Real-time Microscopic investigation of Deformation and Failure in Al 6061-T6

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Modeling of the inelastic response of metallic materials such as Al 6061-T6 is of significant interest in numerous applications in the aerospace, automobile, and naval industries. These models must encompass the early stages of deformation as well as the later stages leading up to failure. Typical models are based on phenomenological descriptions of the constitutive response during the early stages of deformation, and on micromechanical models of damage nucleation and growth (such as the Gurson model) during the later stages that generate intrinsic softening of the material response. Calibration of these models is typically based on measurements of the macroscopic response of the material and is inherently a nonunique process. While there are numerous investigations that implement such models in simulations, there are very few investigations that provide an experimental evaluation, both of the calibration of the models and of their use in predicting the deformation and failure in structural applications. In this presentation, we will first provide an overview of the experimental efforts that have attempted to provide the underpinnings of such models and their calibration. This will then be followed by a quantitative examination of the underlying deformation and failure mechanisms through a detailed, real-time, multiscale investigation of the deformation and failure processes in Al 6061-T6 under shear dominant loading conditions. Specifically, we utilize an in-situ loading stage in a scanning electron microscope and monitor both the macroscopic response and the local deformation and failure at high spatial resolution. The loading on a specially-designed specimen is halted at numerous stages during the overall loading process and at each stage, the changes in the geometry of the surface of the specimen are obtained at high magnification; tracking of 2nd phase particles and grain boundaries allows the quantitative determination of the evolution of the strain field at different points in the specimen. We identify and quantify the development of discontinuous and discrete deformation gradients both within grains and at grain boundaries. We further examine the errors introduced in adopting homogenized approaches to handle the mechanical response. Finally, the deformation and microstructural changes leading up to failure within the localized bands are identified, and the strain at the onset of final failure is determined at different (low) triaxiality levels.