

Detection of Remote Sensing Warp Tension during Weaving on Plain Twill and Satin Fabrics

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Abstract

Warp tensions were measured while a machine was operating on a woven cotton fabric with three different woven patterns. This study was carried out with image analysis methods using a high speed camera. Three weave pattern types: plain, twill and satin were woven on the same weaving machine, and thus it could be understood how weave pattern differences affect warp tension. Each of these three weaves was woven in three weft densities: 20, 28 and 45 wefts per cm. These fabrics were able to be made on a weaving machine with an automatic dobby. It was aimed to investigate warp tension differences for three basic weave patterns while keeping all machine settings constant. The weave settings of the dobby were changed for plain, twill and satin weaves. Warp tension calculation was based on the warp elasticity theory. Warp elasticities were measured by image processing methods in MATLAB using a high-speed camera. It was aimed to improve upon the new method of warp extension measurement of fabric when the loom is in operation. It was observed that the warp tension in plain fabric was higher than for twill and satin under the same conditions.

Key words: weaving, fuzzy logic, warp tension, image processing.

■ Introduction

Automatic fabric control systems allow us to perform accurate analyses to improve fabric quality. Fabric inspection using a high speed camera is beneficial, but this has many challenges. Accurate analysis of the extension inequalities in a fabric's internal structure will be crucial for the production of homogenous fabrics.

We do not know all information about the initial structure of fabric. However, we can use advanced technology to better understand fabric structure. There is no other work on establishing warp tension when the weaving machine is running. The effects of plain, twill and satin weave on warp tension were measured for the first time. The studies mentioned could only be carried out with the use of new image analysis technology. We can explain the differences in the measurement as follows: A weaving machine has more mechanisms such as shedding, weft insertion, beat up, take up and let off systems. Moreover, irregular shed-

ding systems bring about different warp extensions. Therefore, each warp yarn gains a different extension, and thus every warp has different elongation and tension. Using computer technologies, our studies confirmed that the inequality of warp elongation in the weft at different places in the fabric depends on unequal fabric properties, such as air permeability and the covering feature. In addition, for every weave type: plain, twill and satin, warp tension changes were investigated on the same weaving machine. Automatic control systems allow us to better understand this non-homogeneous structure. This study gives us a new view on weaving more homogenous fabric. Using automatic control systems is advantageous to acquire high quality fabric production. The tension of warp yarns was calculated for the three different weft densities of each of the plain twill and satin weaves using computer technologies. This work also revealed the change in warp tension due to plain, twill and satin weave under the same weaving conditions. Computer systems are used extensively in process control. The advantages of automatic control systems in the textile industry have come to the forefront. This study includes a new view on problems already known and discusses the problems presented comprehensively. Ngan et. al. referred to the pattern of the fabric as 'motif'. A fabric pattern sample with the smallest repeating motif on the fabric surface was investigated using a motif-based method to detect defects in 16 out of 17 wallpaper groups with a 2D

patterned texture. It assumes that most patterned textures can be reconstructed into tabulations and their structure-motifs [1]. Automated fabric inspection is used to operate the systems, but this is expensive and works correctly only for plain and twill fabrics of certain weft density, which are called 'unpatterned fabrics' [2]. Fourier based methods characterise the spatial frequency distribution of images, but they do not consider information in the spatial domain and may ignore local deviations [3]. Gabor filters were recognised as a joint/spatial-frequency representation for analysing textured images and detecting defects that contain highly specific frequency and orientation characteristics [4]. Zhong et. al. worked on establishing the weave pattern using image analysis [5]. Kuo et. al. improved the dynamic fabric inspection system, which has four defects: holes, oil stains, warp-lacking, and weft-lacking, only for plain fabric. A high-resolution linear scan digital camera was used for image analysis. First, fabric images are acquired and then transferred to a computer for analysis. Finally, the data are adopted as input data for neural network analysis, which is obtained from readings after analysing the images [6]. The defect detection problem was studied by Zhi X., Y. et al. in order to achieve translation invariance and a more flexible design, where for the wavelet design they focused on the subsampled wavelet transform. Adaptive wavelets were designed for five kinds of fabric defects. Achievement of a robust and accurate detection of fabric defects

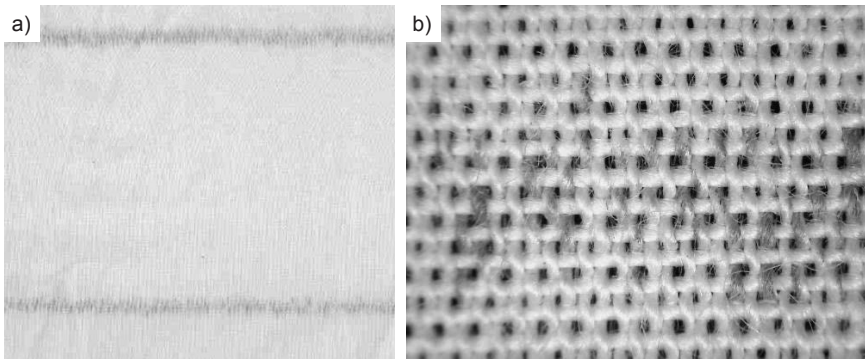


Figure 1. a) Two reference weaves on fabric, b) warp references on the fabric.

was improved with the orthogonal wavelet transform. Our design largely improves on the ratio of wavelet transform energy between the defect area and the background [7]. The velvet transformation method is often a preferable method in identifying the process of fabric defects. In studies in which the “Velvet Method” was used, very good performance is obtained especially for certain small defects. Moreover it is seen that it needs less computational effort than in the statistical approach [8]. Unser et al. described a new approach to characterisation of the multiple scales of texture properties using the wavelet transform. They reported that the DWF (discrete wavelet frame) feature extraction technique was incorporated into a sample multi-component texture segmentation algorithm and some illustrative examples were presented [9]. Bradnorova et al. improved the velvet transfer method by identifying fabric defects. This study had very good performance especially for some small defects [14]. Mak et al. made a real time image processing system using a Gabor filter [15, 16]. In previous studies, warp tension measurements were made on the warps of the weaving machine, where the warp was in the form of thread. In this study, while warp tension was in the fabric, elasticities were measured by image analysis methods and warp tension was obtained by calculation, respectively. In addition, the work was carried out while the weaving machine was running, thus detecting warp tension in a fabric during weaving for the first time.

Materials and method

Material

In this study, three fabric patterns, that is plain, twill and satin cotton fabric, were used. These fabrics contain 20 tex weft yarns and 7x2 tex warp yarns, with weft

densities of 50 ends/cm, but also with weft densities of three different types: 20, 28 and 45 weft/cm. These three fabrics (plain, twill and satin) were woven on the same weaving machine with an automatic dobby system, namely a dornier weaving machine, by changing the weft densities, respectively.

The warp elongation was measured by analysis of photographic images for three different weft density fabrics; 20 weft/cm, 28 weft/cm and 45 weft/cm. The ability to mount various lenses in the camera used was an important parameter in this study. At full resolution, it runs up to 6.5 frames per second. The experimental setup consisted of the CCD camera used with 13.5 mm lens. Modifying a normal camera and lens structure, a Charge Coupled Device (CCD) is obtained, and its electronic film plates are used instead of normal film. 1 mm² CCD devices smaller than the detector are used to ensure that the smallest picture element of the image is composed of thousands of extremely-sensitive-to-light pixels [10]. The detectors produce an electronic signal in proportion to the brightness of a signal photon hit. The numerical value of the signal size determined is recorded. Image processing manipulates saved images, and hence the current image and graphics are changed or used for improvement [11]. In this study a commercial camera with the brand name Guppy PRO was attached to a computer. The camera obtained images of the fabric on the weaving machine placed at the desired distance. Four light sources were placed in front of and behind the fabric surface at 45° angles. The camera took images weaving machine operation. Images were analysed in MATLAB R2012. The measuring system was calibrated at a constant distance (λ), calculated as the millimeter distance divided by the pixel distance.

Method

The high sensitive camera took a photo of the fabric surfaces when the loom was working. Warp elongations could be found with the image processing method via computer software. The warp elongations of each fabric, which were of woven cotton yarns, were detected and examined. The strain for each warp yarn elongation was measured and calculated. Each warp was extended differently because of the various harness on the loom. Warp elongations were spread along with the reed belong. Warp elongations were measured by a method based on the elongation formula. It was almost impossible to have any device for the use of the stretch formula in the weaving machine’s work due to warp yarns taking the form of fabric in the weaving region. The tension of warp yarn is not in a free state, but in the form of fabric. Considering all these conditions, the warp tension had to be made by the reference marking method on the warp yarns. Warp elasticity was calculated using the change in the first referenced length of the warp (L_0). L_0 was two parallel straight lines drawn on the warp threads. These two straight lines take the form of a wave with fabric formation. This deformation is caused by the individual tension of each warp in the reed region. Warps entering the fabric are stretched according to the type of fabric and reed impact strength. The reed impact force directly depends on the change in weft density. After the warps have entered the fabric, the distance between the references on them should be measured. However, references are no longer linear and impossible to measure directly because the distance between the two waves cannot be measured (see **Figure 1** part b). A computer program was written that can measure the distance between two waves in real time. In the program “ L_f ” values are calculated from the images received from the highly sensitive digital camera. L_f is the distance of the reference marking on the warp on the fabric. The vertical distance between the references on each warp visible on the fabric surface is found individually by the pixel counting method of the image analysis program (see **Figure 1**). The distortion of the reference lines (marked dark on the photo) in the fabric allows two parallel graphs to be obtained naturally. We now have a fabric and reference waves on it. The Matlab program takes the arithmetic mean of the measured pixels between these parallel waves. In this way we find the last length in the theory of elasticity through the fabric. The final length of the warps is found

if the fabric crimp is included in the calculations when the weaving machine is running. Since the fabric gaps are black, the reference colour is selected as red (marked dark on the photo). Otherwise, fabric gaps in image analysis could produce misleading data. The shadow on the weft of the upper warp could also cause problems in image analysis, hence a light source was placed on either side of the weaving machine. During image analysis in Matlab, red image filter software was used to get rid of all other images. The remaining images are then synthesised again in gray, and the pixel count is completed (see **Figure 2**). Finally, the mean distance between dots (L_{fpx}) can be found by measuring the mean distance of both sides.

In **Figure 3**, as the vertical axis increases, the grey changes to white, and at the minimum points it approaches black; as the horizontal axis increases, the image pixels are counted from the middle to the black marks. The pick point is the distance between the middle line and dots with pixels. The vertical distance for each pixel of the reference lines on the fabric is found with this method. This process is done in two parts, the results of which are collated in **Figure 5**.

The pixel counting process based on the white to black colour change on the grey filter is shown in **Figure 4**. In finding the length of the fabric, the first place where the white colour changed in each pixel column was recorded, as a consequence of which L_{fpx} is found. The values in the ordinate are pixels, which are converted to millimeters to reconstruct the graph.

The arithmetic mean of the values (L_{fpx} , L_f) in both regions is taken, and the result obtained can be seen in **Figures 5** and **6**. We measure the distance after weaving distribution after the fabric is taken from the machine. MATLAB separates the image as the upper side and down side using the horizontal axis. As the first step MATLAB calculates the upper side and establishes upper weave statistics. In the second step MATLAB calculates the down side and forms weave statistics. At the end of the analysis, mean distances are found between two the weaves.

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

$$\varepsilon = \frac{\Delta L}{L_o} \quad (2)$$

$$\Delta L = L_y - L_o \quad (3)$$

$$L_f = L_{fpx} \cdot \lambda \quad (4)$$

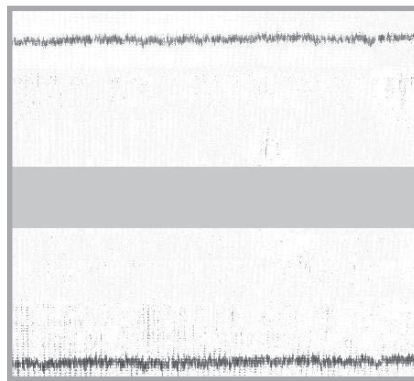


Figure 2. Image synthesised again in grey by Matlab.

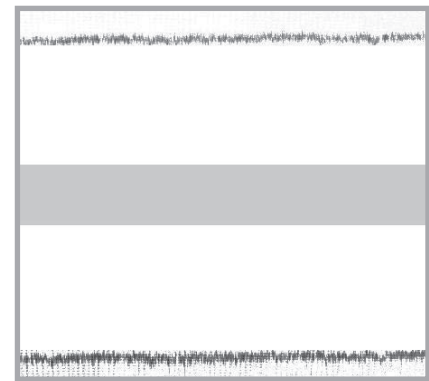


Figure 4. Unnecessary data interruption with harmonic mean [22].

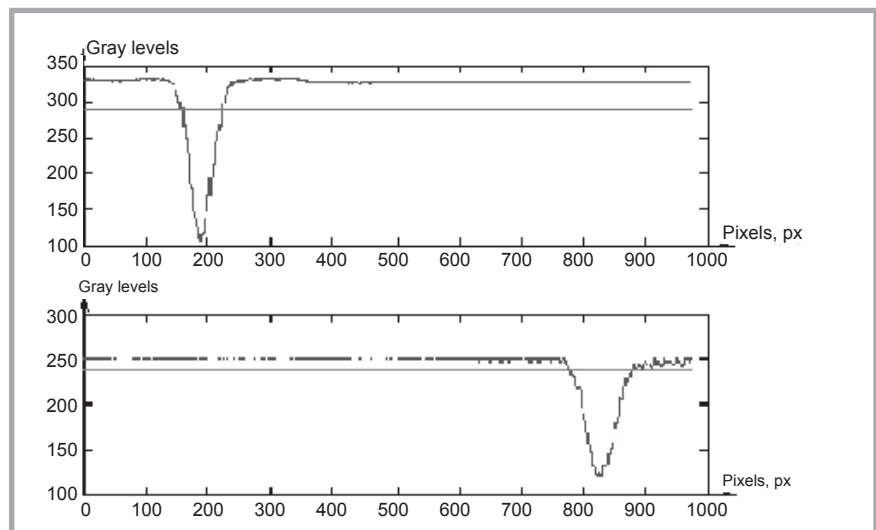


Figure 3. Place to be cut in the harmonic average calculated, shown as straight line [22].

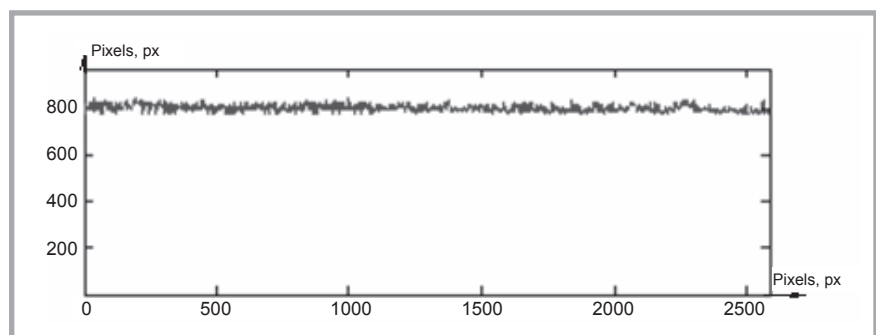


Figure 5. L_{fpx} – adding the numbers of the pixels by image processing of the two regions as pixels (px)[22].

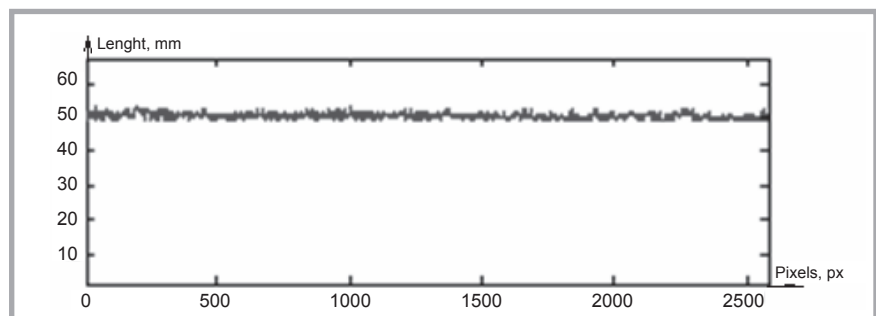


Figure 6. L_f – the total number of pixels between two lines in **Figure 5** in millimeters [22].

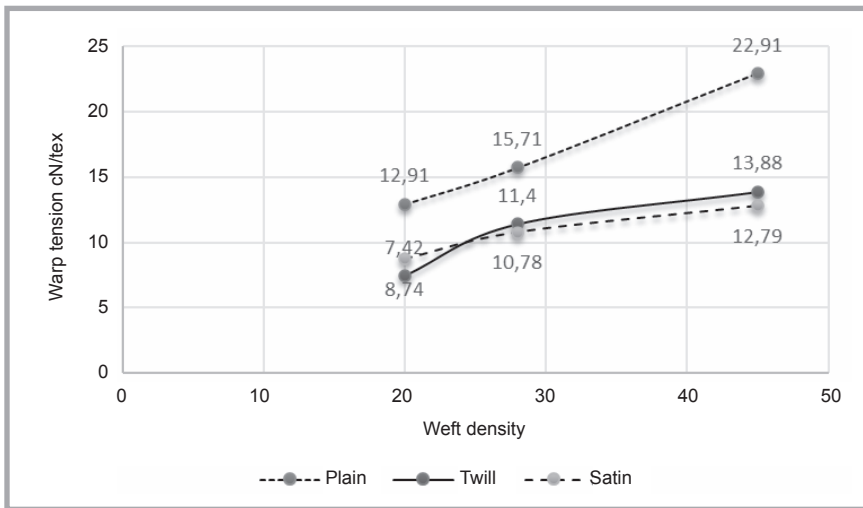


Figure 7. Change in warp tension in the inner structure of the fabric according to weave type and weft density during weaving machine operation.

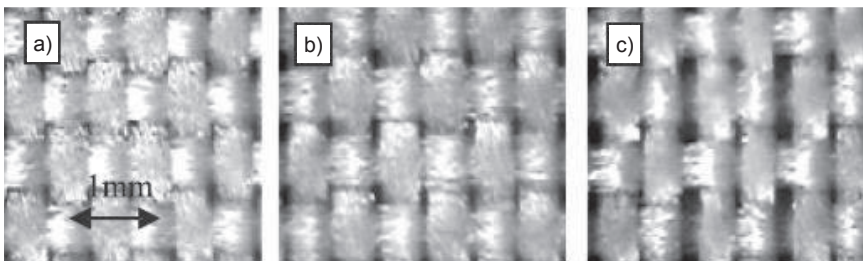


Figure 8. Image of fabric at distances of 5 cm (a), 25 cm (b) and 70 cm (c) from its edge [20].

Table 1. Measurement of fabric lengths using images processing [22, 23].

Weave	Weft density	Measurement dot distances as pixel L_{fpx} , px	Unit conversion coefficient μ , mm/px	Conversion fabric length L_f , mm
Plain	20 weft/cm	1577.35	0.063	99.48
	28 weft/cm	1528.92	0.062	95.96
	45 weft/cm	1578.30	0.063	100.06
Twill	20 weft/cm	1708.50	0.058	100.05
	28 weft/cm	1673.53	0.060	101.78
	45 weft/cm	1567.90	0.0637	99.94
Satin	20 weft/cm	1584.50	0.0636	100.90
	28 weft/cm	1586.55	0.0646	102.54
	45 weft/cm	1547.32	0.0638	98.87

Table 2. Image processing summary of different weave types [22, 23].

Weft density	Plain	L_f length, mm				L_w length, mm			
		C_{Loom}	Twill	C_{Loom}	Satin	C_{Loom}	Plain	Twill	Satin
20 weft/cm	99.4	0.06	100.5	0.039	100.9	0.04	106.3	104.4	104.9
28 weft/cm	95.9	0.11	101.7	0.039	98.5	0.03	107.2	105.8	105.6
45 weft/cm	100.0	0.95	99.90	0.060	98.8	0.066	109.6	106.6	105.3

Table 3. Calculated warp elongation values (%ε) with weft densities, each weft density and each weave type on the loom [22, 23].

Weft density	Warp elongation, %ε		
	Weave type		
	Plain	Twill	Satin
20 weft/cm	4.22	2.43	2.87
28 weft/cm	5.14	3.73	3.54
45 weft/cm	7.49	4.54	4.20

Table 4. Warp tension i.e. change with each weft density and each weaving type (cN/tex) [22, 23]. Note: $E = 324.63$ cN/tex cotton yarn stiffness.

Weft density	Warp tension, cN/tex		
	Weave type		
	Plain	Twill	Satin
28 weft/cm	15.71	11.40	10.78
35 weft/cm	14.38	11.40	11.91
45 weft/cm	22.91	13.88	12.79

$$L_y = L_f \cdot (1 + C_{online}) \quad (5)$$

$$\Delta L = L_f \cdot (1 + C_{online}) - L_0 \quad (6)$$

$$\varepsilon = \frac{L_f(1+C_{online}) - L_0}{L_0} \quad (7)$$

$$L_y = L_f \cdot (1 + C_{online}) \quad (8)$$

Where,

- L_0 – first the distance between the lines ($L_0 = 102$ mm),
- L_y – the distance between the lines after weaving,
- L_{fpx} – the mean distance between the two weaves on the fabric in pixels (taken input matrix),
- L_f – the mean distance between the two weaves on the fabric in mm,
- L_y – the length of warp yarn in the fabric,
- C – the warp crimp,
- C_{online} – the warp crimp on the loom,
- μ – fabric shrinkage on the loom,
- λ – the unit converter between pixels in millimeters,
- ε – the warp elongation in the fabric,
- E – the cotton yarn stiffness.

Results and discussion

The results taken from image processing are given with pixels. The image processing was used while the loom was working, thus this analysis was performed in real time. The test results can be seen in Table 1 and 2. Fabric length (L_{fpx}) was measured as pixels from photos using the Matlab computer program, which is shown between two dots with weft densities and each weaving type.

$$L_0 = 102 \text{ mm}$$

L_0 – first warp length between two dots, belonging to the warp beam.

$$L_f = L_{fpx} \cdot \mu \quad (9)$$

L_f – fabric length (mm) converted from photos with pixels.

$$C_{online} = \frac{L_y - L_f}{L_f} \quad (10)$$

This is the general crimp formula when the loom is working.

$$L_y = L_f \cdot (1 + C_{online}) \quad (11)$$

Mean length of warp in the fabric with real time loom working calculated.

The tensions of warp yarns are found by multiplying their elasticity values by the stiffness value E. Warp tension in the fabric while the weaving machine was working was calculated according to both the weft density change and fabric type change. The tension of the warp yarns was calculated for three different weft densities of each of the plain twill

and satin weaves. Warp tensions vary widely for each weft density with changing fabric types. In **Figure 7**, we can clearly understand how the warp tension changes according to both the weft density change and fabric type change.

Other researchers found changed warp strain along with the loom [12, 13]. We can see variations in elongations in **Figure 7**. Süle found that warp yarns around the frame showed similar results with a change in the loom [18]. Warp tension was lower in the edge zones and increased towards the middle of the loom. It took the highest values around the middle of the loom width. The reason for this warp tension variation over the warp width was the slip of the weft yarn inwards in the fabric edge zones [18]. It is a very interesting phenomenon which extends the knowledge about the inequality of woven fabric in the width, which was investigated earlier by other authors [20, 21].

Here we see that the images of the fabric at different places in the width are not the same; the warps are flatter in the border part of the fabric (**Figure 8**), while in the central part fabric the projections of the warps in the plane of the fabric are significantly lower [21]. Rukuiziene Z. and Milasius R. showed that the fabric extension in the central region was increased when compared with the extensions in the borders of the fabric. Warp projection inequality influences many fabric characteristics, such as air permeability, thickness and even fabric strength and elongation. The investigations showed a particular regularity of fabric structure and properties which were unequal in width. An example of such regular structural inequality in width is presented in (**Figure 8**) [20]. Thus, the same fabric properties change in the weft direction. Our findings give results similar to those studies.

■ Conclusions

In previous studies, the tension values inside fabric were not considered, but the effects of the change in fabric type on the physical properties of the fabric were measured. The tension values of yarns in fabric have not been studied before. In this study, it is fully understood how the tension values of warp yarns of fabric change according to different weft densities and three different weave types while the weaving machine is running. In order to understand warp tension change according to fabric type, analyses were

made of the middle part of these three types of fabric. For all weft densities the warp tension in plain weave is variously high, increasing along with the weft density. Twill fabric has a slightly higher warp tension than satin fabric, except for a weft density of 20. In this study, the warp tensions calculated are based on the warp elasticity. Increasing the weft density in these three basic weaving structures increased the warp tension.

Furthermore, these warp tensions were obtained from the weaving machine, which was not working on the cut fabric. Significant findings were obtained to understand the mechanical properties of the fabric's internal structure while the weaving machine was operating. □

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