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Elijah N. Borodin, Alexander E. Mayer

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Structural model of mechanical twinning and its application for modeling of the severe plastic deformation of copper rods in Taylor impact tests

Elijah N. Borodin[1,2], Alexander E. Mayer[2]

[1] Institute of Problems of Mechanical Engineering RAS, St. Petersburg, Russia, 199178, V.O., Bolshoj pr., 61
[2] Department of Physics, Chelyabinsk State University, Chelyabinsk, Russia, 454001, Br. Kashirinikh str., 129

Corresponding author: Elijah N. Borodin, Institute of Problems of Mechanical Engineering RAS, St. Petersburg, Russia, 199178, V.O., Bolshoj pr., 61, e-mail: elbor7@gmail.com

Abstract

We propose a new structural model of the mechanical twinning applicable for description of severe plastic deformation in 2D formulation. The twinning model together with the dislocation plasticity model is applied to modeling of the dynamical axis-symmetric Taylor tests with copper samples. Contributions of the dislocation plasticity and twinning in the formation of the shape of the compacted rod are revealed; modification of the defect structure behind the propagating shock wave is considered. The dislocation plasticity gives the main contribution in the case of low impact velocities (about or less than 100 m/s), while the twinning predominates at high impact velocities (about 500 m/s). Substantial influence of both mechanisms of plasticity takes place at moderate impact velocities, which results in formation of an area of the intensively twinned material near the colliding base of the rod and an adjoined area with a high density of dislocations; all this reflects on the profile of the lateral surface of the deformed rod.

Introduction

In most cases, the dislocation plasticity (Meyers and Chawla, 2009; Hirth and Lothe, 1982) is the main mechanism of the plastic deformation of metals. There are a lot of models of the dislocation plasticity, which describe the deformation in the quasi-static (Leung, 2015; Baik et al., 2003; Estrin et al., 1998) and in the dynamic conditions (Mayer et al., 2013; Krasnikov et al., 2011; Meyers et al., 2002). Some of the models include the equations of the dynamics and kinetics of dislocations (Mayer et al., 2013; Baik et al., 2003) that allows one to describe in detail the processes and results (Krasnikov and Mayer, 2012) of structural changes in metals subjected to deformation, and to take into account the inertness of the plastic deformation, which automatically captures the properties inherent for the dynamic deformation (Mayer et al., 2013; Krasnikov et al., 2010). At low temperatures or high strain rates, the mechanical twinning becomes an alternative mechanism of the plastic deformation in metals with a low value of the stacking fault energy (Meyers and Chawla, 2009; Christian and Mahajan, 1995).

As a rule, the existing models of plasticity describe the action of a single plasticity mechanism, but not some set of them (Wang et al., 2010; Clausen et al., 2008; Staroselsky and Anand, 2003). An interesting thermo-mechanical model of twinning was proposed by Rajagopal and Srinivasa (1995, 1997). In the paper by Guillemer et al. (2011), a model was proposed, which takes into account the twinning and de-twinning at negative and positive values of pressure respectively. Tomé with coworkers developed a composite grain model for description of the shear