef. (> 0.99). This suggests the range of parameter combination which can be selected so as to achieve better correlation between actual and experimental estimation of pilling profile. It helps in identifying optimal values of parameters. 2nd subplot of E*N shows that to retain higher value of Corr. Coef. Value, for increase in value of E from 4 to 9 there is corresponding decrease in value of N= 82 to 64.

3rd subplot shows decrease in Corr. Coef. Value as moved away from combination of t = 0.853 and E= 4, either upward(increase in E) or rightward (increase in t)direction.

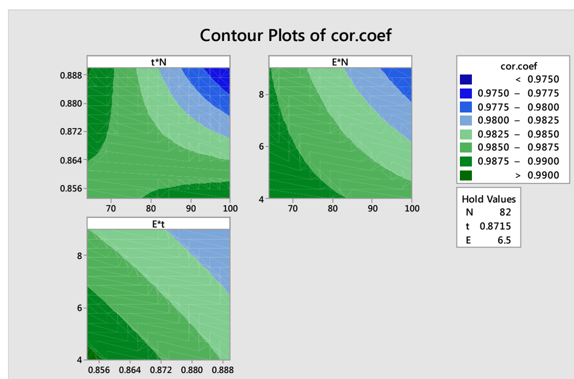

Fig.7- Contour plot

III. Conclusion

On the basis of correlation results, the measurements of parameter like pill-area acquired on this machine, associated with pilling profile have been strongly correlated- validated by the readings taken on the stereo microscope.

Factorial analysis has shown that over wide ranges of parameters used for generation of binary image of pills, correlation coefficient values remain very high (greater than or equal to 0.9). This means small variation in parameter values within the range will not affect the results.

Strong positive correlations between two sets of measurements indicate that objective assessment using the newly fabricated device can be used as a quicker method for objective evaluation of pilling of fabrics.

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