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Triple-Shock Reflections Using A New Reactive 10-Moment Model

William Morin, James G. M^{c}Donald and Matei I. Radulescu
Department of Mechanical Engineering, University of Ottawa, Ottawa, Canada

ABSTRACT

Detonation waves in gases present a distinctive cellular structure that controls the overall rate of energy release. The cellular structure consists in repeated triple shock reflections driven by the coupling of reactivity to the stronger parts of the front, the Mach shock. These triple shock interactions play a critical role in maintaining the propagation of the detonation front. To date, very little is known about the sequence of physical processes associated with triple shock collisions in reactive gases. Some authors, assuming that the triple shock reflection is analogue to the Mach refection of an incident shock, studied this problem numerically using a Navier Stokes description. However, the Navier Stokes model is known to offer limited accuracy when dealing with situations far from thermodynamic equilibrium.

As originally suggested by Zel'Dovich (1966), large reaction rates can occur due to the coupling between the kinetics and the non-equilibrium structure of the shock wave. Recent studies using molecular dynamics revealed that shocks may couple with reactivity in the limit of fast kinetics (Murugesan 2023). These findings provided a novel explanation for the anomalously high reaction rates observed in experiments. In this work, a numerical investigation using the 10-moment model is presented. This model allows for the quantitative evaluation the non-equilibrium translational and rotational modes. Furthermore, a new reaction model that takes into account temperature anisotropy is introduced. Calculations of one-dimensional shock to detonation transition and two-dimensional triple shock reflections in a reactive gases are presented assessing the importance of non-equilibrium effects to detonation dynamics.