Voyiadjis, George Z.; **Jeong, Juyoung**; **Kysar, Jeffrey W.**

Grain size dependence of polycrystalline plasticity modeling in cylindrical indentation.

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Summary: Grain boundary strengthening effect for polycrystalline copper is studied numerically using crystal plasticity in conjunction with cylindrical indentation simulations under the plane strain condition. In order to compare with an isotropic, heterogeneous continuum model a new constitutive relation is developed. This new nonlocal continuum model that encompasses the heterogeneity in yield strength based on the exponentiated Weibull function can predict the plastic properties of materials in the micron length scale. The spatial description of the deformation gradient two-point tensor is utilized to capture the intrinsic size effect in line with the subsequent deformation measures. Moreover, the total geometrically necessary dislocation density is obtained from the non-zero components of Nye dislocation density tensor. From the simulation, the relationship between the effective Green-Lagrange strain and effective stress measures is explained using the persistent long-range order and intermittent short-range order. The observation derived from the analogy between the cylindrical indentation and the progress in cylindrical voids describes how different average grain sizes of polycrystalline materials are compared with the behavior of isotropic materials. The trajectories of directions of both principal stretch and maximum shear strain explain that the internal stresses induced by cylindrical indentation either hinder or reinforce the dislocation flow, forming strain localization sporadically. The grain size dependence of polycrystalline modeling incorporates the Hall-Petch strengthening as well as the homogenization of anisotropic polycrystalline metal into the isotropic effective medium. This is a physically-based model that is used to model failure characterization in metals.

MSC:

74C20	Large-strain, rate-dependent theories of plasticity
74E15	Crystalline structure
74M15	Contact in solid mechanics
74A20	Theory of constitutive functions in solid mechanics
74Q15	Effective constitutive equations in solid mechanics
74S05	Finite element methods applied to problems in solid mechanics

Keywords:

nonlocal continuum model; exponentiated Weibull probability distribution function; contact; nanoindentation; crystal plasticity finite element method; Hall-Petch effect; homogenization

Software:

UMAT; Neper; ABAQUS/Standard; ABAQUS; MTEX

Full Text: DOI

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