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Length scale effects on the shear localization process in metallic glasses: A theoretical and computational study

Prakash Thamburaja

Summary

Some recent experiments on sub-micron and nano-sized metallic glass specimens have shown that the shear localization process becomes more stable and less catastrophic when compared to the response exhibited by large sample sizes. This leads to the discovery that the shear localization process and fracture can be delayed by decreasing sample volume. In this work we develop a non-local and finite-deformation-based constitutive model using thermodynamic principles and the theory of micro-force balance to study the causes for the aforementioned observations. The constitutive model has also been implemented into a commercially-available finite-element program by writing a user-material subroutine. With the aid of finite-element simulations, our constitutive model predicts that metallic glass samples have the intrinsic ability to exhibit: (a) the delaying of (catastrophic) shear localization with decreasing sample size, and (b) homogeneous deformation behavior for sample volumes smaller than the shear band nucleus.

The cause for the observations listed above is the increasing influence of a non-local interaction stress with decreasing sample volume. This interaction stress has energetic origins and it affects plastic deformation due to the strong coupling between plastic shearing and free volume generation. Akin to strain-gradient plasticity theory, the role of the interaction stress is to strengthen the material at locations where the defect density/free volume concentration is higher compared to the rest of metallic glass sample.