Multiple necking in an expanding metal ring: polycrystal plasticity approach and texture influence

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Abstract

The onset of plastic strain localization in a metal ring under dynamic expansion in the form of multiple necking is classically analyzed at the macroscopic scale as a consequence of the development of unstable perturbation modes of the structure. However, the polycrystalline material microstructure influences the necking process since the inherently heterogeneous deformation at the mesoscale, due to the difference of grain orientations, initiates the development of instability modes. Simulations of stretching copper rods mimicking a piece of an expanding ring is performed with a crystal plasticity finite element code in which a Voronoï tessellation algorithm reproduce the grain structure. A Teodosiu type constitutive law taking dislocation densities as internal state variables rules single crystal behavior and the evolution of critical shear stresses is governed by the slip system interaction matrix identified by Madec and Kubin (2017). For an initial isotropic texture and a prescribed mean grain size, the variability of neck locations and amplitudes can be significant between different grain sets. On the contrary, a pronounced texture, which reduces grain orientation heterogeneity, modifies the neck development in terms of timescale and usually yields more regularly spaced neck positions. Another interest of crystal plasticity simulation is to model in-grain slip activity in highly deformed necks that may drive their subsequent failure. In such grains, lattice rotation is significant and the set of activated systems continuously evolve leading to non-monotonous increase of critical shear stresses before saturation by dynamic recovery.

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