ELASTO-VISCOPLASTIC FINITE ELEMENT ANALYSIS OF POLYCRYSTALS

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A mesoscale model for predicting the evolution of the grain structure and the mechanical response of polycrystalline aggregates subject to large deformations is presented. The grain structures modelled are either experimentally observed or are computer generated and statistically similar to experimentally observed grain structures. In order to capture the inhomogeneous deformations and the resulting grain structure characteristics, a discretized model at the mesoscale is used. This work focuses on Al-Mg-Si alloys. Scale bridging is used to link to the macroscale. Examples involving two-dimensional grain structures and current work on three-dimensional grain structures are presented.

The present work provides a theoretical and computational framework to model the mesoscopic behavior and interactions between grains during finite strains. The mesoscale is characterized by a statistically representative volume element (RVE), which contains the grains of a polycrystal. Light optical microscopy (LOM) and electron backscatter diffraction (EBSD) are used to observe and characterize the grain structures of the homogenized material before deformation. A method for observing and quantifying three-dimensional grain structures has also been developed. The observed grain structures are used both as models directly (for two-dimensional cases) and to define statistical characteristics to verify the similarity of computer generated grain structures (for three-dimensional cases). A Monte Carlo method based on the Potts model is used to define three-dimensional grain structures. In order to make the representative grain structure appropriate for scale-bridging, we design them with periodicity.

A three-field, updated Lagrangian finite element formulation with a kinematic split of the deformation gradient into volume preserving and volumetric parts is used to create a stable finite element method in the context of nearly incompressible behavior. A fully implicit two-level backward Euler integration scheme is derived for integrating the constitutive equations. We describe the finite element formulation including the consistent linearization of a set of nonlinear equations. In addition, the average of the boundary conditions and bulk response must match the macroscopically measured bulk response.

To illustrate and verify the proposed model, we analyze examples involving two-dimensional grain structures and compare with results from a Taylor model. Current work on three-dimensional grain structures are also presented.