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An Efficient Phase Field Model for Fatigue Fracture

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The core idea of the phase field model is to represent a discrete, discontinuous phenomenon with a smooth function. For fracture mechanics an additional field variable is introduced to describe the crack. The biggest advantage of the phase field fracture model is its unified framework of the entire crack evolution behavior, including nucleation, propagation, branching, kinking. These phenomena can be covered by one single model. The phase field fracture has been successfully applied to a quasi-statics case. However, there is still a lack of studies on how to efficiently simulate the fatigue fracture phenomenon. In this work, we propose an efficient phase field schemata for cyclic fatigue simulation.

We extend the model from Kuhn and Müller [1] with an additional potential energy term, which provides the necessary driving force for the fatigue fracture evolution. This additional potential is related to the newly introduced damage parameter, representing the damage caused by cyclic fatigue. The additional potential energy is coupled with fatigue parameters from the S-N diagram, which allows the model to generally and elegantly integrate all the influence from the environment to the fatigue propagation behavior. The evolution of the crack field is derived from the total energy with the help of variational principal. The model is consistent with the empirical fatigue propagation property, including the Paris' law and mean stress effect. The model is also robust under complex load simulations.

Traditionally, the fatigue simulation suffers from its huge computational effort since the fatigue crack will only occur after a large number of loading cycles. The cycle number increment influences the computing time of the fatigue simulation and impacts the crack patterns. Thus, the cycle number increment choice is a critical point in the phase field fatigue simulation. We introduce an adaptive cycle increment algorithm, where the cycle number increment is associated with the fatigue damage increment. Our algorithm provides a moderate computing time without losing accuracy compared to the classical computing strategies. Our method is also suitable for parallel computing.

The model has been applied to three-dimensional problems with the real material property. The fatigue life obtained from the phase field model can be verified by experimental and analytical findings.

REFERENCES

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