Impact of depth of field reduction on stereo DIC-based model validation

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Abstract. This study is a part of a series of investigations aimed at improving the credibility of validation of Finite Element (FE) models using full field Digital Image Correlation (DIC) measurements and identifying sources of uncertainty that are often overlooked. Validation typically relies on the quantitative comparison of kinematic fields (notably strain) through difference maps. A critical challenge is interpreting these differences and attributing them to their underlying causes. Within this context, the current research investigates the impact of image blurring resulting from limited depth of field in tests with relatively large out-of-plane movements. To isolate this effect, a benchmark test based on rigid body motion in the depth direction is performed, reproducing similar conditions without introducing actual deformation. The findings highlight that such effects can introduce significant uncertainty in stereo DIC measurements, especially in small strains conditions at relatively large out-of-plane motions and should therefore be explicitly considered in validation.

Introduction

Full-field deformation measurement, like Digital Image Correlation (DIC), provides spatially dense information impossible to attain with conventional point-based sensors. This high data density naturally aligns with the output of Finite Element (FE) simulations, creating an opportunity for direct and detailed quantitative comparisons between experiments and simulations. Despite this apparent similarity, the use of DIC as a rigorous validation tool for mechanical modelling remains relatively immature, though it is gradually gathering attention in the community. Existing studies on quantitative FE model validation can broadly be divided into two main approaches. The first one relies on decomposing the surface measured kinematic field using a set of predefined two-dimensional kernels, which are formed from discrete orthogonal polynomials [1, 2]. The coefficients of the fitted kernels are collated into a vector and compared with that of the model. However, these approaches are limited because they do not take into account the intrinsic systematic errors in the DIC process. The second approach relies on creating synthetic images from the FE model, a so-called Digital Twin (DT), which is then processed using the same DIC configuration [3]. This “DIC-levelling” approach enables direct, point by point comparisons and has delivered promising results in more complex applications. The main challenge however is to understand and quantify the full set of DIC error sources. Most of the existing literature does not systematically address uncertainty quantification (UQ) in model validation [4, 5]. Notable recent works by Peshave et al. [6, 7] provide a comprehensive overview of potential uncertainty sources and highlight the importance of involving heterogeneous DIC noise maps to better represent random uncertainties in practice. These studies show that many of the uncertainties can be handled either through statistical analysis of stationary images or by using the digital twin. However, the specific impact of losing depth of field during out-of-plane deformations has not been considered yet.

The present work focuses on this overlooked issue. It investigates the effect of depth of field loss experimentally through a dedicated test and explores whether this phenomenon could be potentially representable by the digital twin. To do so, the study looks into advanced principles from optics and photography to better understand and describe the mechanisms behind depth of field induced blurring, and the consequent effects on the measured kinematic fields.

Optical principles

Depth of field blurring occurs when a point on an object is not perfectly focused on the image sensor. In this case, the light rays originating from that point do not converge to a unique point on the camera sensor but spread over a small area called the Circle of Confusion (CoC). The diameter of the CoC depends on the distance of the object to the focal plane, as well as the optical settings (focal distance and the aperture size) [8]. When the object is exactly in focus, the CoC is minimized, hence a sharp image is captured. As the object moves away from the focus plane, the CoC increases and creates the visual effect of blur. In the context of DIC, this blurring effect causes the neighbouring fuzzy circles overlapping each other and blending details together. Hence it eventually smooths the speckle pattern and reduces local intensity gradients. The correlation algorithm may then interpret these pattern changes as apparent deformation, causing spurious strains affecting the measurements.

Experimental setup

A dedicated test was designed to experimentally isolate and quantify the effect of depth of field blurring during rigid body motions. This test uses the same specimen as that tested for the FE validation study, which is translated step by step from the focused state along the out-of-plane (depth) direction. The imposed displacements were chosen to match the range of out-of-plane motion observed at the loading tip in the reference FE model validation study. At the starting position, the cameras were carefully focused to get a sharp reference image. The specimen was then progressively moved away from this focal plane while remaining undeformed. These slight shifts relative to the focal plane caused gradual loss of focus visually apparent on the captured images. Each defocused image was then correlated to the initial (fully focused) reference image using the commercial software MatchID. This setup provided a controlled way to practically assess how optical defocusing alone can influence DIC measurements.

Results and discussion

As shown in Fig. 1, there is a spurious strain bias (spatial average) which increases monotonically with the magnitude of the out-of-plane motion, while the spatial distribution of strain remains fairly random. In addition, the spatial standard deviation of the spurious strain grows exponentially with increasing out-of-plane motion, indicating that the random part of the error also grows along with the bias. In fact, even in the absence of any real deformation, rigid body motion in the depth direction introduces an additional source of error. Such an effect contributes to the overall error budget and should be accounted for in the FE model validation framework, along with the other sources of error. In practice, the out-of-plane movement is not uniform in the real bending test, so this contribution to the error budget should ideally be incorporated in the DT. This is underway.

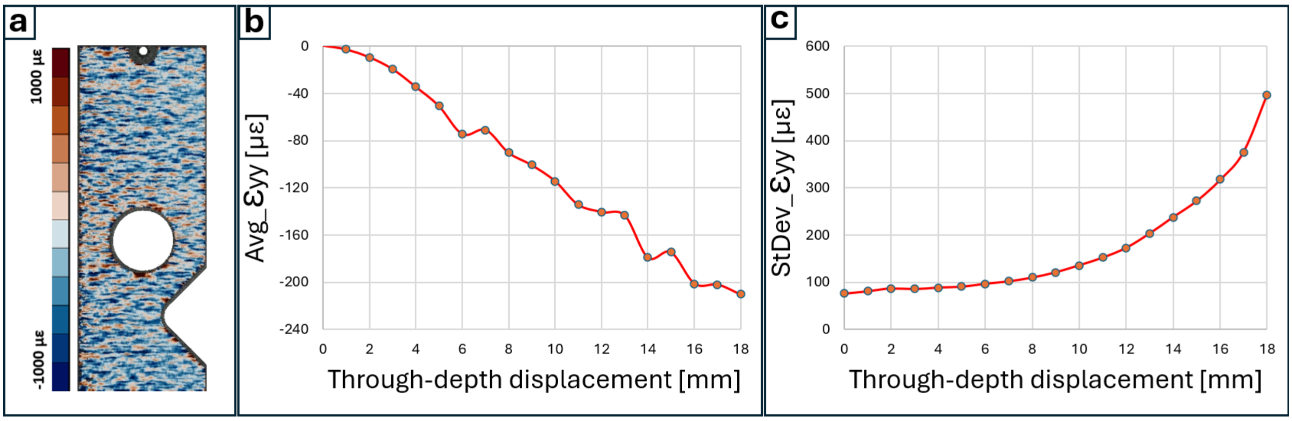

Fig. 1 – Spurious longitudinal strain: Spatial distribution at final stage of motion through depth (a), evolution of the [spatially] averaged value (b) and standard deviation (c) through time.

References

[1] E.A. Patterson, et al., *Calibration and evaluation of optical systems for full-field strain measurement.* Optics and Lasers in Engineering, 2007. **45**(5): p. 550-564.

[2] K. Amjad, et al., *Quantitative comparisons of volumetric datasets from experiments and computational models*, IEEE Access, 2023. **11**: p. 123401–123417.

[3] P. Lava, et al., *Validation of finite-element models using full-field experimental data: Levelling finite-element analysis data through a digital image correlation engine.* Strain, 2020. **56**(4): p. e12350.

[4] E.M.C. Jones, et al., *Anisotropic plasticity model forms for extruded Al 7079: Part II, validation.* International Journal of Solids and Structures, 2021. **213**: p. 148-166.

[5] A. Peshave, et al., *Metrics to evaluate constitutive model fitness based on DIC experiments.* Strain, 2024. **60**(5): p. e12473.

[6] A. Peshave, et al., *Practical uncertainty quantification guidelines for DIC-based numerical model validation.* Experimental Techniques, 2025. **49**: p. 437-457.

[7] A. Peshave, et al., *DIC-Based Finite Element Model validation: A practical case study for in-plane loading of a composite laminate.* Experimental Mechanics, 2026. **66**: p. 37-66.

[8] M. Potmesil, et al., *Synthetic Image Generation with a Lens and Aperture Camera Model*. ACM Transactions on Graphics, 1982. **1**(2): p. 85–108.