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THERMODYNAMICS ASPECTS OF METAL BEHAVIOR AT EXTREME LOADING RATES

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ABSTRACT

Shock physics community is accustomed to the use of scale-less equations of state (EOS), strength and damage models. We question validity of the models for materials subjected to extreme loading rates. There is experimental evidence that shock loading promotes the formation of strong but not quite stable dislocation structures, wherein there is a continuous competition between the dislocation nucleation, storage and thermal annihilation. Often, the dislocation structures coexist with or are replaced by deformation twins. The dynamic meso-structural reconfiguration is responsible for an abrupt increase of plastic hardening at strain rates greater than 10^3/sec. Frequently, shocked metals preserve the stress induced defect structures but do not retain memory of the instantaneous shock strengthening. For instance, shocked copper and tantalum exhibit an abrupt dynamic strengthening during active loading process. However, the pre-shocked samples tested at quasi-static conditions display a substantially milder strength. Lastly, line-VISAR experiments are depicting strong velocity fluctuations along free surface of shocked metals. Usually, grain size is considered the primary cause for the perturbations. While accepting the explanation, we also suggest that the effects are strongly coupled with the stress induced dislocation structures (and/or deformation twins). These and other experiments indicate that the stress induced defects play an extra-ordinary role in the dynamic behavior of metals.

Our goal is to introduce shock physics into the broader community of computational and theoretical mechanics. We will discuss current achievements in multi-scale experimental and theoretical shock physics. This includes multi-phase equation of state (EOS), strength models with built-in material length scale and dynamic damage.