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Design and development of an instrument for non- destructive fabric weight measurement

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In this study, an image processing approach for fabric weight measurement has been proposed and tested. The system involves digital capturing of image using a microscope and then its processing in simple steps using image processing software (MATLAB). The study is conducted using a range of woven fabric samples. The fabrics have been conventionally weighed using an electronic weighing balance, and digital images of the sample fabrics are obtained and processed. The process involves application of suitable filters to obtain weft count, warp count, EPI, PPI and yarn crimp. The values are then substituted in standard formula to obtain the fabric weight. The study shows that the results of the proposed method of image processing, based on fabric weight measurement, are well correlated with the results of conventional method of measurement.

Keywords: Digital image processing, Fabric weight, Laplacian mask, MATLAB software

India has been experiencing strong improvement in the textile industry, across different segments of the value chain, from raw materials to garments. Domestic production as well as exports is growing at a constant rate. Total fabric production in India is nearly 50,000 millions of square meter per year, out of which atleast one percentage of fabric is utilised for testing their shade and weight. Testing of fabric weight is destructive type and the loss of fabric is substantial. So, fabric weight measurement by non-destructive method is essential to control the fabric utilisation and cost of manufacture.

Fabric weight is one of the measures of geometrical characteristics of fabrics. Fabric weight is normally expressed in grams per square meter (GSM). A woven fabric made of the cross combination of the warp and filling yarns has a two-dimensional lattice structure. To study the fabric structure, it is useful to observe the periodic arrangement of the surface contours associated with the yam faces and enclosed by neighbouring two yams[1].

The use of computers to simulate human vision in performing weave structure analysis is becoming a research focus in the textile community[2]. Digital image analysis enabled detailed analysis of basic structural parameters of textile products[3]. In an idealized fabric image, the yarns are straight and either parallel or perpendicular[4]. However, it is inevitable that the deformation of the yarns occurs in some regions of the fabric images. The inherent structure of fabric patterns is ‘near regular’. Correction operations, like histogram levelling and autocorrelation erosion, were also to nullify some woven fabric defects[6]. The approach developed uses a Laplacian mask in horizontal and vertical direction separately to decompose the fabric image into two sub-images, each of which containing either a warp yarn group or weft yarn group[7-9]. The sub-images are further analysed to outline the yarn boundaries and hence characterise fabric surface characteristics[10].

The conventional method of GSM measurement is carried out by a human inspector who uses a magnifier, ruler and some other simple tools to count the densities and visually define the weave pattern. Digital image analysis enabled detailed analysis of basic structural parameters of textile products such as yarn diameter, yarn count, etc.[1]. The conventional method of fabric weight measurement is usually carried out by a visual examination which is tedious and time-consuming. Most importantly, it is destructive method and hence fabric wastage and its cost of manufacture will increase. Thus, the conventional method of fabric GSM measurement includes so many limitations which need to be improved.

Therefore, the main objective of this study is to design and develop image processing system for making the fabric weight (GSM) measurement non-destructive and automated using digital techniques.

Methodology

Digital image processing method is designed and developed as given in Fig. 1. A CCD camera equipped

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with a zoom lens was used to capture the fabric images under reflected light. All images were processed using histogram equalisation to re-assign the brightness to improve the visual appearance. Coloured images were converted into two dimensional greyscale images with 256 grey levels to improve the computer processing time and speed for the next image processing steps.

A Laplacian mask was applied to the greyscale fabric images to regenerate two sub-images from the original image. Each sub-image shows only one group of yarns known as warp and weft, using which the required parameters, namely end per inch (EPI), picks per inch (PPI), weft count and warp count can be obtained. The detailed images of fabric and sub-images like weft and warp images are shown in Fig. 2. Thus, the fabric GSM can be measured by using image processing approach by applying Laplacian mask.

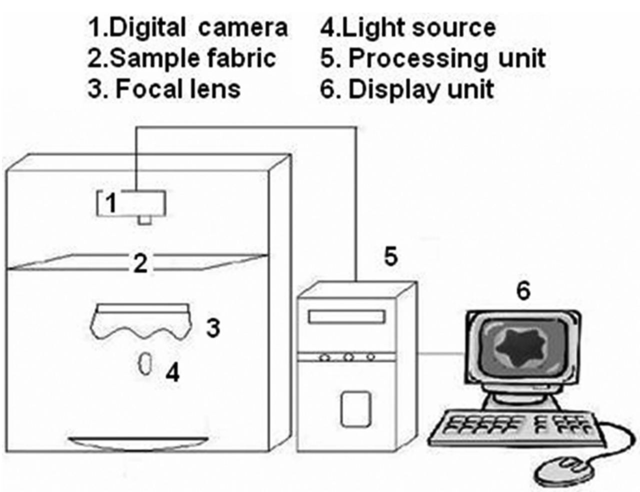

Fig. 1—Schematic diagram of fabric GSM measurement system

System Implementation

A digital image processing approach was developed to evaluate fabric structure characteristics and parameters[1]. The developed approach, decomposed the fabric image into two images, each of which included either warp or weft yarns. Yarn boundaries were outlined to evaluate the fabric surface characteristics and further used to identify the areas of interlaces to detect the fabric structure. The fabric GSM was calculated using the parameters obtained from the image processing approach. This method of measuring fabric GSM can be automated, thus reducing human efforts, errors and fabric wastage.

Ten sample fabrics of size 3 × 3 cm^2 were chosen for image analysis using LEICA microscope. The sample fabric GSM was measured using conventional method, i.e using electronic balance. Then these sample images were processed by proposed algorithm in MATLAB software and the fabric GSM was calculated using the proposed formula. The × 10 zoom microscopic image of the sample fabric was used to calculate the EPI and PPI of the sample and the × 40 zoom microscopic image of the sample fabric was used to calculate the weft and warp counts. These parameters were then substituted in fabric weight formula to get the fabric GSM.

The approach holds good for plain weave resulting in almost equal counts measured using image processing approach and conventional method. Some differences between the counts resulting from the approach and counts measured were identified for twill and satin weave, the reason for which is based on the concept of obtaining the count from the image approach. The image approach calculates the width of the yarn's projection, not the yarn diameter, and uses this information to calculate the yarn's count. Comparing the approach

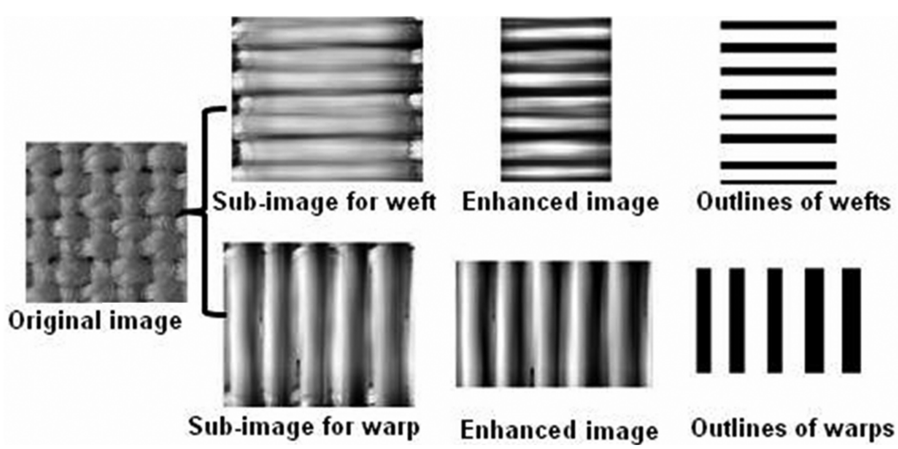

Fig. 2—Applying Laplacian mask on plain weave image

results to the results measured, it was noticed that there was a significant difference in the weft counts compared to the warp counts for both twill and satin weave. Weft yarns have less tension compared to warp yarns during the weaving process. This tension will give the possibility of weft yarns becoming flattened, especially when they have the space. The space provided in fabrics with low yarn densities and/or in fabric structures which have a relatively long float length, like twill and satin weave. This clarifies that there was almost no difference between weft counts for plain weave; however, differences start appearing in twill and satin weaves. So, fabric test specimen chosen for this study is only plain weave.

Algorithm

Following steps are involved:

(i) *Obtain the image of fabric*—The fabric sample image was obtained using a digital camera or a microscope.

(ii) *Input the fabric image to MATLAB*—The obtained image was given as an input to MATLAB image processing software using command X=imread('imagename.extension'). For example, I=imread('sample1.jpg').

(iii) *Convert the image to black and white image for processing*—The image obtained from a microscope as such appears in greyscale because of its minuteness. When digital camera was used the obtained image need to be converted into black and white where each and every pixel is represented either using 1 or 0 using command y=rgb2gray(x).

(iv) *Apply Laplacian mask in horizontal direction to mask vertical components*—Masking was done to filter vertical components thus resulting in sub- image of weft using Laplacian mask defined as H= [-1 -1 -1; 2 2 2;-1 -1 -1]. The image was then filtered using command namely Y=imfilter (X, H)

(v) *Count the number of yarns in horizontal direction (picks)*—The system was then programmed in such a way to count the number of picks. The pivot value was chosen using trial and error method. Selection of pivot value, as shown in Fig. 3 (a), results in correct output whereas Fig. 3 (b) results in incorrect output.

(vi) *Calculate the number of yarns in horizontal direction per inch (PPI picks per pnch)*—The total number of yarns in an inch was calculated from the value obtained from previous step.

(vii) *Calculate the diameter of yarn (weft) in pixels*—The system was then programmed to get the

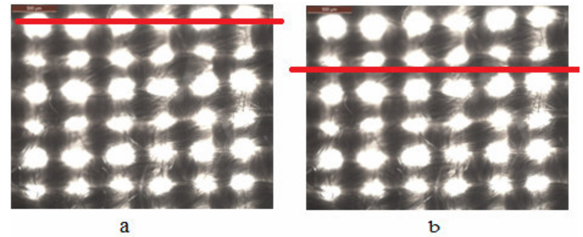

Fig. 3—Selection of pivot value from the fabric sample

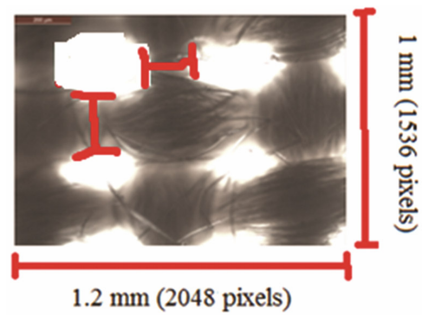

Fig. 4—Diagram showing the dimension in mm and pixels

diameter of the yarn. The obtained value gives the diameter in pixels (Fig. 4).

(viii) *Calculate the equivalent diameter in inch*—The diameter equivalent in inches was calculated by its known diameter in pixels value.

(ix) *Calculate weft count by using obtained diameter in inch*—The count of a yarn is a numerical expression which defines fineness. It is also called as yarn number or linear density. The fineness of yarn cannot be expressed easily in terms of diameter as in the case of wire or rods. The instrument such as micrometer cannot be used to determine the diameter of yarn since most yarns are relatively soft and compressible. Therefore, special methods are used to determine the fineness or coarseness of yarn. One important dimension required in the study of fabric geometry is the 'diameter' of a yarn. A number of simple formulae are available for the estimation of yarn diameter. Out of which the most reliable one for woven fabric is given below:

Yarn diam. for
cotton yarn (d), inch = $1/ (28 \times \sqrt{\text{count}})$ … (1)

The diameter in inches was substituted in formula to get the weft count, s shown below:

Count= $[1/(28 \times \text{diameter in inch})^2]$

(x) *Apply Laplacian mask in vertical direction to mask horizontal components*—Masking was done to

Table 1—Comparison between actual GSM and GSM by new test method of different samples

Sample	Woven fabric particulars				Actual GSM	Obtained GSM
	Warp count Ne	Weft count Ne	Ends /inch	Picks/inch		
1	30	30	78	60	110.5	93.5
2	30	30	78	66	120	123
3	30	30	78	78	140	138
4	24	24	70	62	167.5	158
5	24	24	70	68	180	167.5
6	24	24	78	62	198	187
7	24	24	78	68	210.5	201
8	24	24	78	76	228	232
9	16	16	70	62	247.5	238
10	16	16	70	68	264	259.5

filter horizontal components thus resulting in sub-image weft using Laplacian mask defined as H= [-1 2 -1; -1 2 -1;-1 2 -1]. The image is then filtered using command namely *Y*=imfilter(*X*, *H*).

(xi) *Count the number of yarns in vertical direction (ends)*—The system was then programmed in such a way to count the number of yarns in vertical direction.

(xii) *Calculate the number of yarns in vertical direction per inch (EPI-ends per inch)*—The total number of yarns in an inch was calculated from the value obtained from previous step.

(xiii) *Calculate the diameter of the yarn (warp) in pixels*—The system was then programmed to get the diameter of the yarn in pixels.

(xiv) *Calculate the equivalent diameter in inch*—The diameter equivalent in inches was calculated by its known diameter in pixels value.

(xv) *Calculate warp count by using obtained diameter in inch*—The diameter in inches was substituted in formula to get the warp count, as shown below:

$$\text{Count} = [1/(28 \times \text{diameter in inch})^2]$$

(xvi) *Calculate yarn crimp*—Due to the interlacing of warp and weft threads, a certain amount of waviness is imparted to the warp and weft threads in a fabric. This waviness is called as crimp. Hence, the apparent length of a thread as it exists in the fabric is less than its straightened length. It is defined as the mean difference between the straightened thread length and the distance between the ends of the thread while in the cloth, expressed as a percentage as shown below:

$$\text{Crimp (\%)} = (L - P)/P \times 100 \quad \text{... (2)}$$

where L is the uncrimp length; and P, the crimp length.

Crimp value of the fabric was not measured using this method. It was normalised for fabric GSM assessment.

(xvii) Substitute all the obtained parameters namely PPI, EPI, warp count, weft count and crimp in GSM formula to get the fabric GSM.

All the obtained values were substituted in formula to calculate the fabric weight (GSM) of the given sample, as shown below:

$$\text{Fabric weight (GSM)} = (\text{EPI/warp count} + \text{PPI/weft count}) \times (100+\text{crimp \%}) \times 0.2327 \quad \text{... (3)}$$

where EPI = ends per inch and PPI = picks per inch.

Results and Discussion

To check the correctness of the algorithm mentioned in this study, ten different woven plain fabrics have been tested using conventional method of fabric GSM measurement (ASTM D3776 / D3776M-09a 2013). The results are then compared with the results obtained using proposed image processing algorithm. Table 1 shows the comparison of actual fabric GSM and fabric GSM by new method.

The actual GSM obtained using conventional method and that obtained using image processing approach show good correlation (R^2 = 0.989) for the selected fabrics. The fabric actual weight can be predicted by using the following regression equation:

$$y = 1.012\,x - 0.009 \quad \text{... (4)}$$

where x is the obtained GSM from the new test method; and y , the predicted GSM.

The approach results show good agreement compared to the results pre-identified for the samples of plain weave type. The approach developed needs improvement to analyse the sample of satin and twill weave, because of its internal structural complexities.

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