A phase-field approach to high cycle fatigue simulation

Marreddy Ambati*†, Pietro Carrara† and Laura De Lorenzis†

† Institute of Applied Mechanics, Technische Universität Braunschweig
Pockelsstraße 3, 38106 Braunschweig, Germany
e-mail: {m.ambati,p.carrara,l.delorenzis}@tu-braunschweig.de
web page: https://www.tu-braunschweig.de/iam/

ABSTRACT

High cyclic fatigue failure of structures is often influenced by a slow variation of material properties and the total number of cycles to failure is larger than 10^4. The computational study of fatigue crack growth based on the explicit cycle-by-cycle approach becomes unfeasible when dealing with large numbers of load cycles, calling thus for temporal multiscale methods, e.g., cycle jump techniques. Such methods need to reduce the computational time drastically while preserving the accuracy of the solution.

Recently, a novel variational framework to simulate the fatigue behavior of brittle materials based on the phase-field approach to fracture was presented [1]. The standard regularized free energy functional is modified introducing a fatigue degradation function that reduces the fracture toughness as a proper history variable accumulates as in [2]. The approach aims at linking regularized fracture mechanics to fatigue crack growth, thus establishing a framework suitable for any type of (brittle) materials.

In the present work, a simple 'cyclic jump' technique suitable for high cycle fatigue computation is combined with the fatigue model in [1]. The jump approach is based on an extrapolation scheme with a control function which ensures the accuracy of the extrapolation [3]. First, a complete incremental step-by-step analysis is performed for a set of cycles and the global evolution (trend) function is obtained for each state variable monitored. This trend function is then used to extrapolate the state variable over a certain number of cycles. The extrapolated state is used as an initial state for the next cycles. A suitable length of the cycle jump is automatically determined through a criterion with a control function.

To demonstrate the predictive capability and the computational efficiency of the proposed methodology, the results obtained with present approach are compared with those of the explicit cycle-by-cycle simulations.

REFERENCES

[1] P. Carrara, M. Ambati, R. Alessi and L. De Lorenzis. A novel framework to model the fatigue behavior of brittle materials based on phase-field variational fracture approach. *arXiv:1811.02244 [cond-mat.mtrl-sci]* (Submitted).

[2] R. Alessi, S. Vidoli and L. De Lorenzis. Variational approach to fatigue phenomena with a phase-field model: the one-dimensional case. *Engineering Fracture Mechanics* (2018) **190**:53–73.

[3] D. Cojocaru and Am. Karlsson. A simple numerical method of cycle jumps for cyclically loaded structures. *International Journal of Fatigue* (2006) **28**:1677–1689.