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MICROMECHANISM-BASED ELASTO-VISCOPLASTICITY CONSTITUTIVE MODELING FOR ENGINEERING INTERMETALLICS

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Materials having different crystal structures or microstructures exhibit different slip-based flow behaviors and controlling micromechanisms. Mechanism-based constitutive modeling is essential to reliably link microstructure, observed deformation features and the corresponding plastic flow responses. This requires that the micromechanisms governing plastic flow should be reflected in the constitutive variables and functional forms that eventually predict a stress-strain response. However, most of the conventional constitutive models treat such microstructure-sensitive materials variabilities within a unified constitutive framework. Examples are the power law and the thermally-activated plastic flow law, which describe a strain-rate response as a function of stress, temperature and other constitutive variables. This unified approach implicitly assumes an abundance of mobile dislocation sources during plastic flow. Thus, the corresponding flow stress is determined by the critical obstacle length for the mobile dislocations, not by the population of mobile dislocations. The approach has shown reasonable successes in predicting stress-strain responses within limited flow regimes, particularly for forest-like obstacle-controlled flow regimes (Stage II flow and beyond). However, it is often very poor in predicting the flow behavior during earlier stages of plastic flow, *viz.* the elastic-plastic transition and Stage I flow. Such transition stages are important in the evolution of cyclic damage or fatigue of metals. The role of the mobile dislocation density is even more important in modeling $L1_2$ intermetallics. From a new constitutive model of $L1_2$ intermetallics we found that it is possible to represent the complex behavior of this material by modeling the availability of mobile dislocations. Consistent with experimental observations, the model predicts the flow stress and its evolution (i.e. strain hardening) in the early stages of flow, and shows how they vary dramatically with availability of mobile dislocations. The mobile dislocations in this material are *effectively* instantaneously exhausted by the microstructure-sensitive locking mechanism, which is a key flow-controlling mechanism for alloys of that type. The present study shows the major framework of new constitutive modeling and simulation results.