Condensed phase detonation: Are mesoscale effects needed to predict performance?

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Condensed-phase explosives provide one of the most high-power and energy-dense storage materials available. They are commonly detonated to perform work on adjacent materials for engineering applications in the defense and mining industries, with several billion kilograms used in the United States alone per year. Despite their engineering utility and high level of use, very little is known about the reaction-zone physics and high-pressure product states generated during detonation of high explosives due to the extreme conditions that are generated. Condensed-phase explosives will detonate when processed by a sufficiently strong shock wave, producing product energy densities approaching 14 MJ/L and energy release rates exceeding 1 TW/sq. m, which is higher than the radiative flux at the solar surface. Conditions in the detonation reaction zone are at the upper limit of the the condensed matter regime and reach pressures as high as 40 GPa, temperatures of approximately 4000 K, and detonation shock velocities above 9 km/s. These extreme conditions are sufficient to plastically deform any adjacent manmade material and this yielding can induce significant local variations in flow field of the detonation reaction zone, which is on the order 10-100 micron in thickness. Additional localized chemical and thermodynamic variations also result from the shock passage though the heterogenous microstructure of the explosive itself, which generally consists of a composite matrix of chemically complex energetic crystals and inert binding materials with variations on the order of the reaction zone thickness. In this talk, we review the chemistry and microstructure of high explosives, discuss the mesoscale effects present at scales on the order of the reaction zone thickness during detonation, and consider if resolving these mesoscale effects is critical to the prediction of detonation performance for these materials. Potential future research directions relevant to these issues are also suggested.

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