Modelling Frank-Read dislocation sources as pinned and driven mean curvature flow

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Abstract

Frank-Read sources are thought to be a possible mechanism for the generation of dislocation loops with crystalline materials. A first-principles derivation of a simple model for these sources will be presented, focusing on the effect of line tension, the applied stress, and frictional forces acting on a single slip plane, together with a pinning constraint on the ends of the dislocation line. Subsequently, the model is numerically discretised, requiring the implementation of suitable re-meshing and 'topological cutting' algorithms. Despite its conceptual simplicity, the model and discretisation described yield remarkably accurate predictions about the shape and properties of the Frank-Read source, indicating that such sources may be dominated by line tension effects. In particular, it is shown that only one dimensionless parameter controls the dynamics of the Frank-Read source if one neglects crystal anisotropy, and an emergent law relating the length of dislocation line generated by the source over time is observed.

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