Designing innovative materials using 4D imaging informed by Digital Volume Correlation

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Summary: Digital Volume Correlation is an exciting bulk displacement/strain measurement technique in experimental mechanics, materials science and biomechanics. Critical attention is paid to some parameters when designing a DVC experiment which can be handled using our unique platform for DVC. This is illustrated by real applications in healthcare and glass industry.

1. INTRODUCTION

Over the last two decades, advances in 3D imaging techniques such as X-ray computed tomography have enabled in situ imaging of time-dependent processes inside materials. The new opportunities offered by these nondestructive 3D imaging modalities led to the development of Digital Volume Correlation, a powerful contactless technique that exploits the natural contrast of materials to capture 3D internal full-field displacements and strains at different stages of a loading experiment. When designing a DVC experiment, attention is paid to several parameters such as spatial resolution, texture, noise/CT artefacts, measurement uncertainties, and the loading mode/magnitude. Amira-Avizo XDVC software implements powerful DVC algorithms and dedicated tools allowing bespoke DVC analysis for a wide range of applications. This work covers the basics of DVC, how to set up a DVC experiment, and how Amira-Avizo XDVC can be combined with advanced image processing and 3D visualization to (i) optimize the design of new cements for vertebroplasty [1] and (ii) guide the manufacturing of ceramics for high temperature applications [2].

2. EXPERIMENTAL METHOD

Prior DVC analysis, the CT data were coarse-registered to suppress the rigid body motion. Due to the complex shapes of the specimens (vertebrae for vertebroplasty, cylinder for ceramics), a global FE-DVC approach was used to capture the exact shape [3]. The data were segmented and converted into 3D tetrahedral grids (Fig. 1a) with a mesh size that was adjusted following a measurement uncertainty study from repeated scans (Fig. 1b).

3. RESULTS

Our unique platform for DVC combines advanced registration, segmentation, meshing and visualization tools that allow to quantify deformation-induced morphological changes in complex situations. First, the results enabled us to study the impact of injected cement volume on the strain transfer between bone and cement. When the volume of cement covered about half of the total vertebrae, the cement became stiffer. Most of the strain was captured by the bone generating high strains in the bone and high shear at the bone-cement interface. Secondly, the volumetric strains during the phase transformation of zirconia ceramics was quantified during manufacturing. Complex, heterogeneous strains were observed during the transformation which will be used in the future to inform and validate FE models at different scales.

References

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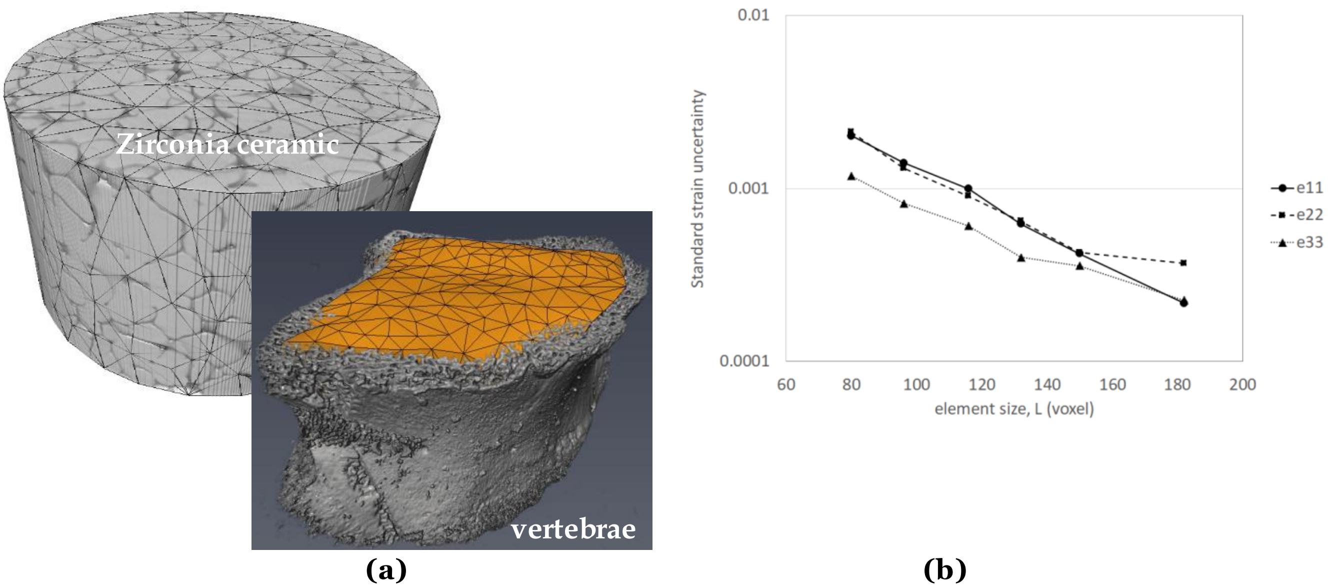

(a) (b)

Figure 1: (a) 3D tetrahedral grids of a zirconia ceramic and a vertebrae. (b) standard displacement uncertainty versus element size (ceramic)