Computational 3-dimensional dislocation elastodynamics at shock loading

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ABSTRACT

Understanding the mechanical behavior of solids at extremely high strain rates is of great scientific and technical interest. Current dislocation-based model of plasticity are typically implemented as quasi-static method. Their applicability to high strain rate condition is limited, because the influence of the elastodynamic stress field at extreme strain rates on the collective behavior of 3-dimensional (3D) dislocations is not clear, and the time-dependent nature is very important when the strain rate is higher than 10^6 s^{-1} (e.g. laser shock loading). To overcome this limitation, we present here the first computational procedure for 3D discrete dislocation elastodynamics (DDE). A novel computational method is developed for calculations of the fully-resolved elastodynamic field of non-uniformly moving dislocation loops. The developed method here extends the technique of retarded potentials, which was originally used to describe the electrodynamics of charged particles moving near the speed of light. Comparison with independent 2D calculations establish the accuracy and convergence of the numerical scheme. It is shown that dislocation loop motion near the sound speed results in significant restructuring of the emitted elastodynamic fields. New insights on short-time dislocation interactions during shock loading are also revealed through a study of the forces between rapidly-moving shear dislocation loops.

References:

[1] YN Cui, G Po, YP Pellegrini, M Lazar, NM Ghoniem, Computational 3-dimensional dislocation elastodynamics, Journal of the Mechanics and Physics of Solids, https://doi.org/10.1016/j.jmps.2019.02.008