Size-effects in porous metal plasticity
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Size-effects in metals have been confirmed in numerous small scale experiments. Whenever large strain gradients are imposed on micron scale samples, such as in torsion of thin wires or bending of thin films, the plastic response exhibits size-dependence with the general trend that 'smaller is stronger'. Similarly, micro- and nano-indentation tests show increased hardness for smaller indentation depths, where large densities of geometrically necessary dislocations accompany large plastic strain gradients.

Under macroscopically homogeneous deformation, size-effects may arise due to passivation layers or at internal microstructural interfaces causing inhomogeneous plastic strain. This includes the well known Hall-Petch effect where plastic strain gradients increase with decreasing grain size leading to higher yield strength. Similarly, size-effects must be an essential part in reliable models for micron scale void growth and hence for homogenized theories of porous metal plasticity.

Higher order strain gradient plasticity theories provide a modeling basis for micron scale size-effects based on assumptions of recoverable or dissipative gradient effects. Non-conventional boundary conditions on plastic flow introduce enhanced modeling capabilities on the micron scale. Although model predictions for some cases are quantitatively reliable, outstanding issues relate to how models should behave in relation to abrupt changes in load path or boundary conditions.

A recent finite strain framework for higher order strain gradient plasticity theory is discussed in relation to basic model predictions and experimental results. The model is applied to size-effects in void growth, with emphasis on extensions of conventional porous metal yield surfaces to include micron scale size-effects.