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PROCEEDINGS

Investigating the Self-Force and Evolution of High-Speed Dislocations in Impacted Metals: A Discrete-Continuous Model and Configurational Mechanics Analysis

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ABSTRACT

The responses of metals subjected to super high rates of deformation ($> 10^5/s$), as shocking loading, is an area of active research. At such extreme loading rates, subsonic, transonic, and even supersonic dislocation (compared with the shear wave speed in metals) play a crucial role in plastic deformation. The behavior of high-speed dislocations is much more complex than that of quasi-static dislocations under static loads, as their self-force is history-dependent, and their evolution of density is rate-relevant. However, the fundamental questions regarding the self-force and evolution of high-speed dislocations in impacted materials is largely unknown. To address this gap, this study proposes an effective calculation method for self-force on high-speed dislocations based on the discrete-continuous model (DCM) of three-dimensional dislocation elastodynamics (3-DDE) and the dynamic J-integral of configurational mechanics. This method is applicable to subsonic, transonic, and supersonic dislocations in both isotropic and anisotropic media, and it can automatically consider the image force if the dislocation is close to the free surface. The effectiveness of the method is verified by comparing it with existing theoretical solutions and molecular dynamics results. The work investigates how crystal anisotropy, complicated motion history, and free surface influence the self-force of high-speed dislocations. Additionally, the study examines how dislocation evolves at high-speed changes under shock wave. The elastic precursor decay is analyzed considering the dislocation elastodyanmics effect.

KEYWORDS

Shock waves; high-speed dislocation; dislocation evolution; crystals anisotropy; self-force

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