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Crystal Plasticity FE Modeling of Ti Alloys for a Range of Strain-Rates. Part II: Image-based Model with Experimental Validation

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Abstract

The second of this two-part paper develops an image-based crystal plasticity finite element model for simulating *hcp* metals deforming at a wide of range of strain-rates. It incorporates a unified flow rule based crystal plasticity constitutive model, combining the thermally-activated and drag-dominated stages of dislocation glide, proposed in part I (Shahba and Ghosh, 2016). The image-based CPFE uses 3D statistically-equivalent virtual microstructures that are constructed by stereology and statistics from 2D surface EBSD maps. The statistically equivalent virtual microstructures are constructed for the Ti-7Al alloy in as-rolled (AR) and rolled-annealed (RA) conditions. The virtual microstructures are discretized into 3D tetrahedral elements that are stabilized to yield locking-free large deformation FE results. This paper demonstrates the competency of the model for simulating deformation of the polycrystalline Ti-7Al alloy microstructures under quasi-static and high rates of deformation. Room temperature compression tests at quasi-static ($10^{-3}s^{-1}$) and dynamic strain rates ($1000 - 4000s^{-1}$) are performed and used to calibrate and validate the constitutive model. The simulations reveal that the decrease in the hardening rate is significant under adiabatic conditions due to the promotion of slip-driven plasticity. The effect of degradation of elastic constants with temperature on the macroscopic behavior is noticeable only at the later stages of deformation. A study on adiabatic heating reveals that grains undergoing severe plastic deformation do not necessarily yield higher temperatures. In contrast, grains that are less favorably oriented for dislocation slip could experience higher adiabatic heating due to higher local stresses.