The Interfacial Thick Level Set method and its applications to Fatigue

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ABSTRACT

Modelling fatigue damage remains a challenging topic in engineering fracture mechanics. The challenges involved in accurately predicting the fatigue life of structural components range from limitations in the computation of crack driving forces to disputable crack growth rate relations describing the fundamentals. To overcome limitations regarding the computation of crack driving forces, new numerical models are being developed by the scientific community. These models allow for a more accurate description of fracture parameters such as the J-integral, stress intensity factor or energy release rate. In recent years, the Thick Level Set (TLS) method has been proposed by Moës et al. [1] to describe material degradation under quasi-static loading. More recently, this non-local damage model has been extended to interface elements, for its application to cyclic loading [2]. The Interfacial Thick Level Set (ITLS) approach offers an advantage over the continuum formulation, as its separates the energy for surface creation from the strain energy in the bulk, allowing for representation of a wide range of materials.

In this paper, an overview is given of the ITLS applications to fatigue. It is demonstrated that the two-dimensional ITLS description is capable of accurately capturing the driving forces of brittle materials such as composites and adhesives. For the fatigue life prediction of ductile materials such as aluminum and steel, the ITLS offers an elegant way of capturing the load sequence effects. Effects such as retardation following incidental overloads can be captured by combining the ITLS with an appropriate plasticity formulation in the bulk material surrounding the crack. The magnitude of retardation strongly depends on the amount of plasticity present in the material, as will be shown by a plane stress - plane strain comparison. It follows from this comparison that the stress state plays an important role in fatigue life prediction. A three-dimensional formulation of the ITLS method is therefore also presented, which allows to accurately capture the stress state along the crack front. The effect of the stress state is demonstrated with a comparison of the elliptical crack front observed in experiments and simulations.

REFERENCES

[1] Moës, N., Stolz, C., Bernard, P.E. and Chevaugeon, N. A level set based model for damage growth: The thick level set approach. *International Journal for Numerical Methods in Engineering.* (2011) **86**:358–380.

[2] Voormeeren, L.O., van der Meer, F.P., Maljaars, J. and Sluys, L.J. A new method for fatigue life prediction based on the thick level set approach. *Engineering Fracture Mechanics.* (2017) **182**:449–466.