Abstract

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Investigations on the elementary plasticity mechanism(s) in fine-grain face-centered cubic metals and alloys: A case study with a high-Mn steel

The strain hardening behavior of a fine grain size (~ 5 μm) Fe-26Mn-1Al-0.14C steel under uniaxial tensile loading is investigated by X-ray diffraction, electron channelling contrast imaging and transmission electron microscopy. It was revealed that the steel without any significant deformation twinning exhibited almost stable high strain hardening rate of ~ 2 GPa until failure at ~ 50% strain, which was comparable to its coarse grain structure revealing profuse twinning. The dominant deformation mechanisms under twinning deficient conditions are formation of Taylor lattice at early strains (~ 2%) and cross-slip of dislocations. The suppression of twinning is explained by lack of dislocation pile ups that usually provide the required shear stress for formation of stacking faults and twinning. Correspondingly, stacking faults were also rarely observed. The strong interactions among extended microstructure defects affected the effective stacking fault energy of the austenite determined using X-ray diffraction, so that it was much higher (~ 60 mJ/m^2) than expected for the chemical composition of this steel. The contribution of dislocation loops to flow stress was estimated to be nominal ~ 33 MPa and assumed to remain constant through the deformation range. The observed flow stress of the steel beyond 2% strain could be interpreted through contributions from lattice friction, dislocation loop and the newly created mobile dislocations obeying Taylor's hardening model. The nearly stable work hardening observed until higher strains could be explained through cessation of cross-slip at high strains and the newly created mobile dislocations breaking away from the pre-existing dislocation obstacles configurations. The implications of this novel strain hardening mechanism based on the cross-slip assisted dislocation patterning proposed by Kubin and Devincre is discussed.

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