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Stress-Gradient Plasticity: Concept and Application

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Many experiments show that the plastic flow stress in metals increases in material volumes on the micron scale and below. Design of metallic structures thus requires new constitutive models to accurately reflect these plasticity size effects. Here, we present a new concept, "stress gradient plasticity", that emerges naturally from the analysis of dislocation pile-ups under a spatial stress gradient and that unambiguously shows that the spacing between obstacles to dislocation motion is a material length responsible for scale effects. We study "stress gradient plasticity" in 2d and 3d dislocation dynamics and implement it in a low-order continuum plasticity framework. We demonstrate size effects in bending, torsion, indentation, and void expansion, and quantitatively explain size effects – both strengthening and hardening – in recent bending and torsion experiments in pure polycrystalline and single-crystal metals. These successes establish stress gradient plasticity as one key to understanding size-dependent plasticity.

Keywords: size-effects;plasticity;dislocations;strength;

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