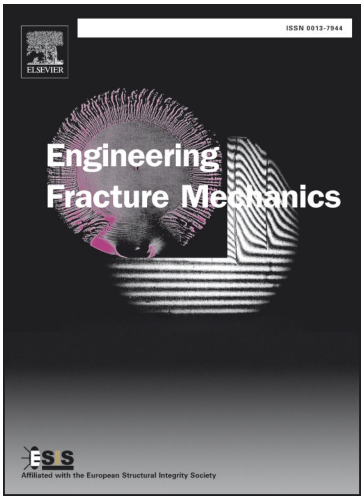

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Effect of nanotwin and dislocation pileup at twin boundary on dislocation emission from a semi-elliptical blunt crack tip in nanocrystalline materials

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Abstract. The effects of the nanotwin and dislocation pileup at the twin boundary on lattice dislocation emission from a surface semi-elliptical blunt crack in deformed nanocrytalline materials (NCMs) are investigated. The nanotwin as a stress source can be described by a wedge disclination quadrupole. Using the complex variable method, complex analytic solution of stress field, the dislocation force and the critical stress intensity factors (SIFs) for the first edge dislocation emission were obtained. Then, through numerical calculation, the influence of twin size, twin orientation, twin position, twin strength and dislocation pileup, the curvature radius of blunt crack tip on the critical stress intensity factors were discussed in detail. The results show that the nanotwin and dislocation pileup has significant influence on the dislocation emission from the blunt crack tip. The presence of nanotwin and dislocation pileup will increase the most probable emission angle, and increase the critical SIFs for dislocation emission, making it harder for the dislocation to emit from the blunt crack tip and thus to decrease the toughness of materials produced by dislocation emission.

Keywords: surface semi-elliptical blunt crack; nanoscale twin; dislocation pileup; dislocation emission; complex variable method.

1. Introduction

Nanocrystalline and ultrafine-grained materials (hereinafter called NCMs) are widely used in various fields because of their superior hardness, high strength and excellent wear resistance comparing to traditional coarse-grained materials[1-20]. These outstanding mechanical properties are due to their specific structural features, particularly their ultrafine grain size and great large number of grain boundaries. But their brittle behavior of low fracture toughness and tensile ductility at room temperature significantly limits their practical utilization. How to make NCMs possess both ultra-high strength and toughness has become an urgent problem for researchers to solve. Recently, some examples of NCMs that combine superior strength and good ductile have been reported. The perfect combination is due to the unique deformation mechanism within the NCMs[21-25]. Whereafter, a lot of deformation modes have been developed to explain the special deformation mechanism in NCMs, such as grain boundary sliding, grain boundary migration, special rotational deformation, diffusion assisted creep, shear banding, nanoscale twining, and so on[18-38]. In particular, grain boundary sliding and other grain boundary deformation play vita role in plastic flow in NCMs in wide temperature intervals. Synchronously, lots of experiments, computer simulations and theoretical models show that nanoscale twin deformation serves as dominant mechanism of plastic flow in NCMs under certain conditions[7-9].

According the work of Ovid′ko, twins are often generated at grain boundaries through the cooperative emission of partial dislocations resulting from transformation of non-equilibrium grain boundary dislocations located on every slip plane and “ supplied ” to grain boundaries due to both grain boundary sliding and stress-driven climb of grain boundary dislocation[7]. For nanotrained materials, grains are subdivided into nanometer-thick twin by massive twin boundary and deformation twin as a stress source can be described by a disclination quadrupole. When dislocations glide along the twin boundary, they will slide unhindered to the grain boundaries. And the followed dislocations along the same slip plane will slide to its equilibrium position determined by the force of applied shear stress and the force of previously emitted dislocations. So there is dislocation pileup along the twin boundary.

Most of the work focused on the nucleation and growth of nanoscale twins, especially on the contribution of nanotwin to the toughening of NCMs. In fact, cracks, holes and other defects are inevitable in the manufacture and use of NCMs. And for NCMs with cracks, so long as the stress intensity of the cracks is large enough, plastic shear will be induced by dislocations emitting from crack tips. The emission of dislocations will cause the crack blunting, further hinder the crack propagation, and finally improve the toughness of NCMs. In addition, the nanotwin and dislocation pileup at the twin boundary that occurs near the crack tip plays an important role in the crack propagation, so it is of great significance to study the interaction between nanoscale twins and cracks.

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