

X-ray microtomography, X-3D-Digital Image Correlation and X-FEM multigrid, a general tool for 3D crack growth law identification.

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ABSTRACT

The present paper aims at showing that coupling the eXtended Finite Element Method with X-ray microtomography and 3D digital image correlation provides a very promising tool to assess the 3D behaviour of arbitrary shaped cracks and to perform comparisons of “experimental” and simulated” crack shapes during propagation [1].

At first, 3D X-ray microtomography enables one to get 3D pictures of the local density of solids. Image and/or volume correlations require a random texture. Exploiting the resolution of the acquisition device available at INSA Lyon, cast-iron samples containing a fatigue crack were selected to provide adequate (random) markers. The graphite nodules provide a random texture in the images (Fig. 1). A testing machine inside the tomograph allows for taking 3D pictures of the specimen during a tensile test. The crack is visible on the deformed picture of the specimen, see Fig. 1:

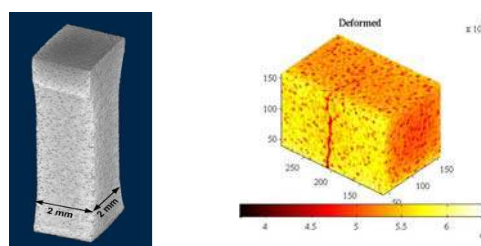


Figure 1. *3D image adapted for 3D DIC and deformed picture of the specimen*

In a second step, a 3D image correlation technique allows for the measurement of 3D displacement fields in the presence of cracks [2] [3]. It opens the way to a study of fatigue crack propagation based on an in-depth determination of the crack geometry. Moreover, stress intensity factors along the crack front may be evaluated by post-processing the measured data. Under cyclic loading, such a tool may clarify the role of partial crack closure induced by crack tip plasticity, not only from a global examination, or free surface investigation, but in the entire sample volume, see Fig 2:

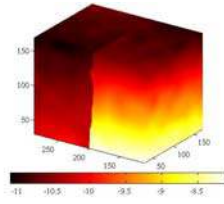


Figure 2. Displacement field along the loading axis (normal to the crack orientation) expressed in voxels (1 voxel = 13.5 μm).

In a third step, a X-FEM local multigrid strategy is presented in order to obtain a simulated crack shape during propagation with a level set modelling of the crack extracted from the 3D image [4]. The method is able to account for the multiscale problem ranging from the scale of the initial pre-existing crack to the scale of the structure itself. This method combines the extended finite element method, which avoids remeshing the structure during the crack propagation, with a local multigrid technique. Furthermore, the use of a single independent structured mesh for the level sets description has been shown to be very robust and accurate.

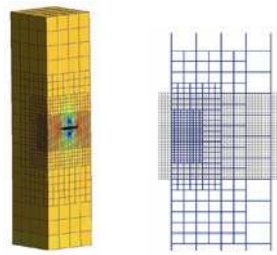


Figure 3. Deformed mesh from local multigrid X-FEM modelling and independent structured mesh for the level sets

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