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Metalized Heterogeneous Detonation and Dense Reactive Particle Flow

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A metalized explosive system comprises a condensed-phase explosive and a large quantity of reactive metal particles, in an attempt to exploit the high energy content of the particles through their rapid combustion. Detonation in such heterogeneous matter and subsequent reaction of the metal particles under strong shock conditions constitute a new area in the dynamics and combustion of dense particle flow, which is characterized by a large number of particle interactions through shocked interstitial fluid or direct inelastic collisions. Progress in the fundamentals of this field is reviewed with an emphasis on particle aspects in three parts: detonation-particle interactions, particle ignition and reaction, and dynamic instabilities of particles. The paper begins with the unique characteristics of the subject heterogeneous detonation including the breakdown of the CJ detonation and detonation shock interaction effects on wave velocity, critical failure diameter, momentum transfer and morphology of particles. Secondly, the concept of a critical diameter for particle ignition, shocked particle reaction mechanism, multiple heat release history and aerodynamic secondary fragmentation combustion are described. Thirdly, particle dynamic instabilities lead to clustering, collisions and coherent jet structure and influence not only the aerodynamic trajectories but also the particle-gas mixing and subsequent energy release. Their mechanisms are revealed through the role of stochastic particle interactions with shock waves and fluid vorticity and turbulence on the formation of the trajectory instabilities of the particles. A hybrid detonation mode is finally invoked to exploit the energy release limit of metal particles. The paper is portrayed in a large number of experiments combined with meso-scale modeling and theoretical explanation.