Hyper-Reduction Framework for Model Calibration in Plasticity-Induced Fatigue of AM1 Superalloy

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ABSTRACT

Many mechanical experiments in plasticity-induced fatigue are prepared by the recourse to finite element simulations. The data generated by these simulations can facilitate the calibration of mechanical parameters by using a reduced order model. The focus of this communication is to illustrate a new simulation protocol for finite-element model calibration. By the recourse to hyper-reduction [1] of mechanical models, more data science is involved in the proposed protocol, in order to solve less nonlinear mechanical equations during the calibration of mechanical parameters. In fatigue, the location of the crack initiation is very sensitive to material heterogeneities. This location is revealed during the experiments. The proposed protocol is versatile enough in order to focus the hyper-reduced predictions where the first crack is initiated during the fatigue test.

In nonlinear mechanics of materials, the Galerkin setting of the reduced equilibrium equations does not provide sufficient simulation speed-up. As shown in[2, 3], the repeated the projection of the finite element equations into the reduced space scales linearly with the large dimension of the finite element model. It is often too much time consuming. The hyper-reduced order model involves a reduced basis for the displacement approximation, a reduced basis for stress predictions and a reduced integration domain for the setting of reduced equilibrium equations. The reduced integration domain incorporates a zone of interest that covers the location of the crack initiation. The proposed hyper-reduction framework is shown to be relevant for the modeling of bending experiments on AM1 superalloy under oligocyclic fatigue at high temperature.

To account for the microstructure generated by a real industrial casting process, the specimen has been machined in a turbine blade. The model calibration aims to identify the loading condition applied on the specimen in order to estimate the stress at the point where the first crack is initiated, before the crack propagation. The model parameters are related to the load distribution on the specimen. The calibration speed-up obtained by hyper-reduction is almost 1000, including the update of the reduced integration domain focused on the experimental location of the crack initiation.

REFERENCES

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