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Multi-phase Modeling on Spall and Recompression Process of Tin Under Double Shockwaves

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ABSTRACT

The dynamical response of materials to multiple shock waves is a critical issue in shock physics and engineering applications. In this work, hydrodynamic simulations are used to investigate the shock-induced spall failure and subsequent recompression characteristics of tin, under the implementation of a multi-phase equation of state, multi-phase constitutive relations, and a damage model. As within experiments, double shock loadings in simulations are driven by layered impactors with different shock impedances. In general, our numerical calculations agree well with recent tin spall experiments and reproduce the free surface velocity characteristics. Interesting dynamic behaviors such as tin shock compression, dynamic tensile fracture, and void compaction are revealed to occur in succession as a result of complex wave interactions caused by multiple impacts. With increasing shock strength, the appearance of β-γ phase transition or melting not only changes the primary fracture characteristic, but also affects the subsequent compaction state and inter-shock interval, which suggests the significant effect of phase transition and its synergism with spall fracture. Meanwhile, the multi-phase simulation results show that certain parts of the tin material are in the mixed phase state during dynamic loading or unloading, like the coexistence of β phase and γ phase. Although current research provides a quantitative understanding of spall features induced by double shocks, better multiphase material models are needed to improve fidelity in describing complex fracture behaviors.

KEYWORDS

Spall; double shock; recompression; phase transition

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