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The Key Role of Dislocation Dissociation in the Plastic Behaviour of Single Crystal Nickel-based Superalloy with Low Stacking Fault Energy: Three-dimensional Discrete Dislocation Dynamics Modelling

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Abstract: To model the deformation of single crystal nickel based superalloys (SCNBS) with low stacking fault energy (SFE), three-dimensional discrete dislocation dynamics (3D-DDD) is extended by incorporating dislocation dissociation mechanism. The present 3D-DDD simulations show that, consistent with the existing TEM observation, the leading partial can enter the matrix channel efficiently while the trailing partial can hardly glide into it when the dislocation dissociation is taken into account. To determine whether the dislocation dissociation can occur or not, a critical percolation stress (CPS) based criterion is suggested. According to this CPS criterion, for SCNBS there exists a critical matrix channel width. When the channel width is lower than this critical value, the dislocation tends to dissociate into an extended configuration and *vice versa*. To clarify the influence of dislocation dissociation on CPS, the classical Orowan formula is improved by incorporating the SFE. Moreover, the present 3D-DDD simulations also show that the yielding stress of SCNBSs with low SFE may be overestimated up to thirty percent if the dislocation dissociation is ignored. With dislocation dissociation being considered, the size effect due to the width of γ matrix channel and the length of γ' precipitates on the stress-strain responses of SCNBS can be enhanced remarkably. In addition, due to the strong constraint effect by the two-phase microstructure in SCNBS, the configuration of formed junctions is quite different from that in single phase crystals such as Cu. The present results not only provide clear understanding of the two-phase microstructure levelled microplastic mechanisms in SCNBSs with low SFE, but also help to develop new continuum-levelled constitutive laws for SCNBSs.

Keywords: Discrete dislocation dynamics; Dislocation dissociation; Single crystal Ni-based superalloy; Critical percolation stress; Size effect

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