Dislocation density based constitutive model for Ti-6Al-4V used in simulation of Metal Deposition

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The presented work is part of a project aimed at creating a constitutive model accounting for microstructural changes in Ti-6Al-4V. This paper investigates the plastic deformation of Ti-6Al-4V at low strain rates and temperatures up to melting point. This model is implemented in the FE software MSC.Marc and used in the simulation of Metal Deposition (MD).
The dependence of flow stress on temperature and strain rate is investigated. Ti-6Al-4V exhibits pronounced flow softening behavior at elevated temperature. Possible mechanisms responsible for this behavior are discussed and a physically based constitutive model is developed.
A dislocation density model is used to describe the hardening and softening. Mobile and immobile dislocations are accounted for in the model. The flow stress has contributions from long-range and short-range interactions of the dislocation substructure. Former is the athermal stress contribution, whereas latter is the friction stress needed to move dislocations through the lattice and to pass short-range obstacles. Thermal energy can assist dislocations to overcome these obstacles. The long-range term is written as

$$\sigma_G = m\alpha G b\sqrt{\rho_i}$$

where m is the Taylor orientation factor which translates the effect of the resolved shear stress in different slip systems to effective stress and strain quantities. G is the temperature dependent shear modulus, b is Burger's vector and α is the proportionality constant.
This provides a natural relation between the constitutive model and microstructure evolution. It is assumed that the mobile dislocations move an average distance (mean free path) - Λ, before they are immobilized or annihilated. The increase in the immobile dislocation density-$\dot{\rho}_i$ is also assumed to be proportional to $\dot{\bar{\epsilon}}^p$, the plastic strain rate.

$$\dot{\rho}_i = \frac{m}{b}\frac{1}{\Lambda}\dot{\bar{\epsilon}}^p$$

The mean free path is assumed to be a combination of the grain size, precipitate spacing and dislocation subcell or subgrain diameter.
Two recovery mechanisms, dislocation climb and dislocation glide are considered in this model. Recovery will increase the mobility of dislocations thereby reducing the immobile dislocation density.