8th. World Congress on Computational Mechanics (WCCM8)
5th. European Congress on Computational Methods in Applied Sciences and Engineering (ECCOMAS 2008)
June 30 – July 5, 2008
Venice, Italy

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

PROPAVANFIS Collaboration* - FRANCE

*Co-authors: Baïetto M.C. (1), Buffière J.Y. (2), Combescure A. (1), Gravouil A. (1), Hild F. (3), Limodin N. (2), Ludwig W. (2), Rannou J. (1), Réthoré J. (1), Roux S. (3), Tinnes J.-P. (2)
(1) LaMCoS, INSA Lyon, F-69621 Villeurbanne, France
(2) MATEIS, INSA Lyon, F-69621 Villeurbanne, France
(3) LMT-Cachan, ENS de Cachan, F-94235 Cachan, France

e-mail : anthony.gravouil@insa-lyon.fr

Key Words: *X-FEM multigrid, X-ray microtomography, X-3D Digital Image correlation*

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:

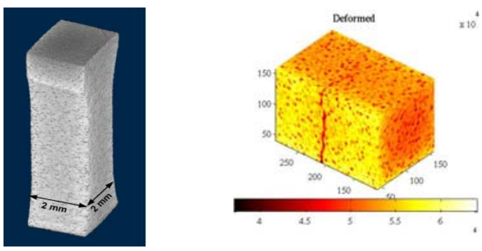

Figure 1. *3D image adapted for 3D DIC and deformed picture of the specimen*

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:

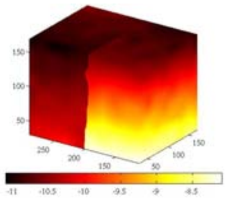

Figure 2. *Displacement field along the loading axis (normal to the crack orientation) expressed in voxels (1 voxel = 13.5 µm).*

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.

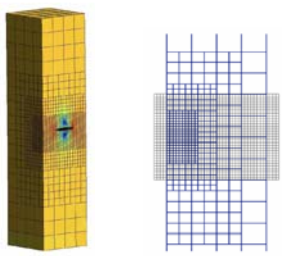

Figure 3. *Deformed mesh from local multigrid X-FEM modelling and independent structured mesh for the level sets*

It opens the way to a study of fatigue crack propagation based on an in-depth determination of the crack geometry. 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.

The support of the Fondation CETIM is gratefully aknowledged

REFERENCES

[1] Ferrié E., Buffière J.-Y., Ludwig W., Gravouil A., Edwards L., "Three-dimensional study of fatigue crack propagation of a semi-elliptical crack : 3D crack visualization using X-ray microtomography and numerical simulation of crack propagation using the Extended Finite Element method.", *Acta materialia,* 54:44, 1111-1122, 2006

[2] Réthoré J., Hild F., Roux, S.: Extended digital image correlation with crack shape optimization. *Int. J. for Num. Meth. in Eng.* doi:10.1002/nme.2070, 2007.

[3] Besnard G., Hild F., Roux S.: 'Finite-element' displacement fields analysis from digital images: Application to Portevin-Le Châtelier bands. *Exp. Mech.* **46**:789-803, 2006.

[4] Rannou J., Gravouil A., Combescure A., "A multigrid eXtended Finite Element Method for elastic crack growth simulation". *European Journal of Computational Mechanics*, Vol 16/2, pp.161-182, 2007