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A MULTI-SCALE INVESTIGATION OF CRYSTAL PLASTICITY THEORY

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ABSTRACT

Some recent experimental investigations carried out under test conditions that minimize imposed deformation gradients, limiting the geometrically-necessary dislocations (GND) density, approve there exist some new characteristics of crystal deformation at micrometer scale: the strength is strongly affected by the internal and whole physical dimensions of crystal, which is different from the grain-size hardening mechanism in poly-crystal; plasticity deformation exhibits strongly temporal intermittency and spatial localization.

In this paper, dislocation storage, multiplication, motion, pinning processes at micrometer scale are investigated in a multi-scale method to reveal some critical events of dislocation motion at this scale. Another side, in this work, a single dislocation line is regarded as the smallest GND. A constitutive theory incorporating a more general strain gradient term is developed to represent a short range interaction of dislocations to predict the crystal plastic behavior at micrometer scale. The gradient term has a different physical meaning from that in MSG distinctly.

At last, associating with the multi-scale simulation results, the various crystal plasticity theories are compared at the different scales and some conclusions are given below. At the grain-size scale, far beyond the spacing of dislocations, inter-granular interaction controls the deformation, so conventional crystal plasticity theory which doesn't have a length scale parameter works well; at microscopic scale, approaching the spacing of dislocations, mechanism based gradient plasticity theory (MSG) seems to be more reasonable, because it reflects the intrinsic length scale of material and the local interaction effect of dislocations to some extent, but the resolution must be low enough to ensure the applicability of Taylor law, so it can't capture the special character of dislocations at micrometer scale. The constitutive theory proposed in this paper seems to be a good complementary to the present various crystal plasticity theories.