INFLUENCE OF X-CT SCANNING PARAMETERS ON DVC MEASUREMENT UNCERTAINTY

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1. Introduction

X-Ray Computed Tomography (X-CT) and Digital Volume Correlation (DVC) are powerful tools for comprehensive characterization of opaque materials. As opposed to high frequency image sampling with classical cameras, CT scanners require tens of minutes if not hours to record a single high-quality set of radiographs. Moreover, numerous states of the sample need to be acquired to describe the entire loading history of a single in-situ mechanical test monitored via XCT. To surpass these limitations, several strategies can be followed. Projection-based Digital Volume Correlation (P-DVC) [1] overcomes these challenges by extracting the measurands (*i.e.*, displacement and strain fields) directly from few radiographs instead of completely reconstructed volumes. Further, the effect of material relaxation originating from its time-dependent behavior is mitigated since X-CT projections are captured continuously (and fast) during loading. The second route includes conventional DVC analyses on scans acquired with different scanning parameters [2]. For instance, a decrease of imaging time is achieved by recording scans with lower quality. Even though this approach does not exclude spurious motions during acquisition, more detailed temporal evaluations can be conducted, for instance, for damage with respect to the underlying microstructure.

The aim of this study was to assess DVC measurement uncertainties between volumetric images acquired with different scanning parameters. Three different configurations were considered to image a slender sample made of continuous glass fiber mat reinforced polyester resin. Internal 3D displacement and strain fields were quantified via FE-based DVC implemented within the Correli 3.0 framework of LMPS.

2. Experimental Protocol and DVC analysis

Among different approaches of DVC measurement uncertainty evaluation, the method applied in this work consists in analyzing consecutive scans of the sample in an unloaded state without artificially adding noise and/or deforming one of the images. Three consecutive scans of a 5.2 mm thick dogbone specimen with the narrowest gauge length equal to 5.6 mm were acquired with the X-View X50-CT scanner of LMPS. The source setting was 150 kV and 80 µA (Table 1). The voxel size (using a 2 × 2 binning at the acquisition stage) was set to be 14.6 µm.

Table 1. Scanning parameters for three configurations (*i.e.*, *HQ*, *LQ* and *continuous* scans)

Scanning parameters	HQ	LQ	continuous
Voltage, kV	150		
Current, µA	80		
Number of projections	800		768
Delay, ms	50		0
Frame average	20	1	
Frame rate, fps	3		
Acquisition duration, min	110	15	4
Volume size	485 × 590 × 1237		
Image scale, µm/voxel	14.6		

The projection acquisition parameters were different for the three configurations. The *HQ* and *LQ* scans were reconstructed from radiographs acquired in a stepwise mode (*i.e.*, at each angle the turntable was stopped) while *continuous* 2D projections were captured on-the-fly without stopping the rotation of the sample (delay parameter in Table 1). Eight hundred radiographs were acquired over a 360° rotation for *HQ* and *LQ* scans while the *continuous* scan was reconstructed from 768 projections. Each *HQ* radiograph was averaged with 20 projections in order to reduce the random noise fluctuations (Fig. 1). The total *HQ* scan duration lasted approximately 2 hours, while the acquisition of *LQ* and *continuous* scans took 15 and 4 min, respectively.

In order to determine the influence of the on-the-fly scanning protocol, the *HQ* imaging parameters were taken as reference in the correlation procedure. The measurement uncertainties were assessed as functions of the spatial resolution (*i.e.*, element size). Nine FE meshes were constructed over the same Region of Interest (ROI) with different element sizes ($140 < \ell < 8$ voxels).

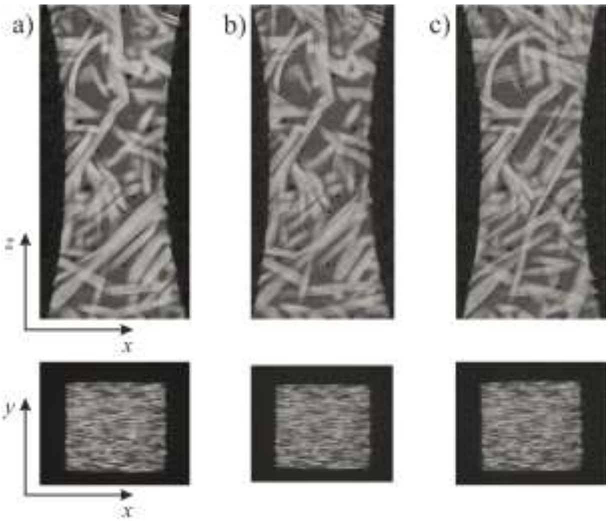

Fig. 1. Front and top mid slices of a) *HQ*, b) *LQ* and c) *continuous* scans.

3. Results and Conclusion

The measurement uncertainties were evaluated as the standard deviation of the nodal displacements $\overline{\sigma}_U$ and elementary eigen strain $\overline{\sigma}_\varepsilon$ uncertainties of the stepwise and continuous projection acquisition approach are compared with respect to the element length in Fig. 2. The *LQ* scan yielded lower measurement uncertainties for $\ell > 24$ voxels. However, smaller elements (*i.e.*, $\ell < 16$ voxels) the continuous scan led to lower standard displacement uncertainties. The same trends are observed for the standard strain uncertainty. However, smaller differences between the two quantities were observed for element lengths less than 50 voxels. Since *LQ* and *continuous* scans reported approximately the same uncertainty levels, it is concluded that savings in acquisition time can be achieved by selecting an on-the-fly scanning protocol without significant impact on the measurement uncertainties.

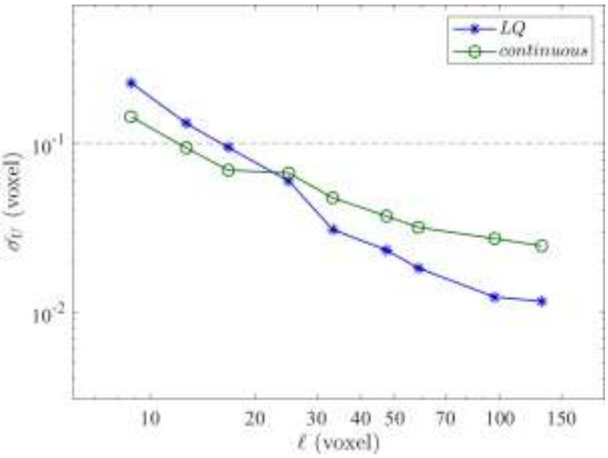

Fig. 2. Standard displacement uncertainties as functions of the element size.

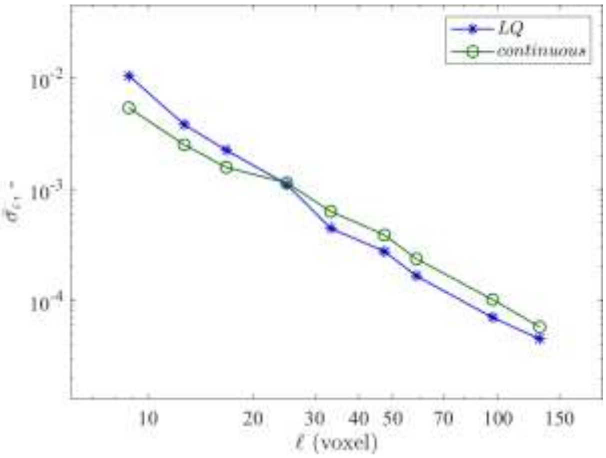

Fig. 3. Standard strain uncertainties as functions of the element size.

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