Uncertainty quantification of Digital Image Correlation measurements based on projected speckle patterns

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Abstract

Validation of computational solid mechanics models intended for use in predicting structural integrity is based on the suggestion that validation should be performed using full-field maps of surface strain and / or displacement, as recommended in the recent CEN guideline [1]. Digital Image Correlation (DIC) is a promising full-field measurement technique, which however requires the estimation / quantification of measurement uncertainty before its application in full-field displacement / strain measurements.

The scope of the present work is to propose a simple methodology to determine the DIC measurement uncertainty. The developed methodology is based on the display of un-deformed and deformed speckle patterns on an LCD screen and the measurement of the imposed displacements/strains utilizing a DIC system. Displacements of the displayed speckle pattern can be created either by moving the speckle pattern on the screen or by moving the screen. Deformed speckle patterns are created using results of FE analyses of structures having geometrical and structural characteristics similar to the physical structure to be measured by the DIC system.

The proposed uncertainty quantification methodology comprises a series of successive steps, which are briefly presented hereafter. Initially the Regions of Interest (ROI) of the structure to be tested under appropriate boundary and loading conditions are defined. Based on these, FE models are developed and solved for the calculation of nodal displacements and strains. The FE results are used in the creation of reference (un-deformed) and deformed speckle patterns utilizing appropriate software, such as DantecSPG [3]. The reference and deformed speckle patterns are then directly imported into the DIC software as image files, and displacement / strain fields are calculated by the DIC software. Consequently, the displacement and strain fields which have been previously calculated by the FE and by the DIC software are decomposed using Zernike, Tchebichef or another decomposition basis, and shape descriptors are determined. A comparison of the shape descriptors from FEA and DIC provides the basis for a quantification of the uncertainty related to the speckle pattern creation and DIC calculations, excluding the effect of the other DIC system parts, such as the cameras, lighting, environmental conditions, etc. Finally the reference and deformed speckle patterns are displayed on a high resolution screen, captured and evaluated by the DIC system; and again, compared to the respective

displacement and strain fields calculated by the FE resulting in the quantification of the entire DIC system's uncertainty, according to the CEN guideline data comparison methodology [1].

The proposed methodology flowchart is presented in Fig. 1.

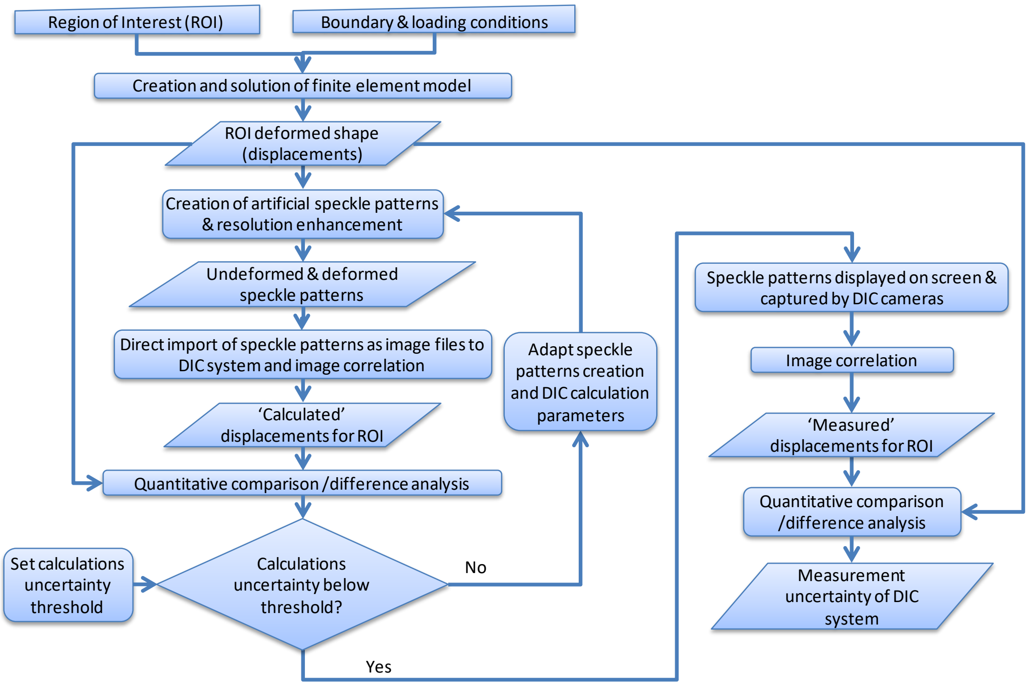

Fig. 1. Methodology of DIC uncertainty quantification based on un-deformed and deformed speckle patterns.

The above methodology for uncertainty quantification has been successfully demonstrated in the framework of the EU project MOTIVATE [2] for the case of un-deformed and displaced speckle patterns of a flat plate under uniform strain, as well as for a plate with a hole under tension exhibiting strain concentration.

Acknowledgement

This research has received funding from the Clean Sky 2 Joint Undertaking under the European Union's Horizon 2020 research and innovation programme under grant agreement No 754660 MOTIVATE and is supported by the Swiss State Secretariat for Education, Research and Innovation (SERI) under contract number 17.00064. The views expressed are those of the authors and not the Clean Sky 2 Joint Undertaking.

References

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