Size effect in polycrystal plasticity

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ABSTRACT

The demand for the micro scale forming and therefore the improvement in the micro manufacturing technologies increased substantially in many industry clusters in the recent years. During these processes the parts with the dimensions in submillimetre scale are fabricated through micro-scaled plastic deformation. Even though there have been various classical theories developed for the modelling of macro scale deformation during conventional metal forming, it is still a challenge to establish models taking into account the size effect due to the microstructural and the statistical phenomena at small length scales. Recent studies have shown that on the scale of several micrometres and below, crystalline materials behave differently from their bulk equivalent due to micro-structural effects (e.g. grain size, lattice defects and impurities), gradient effects (e.g. lattice curvature due to a non-uniform deformation field) and surface constraints (e.g. hard coatings or free interfaces). These effects could lead to stronger or weaker material response depending on the size and unique micro-structural features of the material. Moreover, as the size goes down statistical size effect comes into play as well. The number of grains is restricted where the behaviour of the individual grains become more decisive on the macroscopic response. Current paper studies both the intrinsic and the statistical size effects through a strain gradient polycrystalline plasticity framework (see e.g. Yalcinkaya et al. 2011, Yalcinkaya et al. 2012, Klusemann and Yalcinkaya 2013) for different specimen and grain sizes using Voronoi tessellation, where the polycrystalline aggregate is generated using probability theory. The micro tensile tests for various microstructures are numerically simulated by finite element method (FEM) in Abaqus software, where the effects of different microstructural parameters, boundary conditions and loading rate are addressed numerically. Moreover, the study illustrates the diminishing statistical effect with increasing number of grains and discusses the influence of the boundary conditions and number of active slip systems.

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