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Coupled elasticity, plastic slip, and twinning in single crystal titanium loaded by split-Hopkinson pressure bar

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Abstract Coupled elasticity, plastic slip, and twinning in high-purity single crystal titanium loaded by split-Hopkinson pressure bar (SHPB) are investigated, in the framework of large deformation and by utilizing the finite element method (FEM). A thermodynamically consistent system of equations for combined plastic slip and twinning is formulated. Novel kinematics is proposed to develop the driving forces for slip and twinning processes and to consider plastic slip in twins. Dislocation based crystal plasticity is proposed, with an emphasis on the interactions among all slip modes in multi-variant/multiphase heterogeneous materials. A mechanism for dislocation density evolution during twinning is proposed. The impact loading along the [0001] and $\left[10\bar{1}1\right]$ directions of single crystal high purity titanium is investigated. The evolution of stress-strain field, dislocation density, and volume fraction for each variant in the sample during the entire loading process are obtained and discussed in detail. Results in simulations show that for the [0001] specimen due to the existence of six symmetry primary twin variants with respect to the loading direction and fifteen different slip systems in each variant, the fields of stress and dislocation density are very homogenous in the sample. The simulation results are compared with experimental data for the [0001] and $\left[10\bar{1}1\right]$ specimens. The experimental results are explained and interpreted for both specimens, which include the pole figures, the stress-strain curves, and volume fraction of variants. The simulation results provide an important insight into mechanical responses of high-purity single crystal titanium under high rate loading, and this paper advances the mesoscale modeling and simulations in coupled plastic slip and twinning.

Keywords: dislocation based crystal plasticity, deformation twinning, large deformation, high strain rate loading

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