Accurate predictions of material strength under different loading conditions with large plastic deformation and ductile fracture are of great importance. The aim of this dissertation is to develop an essential understanding of ductile fracture of AISI 4340 steel alloy using both empirical and micromechanics based models. For this purpose, 29 specimens of different geometries with different heat treatments were designed to investigate the effects of stress states. These specimens are categorized into the following three groups: (a) 13 round bars with different notches (axial symmetric tension); (b) 13 flat grooved (plain stain) specimens with different grooves; (c) 3 small round cylinders (upsetting test). Mechanical tests up to fracture were conducted on these specimens to characterize the influence of hydrostatic stress and Lode angle on material plasticity and fracture. Scanning electron microscopy (SEM) observations were performed on both initial and fractured specimens to investigate different micromechanical revelations and features. The Bai-Wierzbicki (BW) plasticity model and the modified Mohr-Coulomb (MMC) fracture model were used to predict plastic flow and fracture initiation behaviors under different loading conditions in finite element simulations. A model optimization method using Isight was set up to achieve good simulation results that were well correlated with experimental data. The effects of heat treatment on material strength and ductility of AISI 4340 steel were also discussed. This work was further carried onto the micro-voids based metal plasticity theory. The well-known Gurson-Tvergaard-Needleman (GTN) model was calibrated for AISI 4340 steel. It is found that the GTN model is not sufficient in mimicking test data for the 16 Rockwell hardness (HRC) plain stain specimens. Therefore, The GTN model is modified to include Lode angle dependence on matrix material plasticity. It is also found that a fixed or constant void volume fraction at failure (ff) for all loading conditions is inadequate. Following a similar derivation of MMC model, the micro-void volume fraction at failure (ff) becomes a function of both stress triaxiality and Lode angle. This new criterion is named (GTN-MMC).

The proposed plasticity and fracture models were implemented in ABAQUS through a user-defined material subroutine (VUMAT) for FE simulations. Good correlations were achieved between experimental results and numerical simulations.

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The public is welcome to attend.