The DCM Simulations of the Matrix Dislocation Gliding through the Matrix Channel under the Influence of the Interfacial Dislocation Network in Nickel-Based Superalloy

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Abstract

The discrete-continuous model (DCM), a discrete dislocation dynamic (DDD) and finite element method (FEM) coupled simulation method, was used to investigate the influence of edge character interfacial dislocation network at the two-phase interfaces on the gliding process of the matrix dislocation between matrix channels in nickel-based superalloy. An enhanced DCM algorithm is used to obtain more accurate stress field in a short distance near the dislocation core. The gliding process of the matrix dislocation with different Burgers vector called D1, D2 and D3 from one channel to another channel is studied. Such a gliding process can be deposed into two steps. In the first step, the matrix dislocation is in one matrix channel and tends to bow into another matrix channel. After the matrix dislocation bows into the matrix channel completely, the matrix dislocation transfers from bowing to gliding along the matrix channel which is considered as the second step. If the matrix dislocation bows into the channel completely, the current configuration is the critical configuration for the entering of matrix dislocation into the channel. If one of the matrix dislocation segments in the channel glides out of the channel for the first time, the current configuration is considered as the critical configuration for the gliding of matrix dislocation out of the channel. The critical stress of the two critical configurations is investigated. If the depositing trailing arm of the matrix dislocation is screw character dislocation, the interfacial dislocation networks have a weak influence on the critical stress of the matrix dislocation entering and gliding out of the matrix channel. If the depositing trailing arm of the matrix dislocation is mix character dislocation, the interfacial dislocation network will hinder the matrix dislocation from entering and gliding through the matrix channel remarkably. After the matrix dislocation enters the matrix channel completely, additionally applied load is needed to push the matrix dislocation to glide through the matrix channel. We found that as the channel width become narrower, the additionally applied load is not increased much for the condition without interfacial dislocation network. When the interfacial dislocation network is accounted for, the additionally applied load is significantly increased. The critical stress is quantitatively studied with different dislocation spacing of interfacial dislocation network. We found that the influence of the interfacial dislocation network is proportional to the lattice mismatch (δ) of the nickel-based superalloy with a certain channel width. The magnitude of the lattice mismatch can be expressed as $|\delta| = |\boldsymbol{b}|/d$, where $\boldsymbol{b}$ is the Burgers vector and d is the dislocation spacing of the interfacial dislocation network. And an equation is proposed to describe the relation of critical stress and channel width by considering the influence of interfacial dislocation network:

$$\tau_{CRSS} = c_1 \frac{\mu}{w'/b} \log(w'/b) + c_2 \frac{\mu}{w'/b} (\log(w'/b) + c_3) \cdot \delta \qquad (1)$$

where c_1, c_2 and c_3 are constants, μ is the shear modulus, and w' and b are matrix channel width and magnitude of the Burgers vector, respectively.

In addition, the dislocation dissociation during the process of dislocation bowing in the matrix channel is investigated. The matrix dislocation is more easily to dissociate, whether or not the interfacial dislocation network is considered, in narrower channel with low stacking fault energy. The direction of applied load and the matrix channel will influence the dissociation of the leading and trailing partial dislocation, and in some conditions the matrix dislocation always intends to dissociate and glide through the matrix channel with interfacial dislocation network.

Keywords: Dislocation dynamics; Nickel-based superalloy; Interfacial dislocation network; Dislocation dissociation.