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Converging shocks for DSD modelling

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Modelling of pyrotechnic systems requires both, a good understanding and precise prediction capabilities of the dynamics of detonation. When using insensitive high explosives IHE (such as TATB-based explosives) the interaction of the detonation front with the confinement can lead to very different detonation velocities. One of the most popular engineering tools used to model this behaviour is the Detonation Shock Dynamics (DSD). In the DSD assumption, the detonation front propagates at a normal shock velocity (D_n) which depends only on its local curvature (κ). For divergent detonations, the DSD limit is very well established both experimentally and theoretically and one can easily propose a model (which obeys the 1D quasi-steady weakly curved detonation theory) to reproduce this behavior. We propose to extend the DSD theory to slightly convergent detonation fronts and to validate it against experimental data. Two series of experiments were carried out. The first series was designed to collect precise information regarding converging detonation. Usually, in such configurations, the detonation is non steady, making precise and simultaneous measurements of velocity and curvature difficult to achieve. The originality of the proposed setup is to drive a self similar convergent detonation at constant speed in an IHE rod by an external explosive tube of greater detonation velocity (allowing an accurate recording of both velocity and curvature). A wide range EOS/reaction rate model (inspired from previous works of Wescott et al.) was then calibrated to reproduce both the strong shock initiation and the newly extended (D_n-κ) law. This model can be used to perform either direct numerical simulation (DNS) on fine resolved mesh grid, or its reduced PZR model (DSD based) on a much coarser grid. This model was then successfully validated against the second series of experiments involving a detonation propagating around an obstacle and exhibiting a non steady converging front while passing the obstacle. Discussions will be focussed on the uniqueness of the (D_n-κ) law on the converging branch ($\kappa < 0$) and the ability of DSD to reproduce accelerating detonation fronts through comparisons between DSD and DNS calculations with experimental data.

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