MODELING OF MICROSTRUCTURAL EVOLUTION THROUGH DEFORMATION BANDING DURING EQUAL CHANNEL ANGULAR EXTRUSION (ECAP)

S. Mahesh[a], I. J. Beyerlein[b] , and C. Tome[c]

Los Alamos National Laboratory
Los Alamos, NM 87545
[a]mahesh@lanl.gov, [b]irene@lanl.gov, [c]tome@lanl.gov

For over a century now it has been experimentally known that when subjected to large plastic strains individual grains in a polycrystalline material change their deformation mode from homogeneous deformation across the entire grain to a banded deformation mode in which domains or bands form within a grain, each of which shows different slip activity. It is widely believed that minimum energy principles underlie this transition: The banded deformation mode is preferred if the power expended in heterogeneous (banded) deformation is lower than that in the homogeneous mode. Early work by Chin and Wonsiewicz used in nearly every banding model since, treats the power expense in the banded deformation mode as having three parts: (1) the power expended in the course of slip in each band, (2) the power in forming new boundaries between bands, and (3) the power to cause plastic deformation which will restore its surroundings. Recent workers (e.g., Duggan and co-workers) have proceeded to quantify these terms under specific loading conditions (e.g. rolling).

We follow this direction further and generalize the implementation of Chin's and Wonsiewicz's energy criterion for deformation band initiation to arbitrary loading paths. Our approach consists of recognizing the convexity of the slip power as a function of granular stress and strain-rates, and accordingly, choosing polynomial paths in strain-rate space along which compatibility is weakly satisfied and along which deformation power is locally concave. We implement among other things, predicts texture evolution under arbitrary loading conditions. Using this approach we simulate ECAP, a popular process for fabricating nanostructured metals, which subjects the polycrystal to sever plastic deformation and frequent strain path changes. The strong coupling between texture and microstructural evolution under these conditions is predicted.