In-situ mechanical experiments analyzed via 2P-DVC

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Abstract

X-ray tomography is a consolidated tool to investigate material microstructures and their correlation with processing parameters. It can be applied to a wide range of materials and is commonly used for composites, ceramics, metals, and natural materials, among others. Another benefit is the vast range of resolution, which is constantly evolving with the developments of new x-ray sources and detectors – in laboratory tomographs and synchrotron facilities – with one voxel of the volume being able to represent sub-micron dimensions up to the millimeter scale. In mechanical analyses, in-situ experiments can be performed by imaging the same sample sequentially after some loading. This may give a direct visualization of damaging mechanisms such as cavitation after plastic deformation or crack initiation and propagation. The common practice is maintaining the load at a few different steps for complete tomographic acquisitions to avoid (or diminish) motion blur in the reconstructed volumes. In this approach, Digital Volume Correlation (DVC) can be applied to the acquired volumes, giving access to spatially rich 4D measurements.

It is possible to increase by approximately 1000 times the temporal resolution by directly exploiting radiographs taken during the experiment – without the need to stop the loading – instead of entire volumes, allowing further exploration of experiments where significant changes may happen during loading dwells. For this, the so-called projection-based DVC (P-DVC) can increase temporal resolution at the expense of reduced spatial kinematics. In P-DVC, an initial reference volume is reconstructed, and a residual is defined as the difference between the radiographs acquired during the experiment and the volume reprojection. The residual is iteratively minimized by correcting the volume with a motion described by its components on a chosen kinematic basis. When dealing with a radiograph, one drawback is the low sensitivity to displacements perpendicular to the detector plane. Although this may be tackled by rotating the sample during the experiment (with added complexity in the analysis), this remains a physical constraint that may limit the test duration.

This work aims to perform ultrafast experiments by fully exploiting the dual-beam microfocus high-energy tomograph located at INSA-Lyon (France), with 2P-DVC exploring the radiographs taken simultaneously from two crossed tomograph lines. By having the second line orthogonal to the first one, the sensitivity in the out-of-plane direction of each line is enriched, further increasing the spatial resolution of the obtained kinematics compared to

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a single tomograph case. For this, a single initial volume is reconstructed with the Astra toolbox using radiographs from both lines after a precise calibration of the system geometry. Then, radiographs are acquired on the fly from both lines during the mechanical test. In a post-processing step, the difference between these radiographs and the volume reprojection in both directions is minimized simultaneously with respect to kinematic parameters. The latest advances in this methodology will be presented with examples of experiments with fast phenomena, such as viscoelasticity or crack propagation, showing the current state of the implementation and usage at the MatéIS laboratory. This work is performed within the ADAM project of the research program DIADEM and received government funding managed by the French National Research Agency (ANR) under the France 2030 program, reference ANR-22-PEXD-0002.