Strength Experiments of Iron

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Abstract

The discovery of the reversible α→ε phase transition in iron has its roots in the origins of shock physics [1]. We revisit this classical system in the context of measuring, via proton radiography, the dynamic strength of ε-Fe under quasi-shockless loading.

Introduction

Iron is driven across the 130 kbar α-ε phase transition boundary under high-explosive drive, and the strength of ε-Fe is inferred by growth of the resulting Rayleigh-Taylor hydrodynamic instability of the Fe-gas interface, as the effects of dynamic material strength suppress RTI.[2,3] The RT perturbation has been imaged with proton radiography, thus providing a detailed and accurate time history of the RT growth that can be compared with forward analysis via elastic-plastic hydrodynamics simulation. Simultaneous velocimetry (PDV) of the iron free surface allows for monitoring the phase transformation/reversion and, when coupled with the RTI data, allows for the development of a phase-aware dynamic strength model.

Results and Discussion

The phase transition occurs under pressures greater than 280 kbar, and strain rates on the order of 10^5 sec^{-1} (peaking at over 10^6 sec^{-1}). PDV reveals detailed information of the phase transition from the 3-wave (P1/P2/PIR) structure present at the iron free surface. Proton radiography of the perturbed RT unstable interface shows considerable enhancement of dynamic strength for not only ε-Fe but also the reverted α'-Fe material. Forward analysis via hydrodynamics simulation utilizing the PTW strength model [4] shows the dynamic strength of ε-Fe to be comparable to that of austenitic stainless steels.

References

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