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Modelling and Experiments of the Triple Point Reflection in Detonations

Zangene F[1]*, Radulescu M[1]
*fzang055@uottawa.ca
[1] Universityof Ottawa, Canada

Experiments in reactive mixtures show that detonation waves exhibit a highly dynamic cellular structure comprised of the incident, Mach and transverse shocks [1]. These three shock waves and the slip line, which separates gas passing through the incident and reflected shocks with the gas passing through the Mach shock, are joined at the triple point. The periodic interaction of these three shock waves in reactive mixtures forms the cellular structure of the detonation. These interactions are believed to control the propagation mechanism, as they generate highly overdriven detonations well above the Chapman Jouguet (CJ) speed, which then decay through the cycle and reform from new triple point collisions. Therefore, the outcome of the triple point reflection off a wall or another triple point is important in predicting the detonation's propagation mechanism.
The objective of this study is to formulate a model to determine the strength of the newly formed reactive Mach shock after the triple point reflection within a detonation cell. Experimental evidence showed that this Mach shock is an overdriven reactive wave. However, in the available three shock theory [2], all the shocks are assumed to be inert. We attempt to modify this model by incorporating the assumptions of a reactive Mach shock and using the real gas calculations. The model is further tested using mixtures with different specific heat ratios (ranging from 1.1 to 1.5) and various angles of the incoming shock (ranging from 16° to 50°) to resemble different scenarios of the triple shock reflection. We show that regardless of the mixture, all the frozen composition calculations overlap with each other. However, the equilibrium composition calculations reveal that the most compressible gases exhibit the greatest deviation from the frozen calculations. To verify the accuracy of the model, detonation experiments with self-propagating enlarged cell structures are conducted. The triple point reflection process was monitored with high-speed schlieren videos permitting to measure the strength and angle of the incoming shock and newly formed Mach shock. The experiments were performed in mixtures which span the degree of cellular regularity of detonations and compressibility of gas in reactive gases. The experimental data of the detonation dynamics are compared with the model predictions, and a high level of agreement between the two is observed.

References

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