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Comparison of finite element crystal plasticity and self-consistent crystal plasticity

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ABSTRACT

Fatigue is often the defining factor of a component's life. Many different models have been developed to predict it. One of the most important model types of today are models based on crystal plasticity. The theoretical basis for crystal plasticity was developed in the 1970's. As the computational power of computers has increased significantly in recent years, the popularity of crystal plasticity models has also increased greatly. Crystal plasticity fatigue models are great tools for understanding fatigue as they offer information, which is difficult to obtain experimentally, and they reduce the need for physical experiments. [3]

Crystal plasticity finite element method (CPFEM) allows the investigation of fatigue on microscopic level. It can be used to accurately represent the micromechanical fatigue behavior, such as the interactions between grains, the effects of grain orientation and the effects caused by inclusions and other faults in the material. Understanding these micromechanical effects is essential for understanding fatigue as a phenomenon. The main drawback of CPFEM is that it is computationally demanding. As the size of the simulated microstructure is increased, the computation time increases rapidly. An example of a microstructure generated for CPFEM is shown in fig. 1. The model used in this work is developed by Lindroos et al. [2].

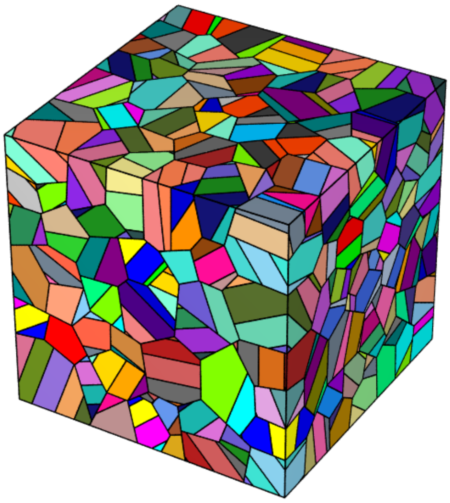

Figure 1. Microstructure generated for CPFEM simulation.

Self-consistent crystal plasticity offers a less computationally demanding alternative for CPFEM. The self-consistent method used in this work uses the β-rule [1] for scale transition from macroscopic level to grain level. As the self-consistent method is a mean-field approach, it does not provide the same level of information about the behavior of the microstructure. Although it is capable of producing the stress-strain behavior of single grain, it does not allow the investigation of interactions between grains. This is because the interactions are not accounted for explicitly but instead grains experience neighboring effects through homogenization. The β-rule estimates the local stress and strain as a function of the macroscopic loading state.

This work focuses on the differences in the results produced by these models in cyclic loading. The macroscopic behavior produced by the models is first compared. These results are compared to a physical fatigue test. Then the models are compared based on grain-level behavior. The stress and strain distributions are investigated and their abilities to model material damage are evaluated. Overall, both models match the results from physical fatigue tests well. On microscopic level differences in behavior are noticed between the models.

Keywords: fatigue model, micromechanics, virtual fatigue testing.

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