Modeling of fatigue crack growth phenomena using the variational phase-field approach

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ABSTRACT

Fatigue is a key phenomenon in mechanics, and is largely responsible for most of structural failures. Despite the significance of the problem, most existing fatigue theories are based on empirical laws that lack of generality and predictive capabilities. Recently, in Carrara et al. [1] a variational phase-field framework for brittle materials was proposed to model the major features of the fatigue crack propagation, which includes the approximate Palmgren-Miner rule and the monotonic behavior as special cases. Here, the standard phase-field free energy functional is modified similarly to [2] so as to allow the fracture toughness of the material to decrease as a suitable fatigue scalar history variable increases. Although this approach is able to qualitatively reproduce fatigue-related phenomena as the crack nucleation, stable and unstable propagation phases, the Paris regime, the fatigue crack growth rate curve and the Wöhler curve, some issues remains open. In particular, an experimental validation is required along with the study of more specific behaviors such as the overload and the crack closure effects. While the former issue calls for a calibration procedure of the model, the latter requires the introduction of further dissipative mechanisms able to reproduce the so-called small scale yielding behavior. Such a characteristic phenomenon is due to the crack tip-induced strain singularity leading to the presence of a limited zone ahead of the crack tip where non negligible plastic dissipation develops and influences the fatigue crack growth.

In this work the model proposed in [1] is adapted so as to include plasticity and to reproduce the small scale yielding behavior. Numerical results are compared to available data to demonstrate the flexibility of the framework in [1] as well as the accuracy of the model. Particular attention is paid to reproduce the crack growth rate curve along with the Paris law [3] and the $S-N$ or Wöhler curve [4].

REFERENCES

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