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

Computation of Stress Intensity Factors for 3D Cracks in a Turbine Rear Fan Blade: Comparison of FEM and XFEM Solutions

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Key Words: *Stress intensity factors, FEM, XFEM, Turbine Rear Fan.*

ABSTRACT

This contribution presents the results of a comparative study of two methods for the computation of stress intensity factors (SIFs) in a state-of-the-art industrial damage tolerant analysis of engine components.

Two methods are investigated:

- the first method involves the classical Finite Element Method (FEM). In this approach, a parameterised mesh of the crack is inserted in an un-structured original mesh. The two meshes are intersected and adapted. The parameterised mesh of the crack includes a mesh of the crack plane with triangles and a regular mesh centered on the crack front of which the first layer consists of quarter-point elements (also called Barsoum elements) and the next layers consist of hexaedra. The method, called FILI (for FIssure LIbre), was developed by Snecma - site de Villaroche [1]. It very much relies on the capabilities of the meshing utilities GHS3D and YAMS for the tedious mesh adaptation operations. The FE problem is solved using Samcef (though the method is also operational with Abaqus). The SIFs are obtained after computation of the J-integral in domain form, as implemented in Samcef.

- the second method involves the eXtended Finite Element Method (XFEM). In this approach, the crack is handled by way of tangent and normal level sets. The discontinuity of displacement and the stress singularity are included by way of additional degrees of freedom and dedicated shape functions. The unstructured mesh does not need to conform to the crack. Appropriate enrichment, mesh refinement (with the Simmetrix meshing library) and SIF smoothing strategies were implemented in order to optimize the quality of the solution. The method was made available to Samcef using the Substructuring Finite Element Method / eXtended Finite Element Method (S-FE/XFE) [2,3,4]. The XFEM is implemented in the *Morfeo* software, which uses some of the libraries developed by N. Moës and coworkers at École Centrale de Nantes. The SIFs are obtained using the interaction integral, a special version of the J-integral in domain form, adapted for handling a thermal load.

The authors investigate various static crack configurations in a Turbine Rear Fan (TRF) blade at the locus of maximum principal stress. In this study, the TRF is only submitted to fixations and thermal loading. This is thus a simple problem of thermoelastic fracture mechanics.

Mode I, II and III stress intensity factors are computed along the front and compared. The quality, accuracy and robustness of the solutions, the computational efficiency, the modeling practices and required expertise of the operator are also compared, leading to the evaluation of the 'technology readiness level' of both methodologies.

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