APPLICATION OF DIGITAL IMAGE CORRELATION TO DEFORMATION MEASUREMENT IN TEXTILE

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ABSTRACT: Digital image correlation (DIC) has proven to be an efficient technique for non-contact full-field strain measurement. Nevertheless, there have been no previous examples of using this technique to analyse strain in flexible textile fabrics. In this paper, a novel approach is developed based on DIC to monitor strain in textiles. The purpose of this paper is to demonstrate that DIC can be used to obtain full field strain maps from textile. The challenge is to use the weave of textile as the device for correlation. This can allow the technique to be applied to monitor strain in valuable textiles, such as historic tapestries.

1. INTRODUCTION

To measure strain in textile materials, conventional contact techniques such as strain gauges and extensometers have several weaknesses. Firstly, they can only provide strain information of single points. Secondly, they have to be in contact with the specimen surface, and can reinforce the material. Thirdly, they can be extremely difficult to attach securely to the surface of the specimen, and conventional adhesives may damage the material.

To overcome the limitations of conventional strain measurement techniques, a 3D DIC system is used to obtain full field strain maps of textile specimens. Both in-plane and out-of-plane deformations are accurately measured using two high-resolution cameras focused to the region of interest in the specimen at two different angles, so that stereoscopic pairs of images are obtained. These images are then correlated and strain information is obtained. In this way, unlike conventional strain measurement means, DIC can provide full field strain maps without the requirement of being in contact with the specimen. A major requirement for DIC is for a contrast on the surface of the specimen [1], so that correlation between the deformed and non-deformed data can be made.

Typically, a random pattern is used for the contrast, so that the DIC system can track the deformation [1]. If the surface contrast is not adequate for correlation, paint speckle pattern is often used to enhance it. However, because one of the long term aims of this work is to monitor strain in valuable textiles such as tapestries, a spray painted speckle pattern is obviously not an appropriate method to use.

This paper presents how accurate full field strain maps can be produced from static tensile tests on representative textile specimens using just the weave pattern of the textile surface as a means for correlation. Various patterns were applied to a three sets of specimens, and one set was left plain. Comparison of the strain maps produced shows that the weave of textile specimens by itself can provide good enough contract, and therefore can be used as the device for correlation. In addition to that, this paper demonstrates that full field strain maps from a long term creep test on a textile specimen can be obtained.

2. EXPERIMENTAL

2.1 Test specimens:

A representative plain weave white textile material was used. The specimens were 50mm wide and approximately 0.55mm thick. Fig. 1 depicts the three different patterns which were applied to the surfaces of the specimens. In order to investigate the reproducibility of the test results, five specimens with each of the patterns were prepared. Also, each of the specimens was tested three times to assess the repeatability of the experiment results. Overall, 20 specimens were prepared and 60 experiments were conducted.

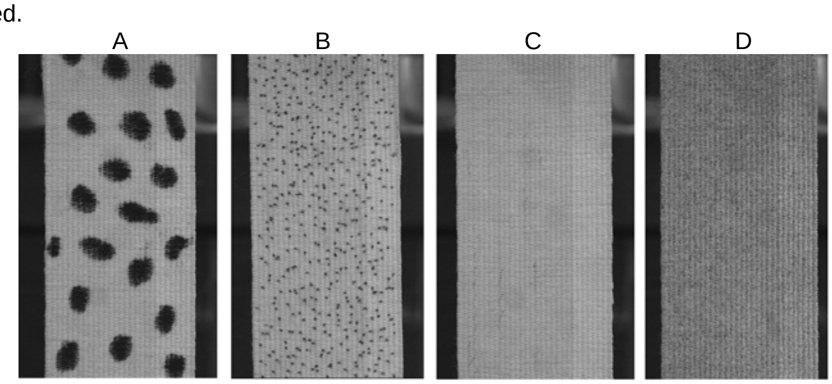

Figure 1- Representative textile Specimens with four different surface patterns

2.2 Specimen surface preparation:

The four sets of specimens were prepared as follows (Fig. 1):

- For set A, a black marker was used to draw a random pattern of dots which are on average between 8 mm and 12mm in diameter.
- For set B, a smaller black marker was used to draw a random pattern of small dots on the surface of the specimens. The size of these dots does not exceed 2mm in diameter, and they cover approximately 30% of the surface.
- For set C, no pattern was applied.
- For set D, a black base paint was sprayed on the surface to create a random pattern which covers approximately 50% of the specimen surfaces.

2.3 Experimental setup:

The two cameras of the DIC system are calibrated using an eight-step process. The calibration plate is used in the procedure has a defined pattern of white dots on a black background. The dots are equally spaced and have the same diameter. During calibration, the plate is slightly tilted toward and away from the cameras to allow three different views to be taken. These views provide the DIC system with enough information about the internal parameters of the cameras as well as the position and orientation of each camera [2]. After calibration, mechanical tests were carried out using an Instron 5569 servo-mechanical test machine, while the DIC system takes images at a given frequency. The frequency of image acquisition is a tradeoff between the number of the number of data points in the plots to be produced, and computational time.

2.4 Static tensile tests:

A 4 mm displacement was applied to each of the prepared specimens over a 120 second ramp. The load which had to be applied varied between 8N and 13N depending on the initial crimp in the specimens. The frequency of image acquisition was set to 1 Hz. Then, the resulting sequence of images we analysed using the DIC system software and full field strain maps were produced.

The results showed that surface patterns B and D generate equivalent uniform strain maps, which are also identical to the strain maps produced from the specimens with surface pattern C; which proves that the weave in the textile representative material provides enough contrast for correlation to work. Initially, the results obtained from the specimens with surface pattern A showed unusually high strain values in the regions inside the black dots. The reason for that is the size of the dots and the large difference between the values of the pixels inside the dots and the pixels in the white regions, which caused the DIC software to treat them differently. The solution to this difficulty is to use a “subtract sliding average” template, which is an image processing filter that slides a template over the image, calculates the average value inside the template every time, then subtracts it from each element in the template. When this technique was applied to the images of the specimens with surface pattern A before strain computation, the resulting strain maps were uniform and identical to the specimens with patterns B, C, and D.

2.5 Long term creep test:

A textile specimen similar to the one shown in the right of Fig. 1 was put under a constant load of 30N for a period of 90 hours. The frequency of image acquisition of the DIC system was set to 0.0033 i.e. one stereo-pair of images was taken every 5 minutes. Then, the images were analysed and the DIC system was used to produce full field strain maps and plot the longitudinal strain against time. The slope of the resulting curve resembles the slope of a steady-state (secondary) section in a typical creep curve. The creep strain in this stage is linearly related to time through the following equation [3]:

$$\varepsilon = Kt \tag{1}$$

Where K corresponds to the creep rate, and can be estimated through the following equation:

$$\frac{d\varepsilon}{dt} = A\sigma^{n} e^{\frac{-Q}{RT}} \tag{2}$$

Where A and n are constants, Q is the activation energy for creep, and R is Boltzmann’s constant [3].

3. SUMMARY:

Full details of the test procedure and results from the quasi-static and creep tests are given in the presentation. These demonstrate that DIC is suitable for measuring deformation in textiles.

4. REFERENCES:

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