6th European Conference on Computational Mechanics (ECCM 6)
7th European Conference on Computational Fluid Dynamics (ECFD 7)
11-15 June 2018, Glasgow, UK

A cohesive XFEM model for fatigue crack growth in structures exposed to arbitrary load conditions

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Keywords: *Fatigue, crack growth, overload, cohesive zone, XFEM*

Numerous structures such as wind-turbines, bridges, cars and aeroplanes, are exposed to fatigue loading. The applied loads can vary in direction, magnitude and order. Therefore, fatigue crack modelling using constant amplitude mode I loading does not generally represent real-life scenarios. A new fatigue crack propagation model is presented which allows to capture the effects of mixed-mode loading, overloading and out-of-phase loading.

The presented model is built upon the phantom-node version of the extended finite element method (XFEM), which enables a crack to grow in arbitrary direction independent of the mesh geometry. The model makes a distinction between a physical crack tip and a numerical one. In between the two tips, ahead of the physical tip, there exists a cohesive zone that represents the gradual failure of the material. The bulk material behaviour is modelled using cyclic plasticity relations.

Both crack tips have their own criterion for propagation. Numerical crack tip propagation occurs once the maximum principal stress around the tip exceeds the ultimate stress. The crack growth direction is based upon the non-local maximum principal stress as was done by Wells and Sluys [1]. For physical crack tip propagation the approach by Iarve et al. [2] is followed, where the ERR is monitored for every solution step and related to a Paris law.

The presented model shows good agreement with experiments in both crack growth rate and crack growth direction for in-phase mixed-mode loading and overloading. Furthermore, the model captures the trends observed in out-of-phase experiments.

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