Detonation Propagation in the Limit of Discretized Energy Sources

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Abstract

In contrast to the classic Chapman-Jouguet theory that assumes a homogeneous reactive medium in which a detonation wave propagates, detonation waves propagating in a medium consisting of discretized energy sources are examined in this study. The one-dimensional Euler equations are numerically solved to simulate the dynamics of the wave propagation. The energy deposition process is modeled as an instantaneous increase in pressure within the volume occupied by each energy source after a finite delay period has elapsed since the source has been triggered by the passage of the leading shock. The steady state detonation velocity resulting from the simulation with a homogenous reactive medium (i.e., continuous energy release) is found to be in close agreement with that predicted by applying the CJ criterion. As the energy sources are discretized and separated by inert media while keeping the average specific chemical energy (i.e., $\Delta q \sim \mathrm{J/kg}$) the same, after propagating over a sufficiently long distance (over 1000 sources), the steady state detonation velocity is found to be significantly higher than that of the equivalent CJ detonation. For example, in a 10% discrete reactive medium (i.e., each two adjacent energy sources are separated by a distance that is 9 times the space occupied by a source) with an average dimensionless heat release $\Delta q/\mathrm{R}T_0 = 50$ and heat capacity ratio $\gamma = 1.2$, the resulting steady state detonation velocity is higher than the equivalent CJ velocity by 9%. The effects of $\Delta q/\mathrm{R}T_0$ and γ on the detonation propagating in a discretized reactive medium are also investigated. For the same source discreteness, the super-CJ detonation velocity is observed to be even higher for a greater $\Delta q/\mathrm{R}T_0$ or a smaller γ. These results may shed light on the propagation mechanism of detonations in condensed-phase explosives with large-scaled heterogeneities that cannot be explained by models assuming chemical energy uniformly embedded throughout the combustible mixture and detonation in gases that exhibit highly irregular cellular structure.

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