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Micro-Macro Finite Element Procedure to Predict Elastoplastic Behavior and Ultimate Failure of Porous Metals

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ABSTRACT

Additive manufacturing gained a significant interest as reliable means of creating net-shape components. The process of layering in the manufacturing process is tied with undesirable porosities in the final parts. Porosity is well-known to deteriorate the mechanical behavior in elastic and plastic regimes. In addition, to altering the material's failure limit. The current work presents a two-stage finite element analysis procedures employing micro/macro mechanical models to predict the effective mechanical behavior and failure of porous metals. Micromechanical three-dimensional representative volume elements (RVEs) with single ellipsoidal void were employed to predict effective elastic-plastic behaviors. A python script was developed and implemented in the commercial finite element software Abaqus to analyze the effect of pore shape on mechanical behaviors. Post-processing micromechanical modeling results were automated to generate the material parameters for macroscale modeling. Three user-defined subroutines were developed and implemented in Abaqus using Fortran to enable macromechanical failure predictions utilizing the framework of extended finite element analysis (XFEM). The strain energy density (SED) was employed for modeling damage propagation and final fracture of different porosity levels. The proposed procedure results were validated against reported testing results from the literature regarding low and high strength steels at different volumetric porosity levels, i.e., low range porosity (less than 10%). Advanced modeling procedure proved excellent agreement with testing results.