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Detection of Warp Elongation in Satin Woven Cotton Fabrics Using Image Processing

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Abstract
In this study, warp elongations in a satin fabric were detected using image processing to reduce yarn breakage during weaving. It was aimed to increase the productivity of the weaving looms. In this work, a high sensitive camera was used for the analyses. The warp elongation was analysed and determined statistically using MATLAB software. The warp elongations in satin woven fabric samples were examined and detected on a working loom using a high sensitivity camera. Additionally the strains for each warp yarn were measured and recorded. Different elongations for warp ends were observed, attributed to the differences in mechanism settings. The difference in the elongation of the warp yarns causes warp yarn breakages, which decrease productivity during weaving. This warp breaking ratio could be reduced by making necessary adjustments to the shedding mechanism on the loom.

Key words: *weaving, fuzzy logic, warp elongation, image processing, yarn breakage.*

Introduction

Competition has reached an inevitable point in the world as science and technology are evolving rapidly. The textile industry has an increasing need for faster production, higher quality fabric, and lower cost. The weaving machine mechanism includes shedding, weft insertion, beat-up, take-up and the let-off system. We need clean shedding, precise weft insertion and warp yarns with a suitable amount of let-off and tension for better fabric quality. Using automatic control systems is advantageous to achieve high quality fabric production. Computer systems are used extensively in the process control. The advantages of automatic control systems in the textile industry have come to the forefront.

Automated inspection becomes a natural way forward to improve fabric quality and reduce labour costs. However, the task is challenging to say the least. Fabric inspection with a computer is therefore beneficial; yet there are challenges: (a) numerous categories of cloths, (b) distinct composition of various wallpaper groups of fabric texture, and (c) similarity in shape between defects and background texture [1]. Automated fabric inspection can operate the systems, but it is expensive and works correctly only for satin fabrics of a certain weft density which are called 'unpatterned' fabrics. Researchers have improved several major methods for 'unpatterned' fabric [2, 3]. There are many companies worldwide working on image processing for fabric control such as Dornier, Uster, Barco Vision, and Elebit Vision [4, 5]. Zhong et. al. conducted some studies on finding a wave pattern by analysing photos obtained at low resolution [10]. Kuo et. al. pointed out that the shapes and gray color values of different defects are not the same as each other. In their experiment, they investigated holes as well as oil, weft and warp defects, and showed that there are some differences between these errors in terms of shape and gray colour values. To increase the performance of the velvet method for identifying fabric defects, the adoptive velvet transform is developed [13, 14]. There are different Gabor filters in literature [15, 16] but there is no exact definition of them. Single-colour woven fabrics can be determined with computer programs by the image processing method. The velvet transformation method is often a preferable method in the identifying process for fabric defects. In studies in which the "Velvet Method" was used, very good performance was obtained especially for some small defects, and it was observed

Figure 1. Photo shoot setup (System via CCD camera).

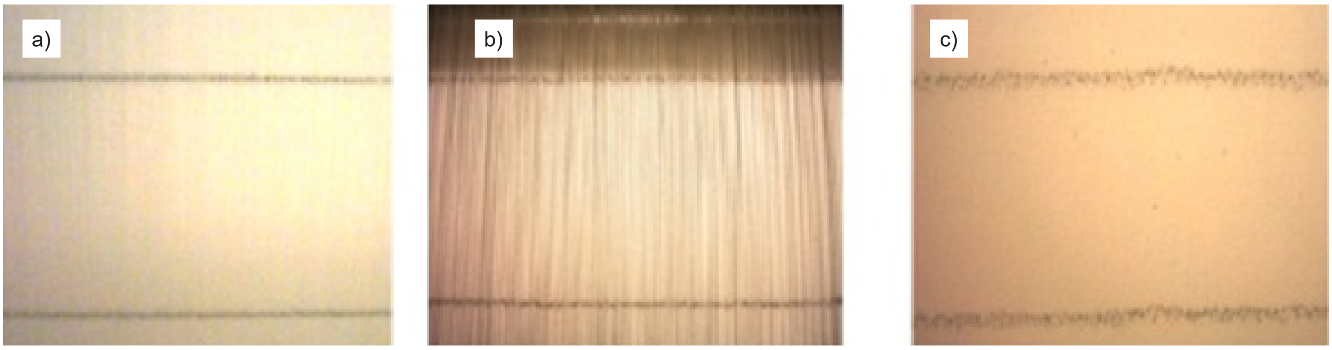

Figure 2. *Photographs of reference grids on the fabrics. The distances measured: a) on the warp beam, b) on the front of reed c) on the fabric when loom is working.*

that it needs less computational effort than the statistical approach, Bradnorova et. al. [17].

Mak et. al. designed a real time image processing system and used a simple Gabor filter [18 - 20]. It was determined that the image processing method is a more suitable method for obtaining woven fabric parameters and the density of yarn [23].

Because of warp yarns across the width of the weaving machine carry different tensions, various elongation in the warp yarn are seen. The occurrence of different mechanisms for warp yarns extensions varies. We researched extensions in the fabric region. In this study, the elongation of warp yarns was also measured using image processing for the fabric. The images were analysed with MATLAB and then statistical analysis were made. The material used was satin cotton fabric in four different weft densities and all other settings were kept constant. In this study, it was obtained that warp elongation values are different by image analysis.

Different warp elongations were observed on the fabric. The elongations of warp yarns on the left, middle and right sides were observed as different on the fabric. The warp elongations of the fabric were photographed for measurements. Images were analysed with MATLAB and then statistical analyses were made.

Material and method

Material

In this study, a satin cotton fabric was used which contains 7×2 tex warp and 20 tex weft yarns with a density of 50 ends/cm. The warp elongation was measured and analysed with photo shoot images for four different weft density fabrics: 20 weft/cm, 28 weft/cm, 35 weft/cm and 45 weft/cm. The experiment was setup using a CCD camera, Guppy Pro (Germany), ***Figure 1***, page 59).

Modifying a normal camera body and lens structure, a Charge Coupled Device (CCD) is obtained and its electronic film plates are used instead of normal film. Digital cameras replace the sensitized film with a CCD photon detector, a thin silicon wafer divided into a geometrically regular array of thousands or millions of light-sensitive regions that capture and store image information in the form of localized electrical charge that varies with incident light intensity[6]. The detector produces an electronic signal in proportion to the brightness of the photons hit. It determines the numeric value of the signal size recorded. Image processing analyses many images at the same time, which could save money for the production plant and improve effectiveness [7].

In a program written in MATLAB, “L_f” values are calculated out of the images received from CCD. In this study a commercial camera with the brand name Guppy PRO was attached to a computer. Loom was fixed on a camera system with scaffolding. The camera obtained images of the fabric on the veawing machine, which is placed at the desired distance. Four light sources were placed on the sides of the loom at 45° angles. Images were analysed in MATLAB R2012. The measuring system was calibrated at a constant distance (λ), calculated as the milimeter distance divided by the pixel distance.

Method

We plotted 15 cm lines parallel to each other on the warp beam from the surface of the fabric, lines “a” and “b” were taken as a reference point on the warp beam (see ***Figure 2***). The fabric could be observed as wavy due to the variation in warp elongation when the lines lost synchronisation of their parallel state, which will make the fabric wavy during weaving later. After warp yarns were woven into the fabric, a second measurement was taken on the woven fabric on the loom, and the mean distance between the dots was calculated using MATLAB (see ***Figure 2***). These lines (see ***Figure 2.a***) change weave formation (***Figure 2.c***) be-

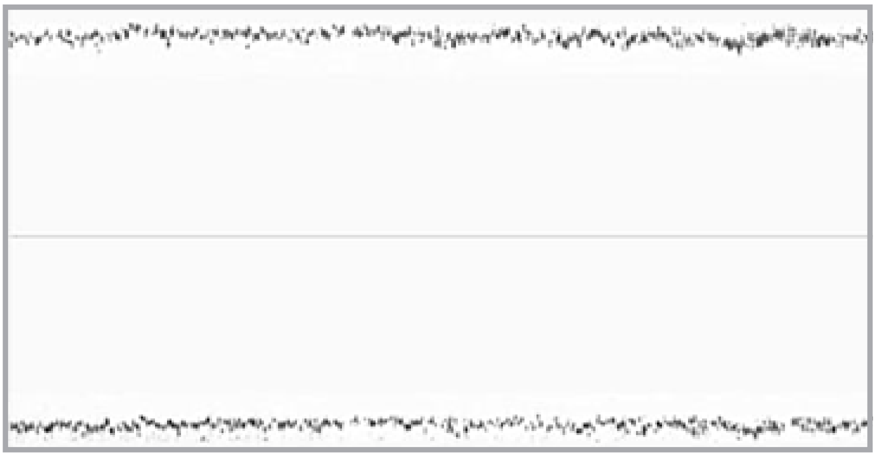

Figure 3. *The program can sperate the photo (**Figure 2.c**) using a horizontal line, creating top and bottom regions and analyze both parts*

cause of weaving process. The program converts the photo applying gray colour filter to the image.

It could be observed as wavy due to the variation in warp elongation. This is represented as a two waves along the width, which means the warp deformation changed weave formation forced to weaving. The MATLAB program separates the image into two groups: upper and lower. First, the program measures image pixels, calculates the upper group and then finds dot statistics. In the second step, the program measures and calculates the lower group and find variation statistics (see ***Figure 3***). The program ends by taking the mean of the distance between the dots.

We measured the distribution distance during weaving. Matlab separates the image into two groups as upside and downside images. In the first step, Matlab calculates weave statistics from the upside group, and then the program analyses the second group. Matlab ends the program by finding the mean distances between two waves as shown below;

L_0 : is the first distance between the lines. (L_0 = 102 mm)
L_{fpx} : is the mean distance between two waves on the fabric in pixels
L_f : is the mean distance between two waves on the fabric in mm
L_y : is the length of warp yarn in the fabric
C : is the warp crimp
C_{online} : is the warp crimp on the loom.
μ : is the fabric shrinkage after taking from the loom (μ = 1)
λ : is the unit conversion between pixels and the millimeter.
ε : is warp elongation in the fabric
$\%\varepsilon$: is $\Delta L/L_o \times 100$ for percent elongation.

$$\varepsilon = \Delta L/L_o \quad (1)$$

$$L_y = L_f(1 + C_{onlin}) \quad (2)$$

$$L_f = L_{f\,px}\,\lambda \quad (3)$$

$$\Delta L_y = L_y - L_0 = L_f(1 + C_{onlin}) - L_0 \quad (4)$$

$$\varepsilon = \frac{L_{f1}\,(1 + C_{onlin}) - L_0}{L_0} \quad (5)$$

$$C_{online} = C \cdot \mu \; (\mu = 1) \quad (6)$$

$$\%\varepsilon = \frac{L_{f1}\,(1 + C) - L_0}{L_0} \times 100 \quad (7)$$

Table 1. *Lengths measured for different weft densities using image processing.*

	Mean length (L_{fpx}), px	Mean length (L_{fL}), mm	Conversion factor, mm/px
20 weft/cm left	1590.05	100.66	0.0633
20 weft/cm middle	1584.50	100.90	0.0636
20 weft/cm right	1559.24	100.74	0.0646
28 weft/cm left	1565.87	101.20	0.0646
28 weft/cm middle	1586.55	102.54	0.0646
28 weft/cm right	1597.67	101.34	0.0634
35 weft/cm left	1564.30	98.16	0.0627
35 weft/cm middle	1584.76	99.99	0.0630
35 weft/cm right	1551.06	98.19	0.0633
45 weft/cm left	1514.48	96.78	0.0639
45 weft/cm middle	1547.32	98.87	0.0638
45 weft/cm right	1508.15	96.37	0.0639

Table 2. *Analysis of results calculated by matlab.*

	L_f, mm (calculated by Matlab), L_w, mm (calculated by crimp equation)							
	Left	Middle	Right	C(crimp)	C online	Left	Middle	Right
20 weft	100.66	100.90	100.74	0.040	0.040	104.68	104.93	104.77
28 weft	99.70	98.52	99.83	0.030	0.030	104.23	105.61	104.38
35 weft	98.16	99.99	98.19	0.060	0.060	104.05	105.99	104.08
45 weft	96.78	98.87	96.37	0.066	0.066	103.17	105.40	102.73

Table 3. *Warp elongation against weft densities. Calculated using* ***Equation 1*** *with L yarn values in* ***Table 2*** *.*

%ε	Left	Middle	Right
20 weft/cm	2.63	2.87	2.72
28 weft/cm	2.19	3.54	2.33
35 weft/cm	2.01	3.91	2.04
45 weft/cm	1.15	3.33	0.72

All features of fabric properties were kept constant during image processing, the distance between the warp beam and fabric region measured, and photographs were taken, given in ***Figure 2***.

L_{fpx} is the mean distance between the two waves on the fabric.

All the mean distances were calculated in pixels. As a summary, additional cal-

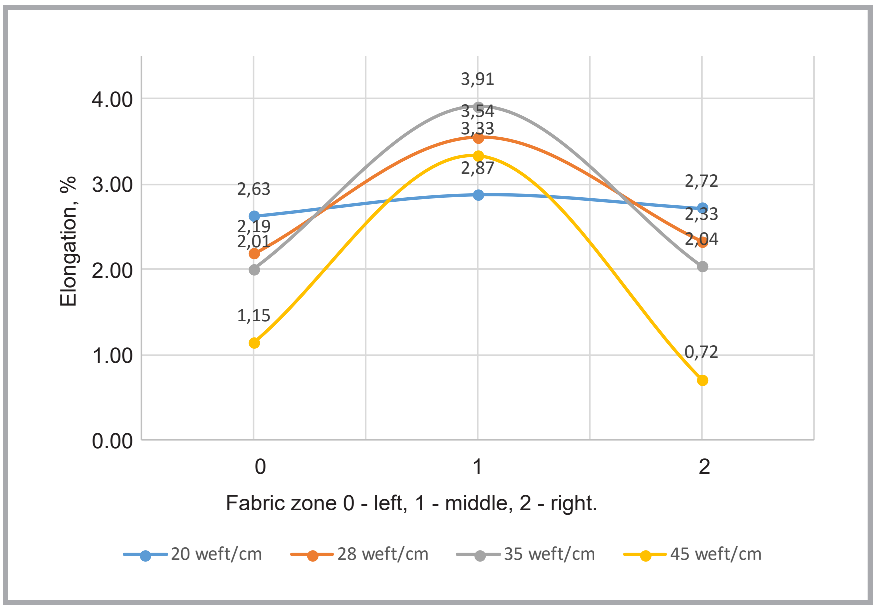

Figure 4. *Elongation percentages of satin fabrics on the loom.*

culations were made using the program between the two distances, as shown in ***Figure 3*** (see page 61).

Results and discussion

The results taken from image processing are given in pixels (see ***Table 1*** & ***2***). The test results can be seen in ***Table 1*** and ***2***, showing warp elongations against weft densities.

Table 2 presents the results for L_f in mm analysed using Matlab for different weft densities. Also the lengths of warp yarns L_w in mm were calculated to find those of the fabric. L_w in mm results were calculated using the crimp equation

$$L_y = L_f\,(1 + C_{online}).$$

Warp elongations were calculated for each study. These elongations changed along the width of the loom. Other researchers found that it changed the warp strain along the loom [8, 9]. We can see elongational variations in ***Figure 4*** and ***Table 3*** (see page 61).

Süle found that warp yarns around the frame showed similar results with a change in the loom width. Warp tension was lower in the edge zones and increased towards the middle of the loom. The highest values were around the middle of the loom width, The reason for the warp tension variation over the warp width was the slip of the weft yarn inwards in the fabric edge zones [22]. Rukuiziene Z. and Milasius R. showed that fabric extension in the central region was increased when compared with the extensions at the edges of the fabric. They also showed the change in fabric extension was affected by loom tension [24]. The porosity, air permeability, thickness, weft crimp, elongation and strength in the weft of the fabric have higher level in the middle region than in other regions [21]. Warp elongation values increase along the distance from the edge. Weft crimps are not equal in the fabric width.

Conclusions

The reference line at the beginning of the research was distorted during weaving due to differences in warp elongation, which caused a wavy line form on the fabric and distorted the homogenesity of the structure. The technique used in this study could be ideal to solve problems on a weaving loom during fabric production to increase productivity. The distribution of elongation of the warp yarn during weaving was tested and evaluated on the fabric surface. According to the test results, the middle zones of the fabric samples showed greater results than the left and right zones. It can be understood that the fabric properties change according to fabric zones, attributed to the calibration of the loom and fabric structure. It was also found that warp elongation increased with an increase in warp density.

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