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Digital image correlation (DIC): Decorrelation problem due to large strains

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Abstract. *The digital image correlation (DIC) method was used to calculate the strain field of a sample experiencing large deformations during a tensile test. Two codes were used for the calculation (the iCorrelate-vision 2D code and GOM software). Three calculation options were applied; the spatial correlation of images was evaluated, as was the incremental correlation of successive images. A comparison of the results is given in the article. Mainly, the decorrelation problem arises due to the poor matching between the correlated subsets in the case of large strains. Poor matching can result from large changes in the speckle pattern. Updating the reference image can minimize these changes. When using a fixed reference image, the correlation algorithm will not be able to track significant changes in the deformed target subset, which will lead to a failure in the matching between the reference and deformed subsets, even when using correlation algorithms with very high efficiency.*

Key words*: Digital Image Correlation, Large strain, Decorrelation, optical inspection of surfaces.*

Introduction

In engineering, visual inspection of surfaces is regarded as the first conventional method for assessing the condition of mechanical and civil structures. The optical inspection technique is considered an extension of visual inspection. Optical inspection techniques are superior to visual inspection as they are capable of detecting not only microscopic defects on the tested surfaces but also cracks under the inspected surfaces [1]. A promising optical method for strain field evaluation is digital image correlation. The 2D-DIC method is an optical technique for non-destructive testing that must follow three basic steps: surface preparation to create an artificial speckle pattern; digital image recording during all the different loading stages; and image processing using computer code to extract the strain field and several other parameters [2].

A full-field strain might be easily calculated using DIC. Essentially, a series of sequential digital photos are taken as the surface deforms, and each distorted photo is compared to a single reference photo that was taken before any deformation. Using a fixed reference image, the prior method is regarded as a traditional DIC.

Methodology

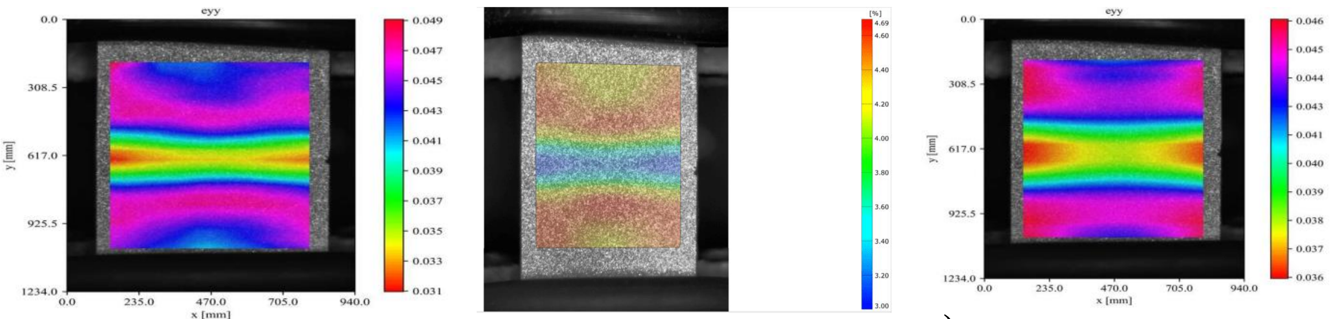
The DIC method was used to inspect a metal surface that was experiencing large strains during a tensile test. The bead-blasting method was used to apply the speckle pattern to the surface of the stainless-steel specimen. Without changing the specimen's dimensions, the bead-blasting process eliminates material from the tested surface. The speckle pattern was created by shining the ring light on the bead-blasted surface. A set of images containing the reference image was selected from sample 13 of the DIC challenge report [3]. The general DIC parameters were set as follows: For the subset size, it was set at 81×81 pixels, and the step size was 40×40 pixels. The values of the subset size and the step size were chosen according to the recommendations of "A Good Practice Guide for Digital Image Correlation" issued by the International Digital Image Correlation Society (iDICs) [4]. The bi-cubic interpolation was applied to achieve sub-pixel accuracy. The full-field strain was computed by analyzing the tensile test photos using iCorrVision-2D code and GOM correlate software.

The deformed images were correlated spatially (by applying one reference image) and incrementally (by updating the reference image). In the case of the spatial correlation, the first image served as a fixed reference image. In the scenario of incremental and spatial correlation, the strain field in the Y-direction Eyy was computed. The strain field was calculated, and a strain-field color map was displayed for stages 3 and 4. Based on the calculations of the iCorrVision-2D code and the GOM correlate program, the results of each case were compared.

Results

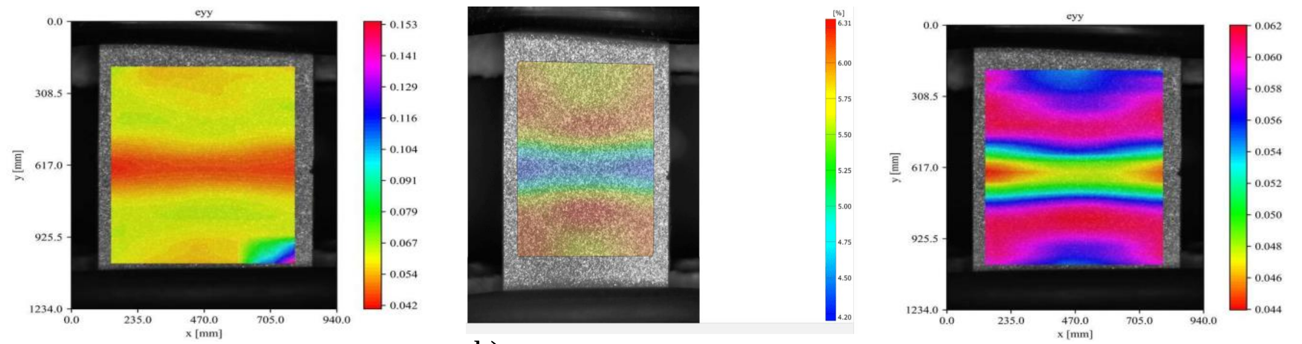
Both spatially and incrementally correlated images were used to compute the Eyy strain field results. Three cases (a, b, and c) with computed strain field data were compared. In case a, images were spatially correlated. The same calculations were repeated for cases b and c with incrementally correlated images. The results of the spatially correlated image were unreliable because of poor matching, or what is known as the de-correlation effect. It is clear from Figures 1 and 2 for the strain field data that the image began to de-correlate after the third-stage image. From spatially correlated images, the strain field value, up to a maximum of about 5 %, could be computed. The strain field values higher than 5 % between the reference image and the deformed image underneath the same scenario for correlation (e.g., the subset size of 81×81 pixels) lead to significant errors in the results. However, the incrementally correlated results showed good agreement for both codes.

This inaccuracy arises from a poor match between the original fixed reference picture prior to deformation and the images at the present stage of deformation. It's crucial to note that case a's maximum strain field value for the third stage of deformation is 4.9 %, which is extremely similar to case b's and case c's values of 4.6 % and 4.69 %, respectively. Figure 1 shows the results from the third stage of deformation, while Figure 2 shows stage 4 of the deformation of the sample.



a) b) c)

Fig. 1. The third stage strain field Eyy for the three cases:
(a) spatial correlation using iCorrelate code; (b) incremental correlation using GOM software; and (c) incremental correlation using iCorrelate code



a) b) c)

Fig. 2. DE correlation problem in the fourth stage of strain field Eyy for the three cases:
(a) spatial correlation using iCorrelate code, (b) incremental correlation using GOM software, and (c) incremental correlation using iCorrelate code

Conclusion

For large strains, the DIC can suffer from the DE correlation. Based on the shown results, it is clear that the incremental correlation outperforms the spatial correlation in the case of large strains. Reducing the differences between the two images with large strains is one way to reduce the DE correlation impact. By employing a deformed image from the previous correlation as a new reference image in the current step of correlation rather than using the same initial image in each correlation step, updating the reference image might minimize the change. When utilizing a fixed reference image, the correlation algorithm will not be able to track significant changes in the deformed target subset, which will lead to a failure in matching between the reference and deformed subsets. Nevertheless, in the majority of cases, the traditional DIC with spatial correlation can provide a reliable strain field result. Large deformations, significant variations in surface illumination, or other factors might alter the speckle pattern during the correlation process, which can have a detrimental DE correlation effect. The problem could be solved by updating the reference image.

References

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