Mechanical instability criterion of dislocation structures from discrete dislocation dynamics

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Abstract

To understand the nature of mechanical instabilities of dislocation structures, which plays a central role, for example, in determining the plastic behavior and fatigue in crystalline metals, it is essential to investigate a critical condition in which a dislocation structure collapses. A criterion for the mechanical instability of arbitrary dislocation structures is proposed in this paper. According to the criterion, the mechanical instability can be described by the positiveness of the minimum eigenvalue of the Hessian matrix, which is composed by the second-order differential of potential energy of the system with respect to the dislocation coordinates. In addition, the collapse mode can be simultaneously determined by the eigenvector of the minimum eigenvalue. We applied the proposed criterion to the veins and dislocation walls under external loading, and it successfully describes the onset of instabilities and the corresponding collapse modes, regardless of the difference in structures and sizes. This success in the criterion paves the way to address the mechanical instability issues on more complex dislocation structures.

Keywords: Criterion, Instability, Dislocation structure, Deformation mode, Discrete dislocation dynamics