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A microstructurally informed dynamic ductile failure model

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ABSTRACT

Dynamic spall failure of ductile metals is a complex multiscale, multirate process. On the macroscale the process involves a period of shock compression followed by dynamic tension set up by the stress wave interactions. During the shock compression, the material undergoes shock-dependent microscopic processes that may include dislocation multiplication, nucleation, trapping, pile-up, annihilation, recovery, cell evolution, as well as vacancy generation and clustering. In addition to shock hardening the material, this new shock-induced defect structure seeds the material with potential void nucleation sites that may be activated during the proceeding period of dynamic tensile loading. In addition to these shock-induced void nucleation sites, the material also possesses pre-existing nucleation sites, e.g., triple junctions, grain boundaries, and second-phase particles. Upon nucleation, these voids undergo dynamic growth to coalescence, constrained by inertia and viscoplastic resistance to deformation. A multiscale predictive model is developed to analyze the role of these time-dependent processes in the experimentally observed spall strength dependence on grain size, impurity content, tensile loading rate, and shock stress magnitude.