A Cocks-Ashby Based Formulation for Incorporating Sub-scale Variations in Rate Sensitivity into Porosity Modeling

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ABSTRACT

Material damage and failure under dynamic loading conditions remains a complex problem, with challenges having to do both with appropriate mechanics models and with robust numerical implementations. The direction of model developments is influenced by longstanding needs, by advances in the detail available from diffraction-based experimental methods, and by advances in computational power both for gathering information from sub-scale calculations and for using more advanced models in design analysis. A subset of relevant issues will be emphasized here, particularly related to formulations that incorporate the effects of material rate sensitivity. The formulation show here makes use of a Cocks-Ashby style treatment of porosity kinetics that includes rate dependent flow in the mechanics of porosity growth. The porosity model is implemented in a framework that allows for a variety of strength models to be used for the matrix material, including ones with significant changes in rate sensitivity as a function of strain rate. For example, models that include state variables for evolving dislocation density can capture transitions into drag-limited ranges of dislocation velocity, with corresponding dramatic changes in effective rate sensitivity. Such changes can be relevant in modeling of high-rate failure phenomena such as spall failure that occurs when release waves overlap during dynamic loading. For high triaxiality cases, extensions to the standard Cocks-Ashby form will also be discussed.

While enhanced rate sensitivity at elevated rates can help to regularize the computational formulation, classical mesh sensitivity can still be observed. Preliminary results from a non-local formulation of the Cocks-Ashby model will also be shown, with an assessment of its efficacy in mitigating classical mesh dependence. In all of this work, attention is paid to the robust numerical solution of the stiff systems of coupled non-linear equations that arise.

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