Architecture-Driven Digital Volume Correlation for Measuring the Deformation of the Cell-Struts in a Cellular Material Undergoing Crushing

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ARCHITECTURE-DRIVEN DIGITAL VOLUME CORRELATION FOR MEASURING THE DEFORMATION OF THE CELL-STRUTS IN A CELLULAR MATERIAL UNDERGOING CRUSHING

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ABSTRACT

Measuring displacement and strain fields at low observable scales of complex microstructures such as cellular materials still remains a challenge in experimental mechanics, often because of images with low definition and poor texture at this scale. Here, we develop a Digital Volume Correlation (DVC) method that allows to measure the deformation of the cell-struts of a cellular material undergoing crushing. It consists of a DIC method assisted with a physically sound weak regularization using an elastic finite-element image-based model at the architecture scale. With this technique, the non-linear response at the architecture scale, in particular local buckling, of a polyurethane foam under compression, is properly described.

Keywords: digital volume correlation, X-ray microtomography, image-based modelling, mechanical regularization, cellular materials.

INTRODUCTION

Digital Volume correlation (DVC) aims at identifying the displacement fields that allow to match several volume images of a sample captured (*e.g.* with X-ray computed tomography) at various loading steps [1,2]. With cellular materials, DVC is confronted with a paradox: the scale of the architecture is merged with that of the texture, whereas the texture should be defined at a lower scale. This problem has led DVC users to consider elements (global DVC) or subsets (local DVC) of large size compared to the architecture [1,2,3], which precludes the measurement of kinematic field below the cellular scale, *i.e.* at the architecture scale. Here, we propose a DVC method that breaks this barrier and improves the resolution of the measurement despite the absence of texture. It is based on the so-called Architecture-Driven Digital Image Correlation Technique (ADDICT) [4]. The idea is to benefit from advanced image-based model routines [5] to build a simple linear elastic finite-element regularization model, but that is associated with the architecture of the material. This model is then used as a mechanically sound *a priori* to assist DIC through a weak Tikhonov-like regularization scheme [6]. The strategy thus breaks with the current practice in the field: the regularization model now incorporates precisely the true geometry of the cellular material at the architecture scale and the regularized DIC is formulated only over the architecture, thus circumventing any homogenization treatment. From a global point of view, we exploit the information coming from the movement of the cell boundaries through the graylevel metric of standard DIC (low frequency part of the solution) and locally prescribe elasticity to complement the solution within the cell-struts (high-frequency part of the solution).

RESULTS AND CONCLUSIONS

The potential of the derived architecture-driven DVC is highlighted by measuring the complex kinematics resulting from crushing in a polyurethane foam subjected to an *in-situ* compression test. The tested cellular sample along with its physical dimensions are given in Fig. 1(a). Some corresponding results are shown in Figs. 1(b) and (c). More precisely, a zoom is performed in Figs. 1(b) and (c) on some regions where large deformations occur. These figures consist in superimposing, on the deformed image, the mesh constructed on the reference image, advected by the measured displacement field. In Fig. 1(b) a classic DVC approach is applied while our approach is implemented in Fig. 1(c). It can be seen that the developed approach accurately identifies the localized large deformations of individual struts, whereas the classic method fails. Therefore, the proposed method pushes the limits of traditional DVC capabilities, which should contribute to better understanding and characterizing the behaviour of cellular materials.

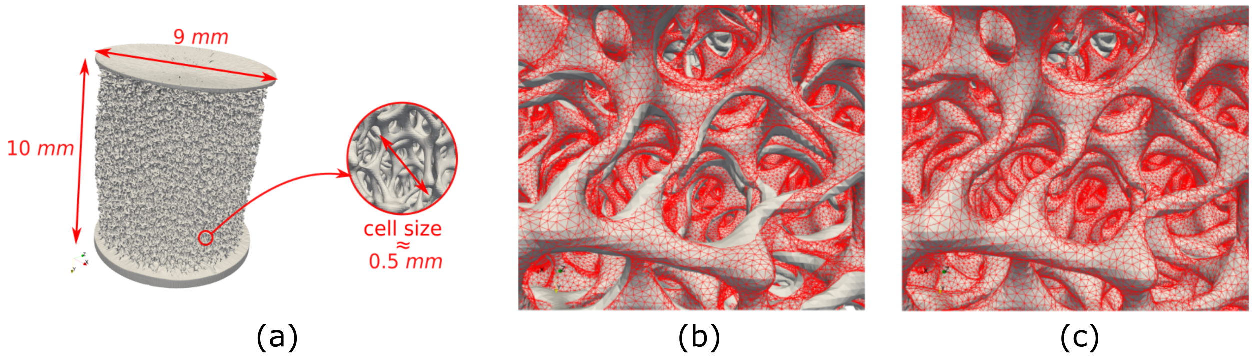

Fig. 1 – (a) Tested cellular sample. (b)-(c) In grey color: deformed image, in red color: mesh advected by the measured displacement. (b) Classic DVC. (c) Developed architecture-driven DVC.

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