Torsion in strain-gradient plasticity: energetic scale effects

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Abstract

We study elasto-plastic torsion in a thin wire in the framework of the strain-gradient plasticity theory elaborated by Gurtin and Anand in 2005. The theory in question envisages two material scales: an energetic length-scale, which takes into account the so–called "geometrically–necessary dislocations" through a dependence of the free energy on the Burgers tensor, and a dissipative length-scale. For the rate-independent case with null dissipative length-scale, we construct and characterize a special class of solutions to the evolution problem. With the aid of such characterization, we estimate the dependence on the energetic scale of the ratio between the torque and the twist. Our analysis confirms that the energetic scale is responsible for size–dependent strain–hardening, with thinner wires being stronger. We also detect, and quantify in terms of the energetic length-scale, both a critical twist, after which the wire becomes fully plastified, and two boundary layers near the external boundary of the wire and near the boundary of the plastified region, respectively.

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