Ductile Fracture Simulations Using a Multi-Surface Coupled Damage-Plasticity Model

S. M. Keralavarma and D. Reddi

Department of Aerospace Engineering, Indian Institute of Technology Madras, Chennai – 600036, India

Ductile fracture by void growth to coalescence depends strongly on the loading path. Classical damage models such as Rice-Tracey (1969) and Gurson (1977) predict an exponential decrease in damage growth rates with decrease in stress triaxiality (ratio of the mean and Mises effective stresses), and no damage growth under purely deviatoric loading paths. However, recent experimental evidence and mesoscopic cell model simulations also indicate an influence of the Lode parameter (or the third invariant of the deviatoric stress), with a significant reduction in ductility predicted under low triaxiality shear dominated loading conditions. Unlike under axisymmetric loadings, void coalescence under shear dominated loadings can occur by shear localization in the inter-void ligaments, not accounted for in the development of classical damage-plasticity models. Here, we present a new multi-surface plasticity model that accounts for three distinct modes of damage growth at the mesoscale: (i) void enlargement by diffuse plastic flow in the matrix, (ii) void coalescence by inter-void necking and (iii) void coalescence by shear localization between voids. Development of the model using homogenization and limit analysis of porous representative volume elements is presented, followed by comparisons of the resulting yield criterion with quasi-exact yield loci obtained using a numerical limit analysis method. Finally, predictions for the macroscopic ductility using the multi-surface model are presented. It is shown that the new model predicts the trends for the ductility as a function of the triaxiality and Lode parameter consistent with some experiments and cell model simulations in the recent literature.