Three-Dimensional Simulations of Detonation Quenching in Narrow Channels

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In the last fifty or so years, extensive work has been done on flame acceleration, transition to detonation, and detonation propagation. This includes basic theory, experiments and most recently full simulations of the reactive Navier-Stokes equations. Here we focus on the process of detonation quenching and possible reignition.

Multidimensional (2D and 3D) simulations were performed for detonations propagating in very small channels to study the details of how quenching occurs. Here, very small means ~1/50th of the characteristic detonation cell size for the mixture. In very early work, we identified a hydrodynamic mechanism for quenching. The principle was that transverse wave collisions were misaligned such that they cut off ever-increasing unreacted (or partially reacted) pockets of gas. These created large pockets of unburned fuel that fall behind the leading shock waves. This effect was observed both in computations and experiments.

Here we describe the quenching process in 3D and beyond the region where pockets have been cut off. To our surprise, we see possibilities of flame reignition leading to tulip flames and the interactions of these with growing boundary layers.

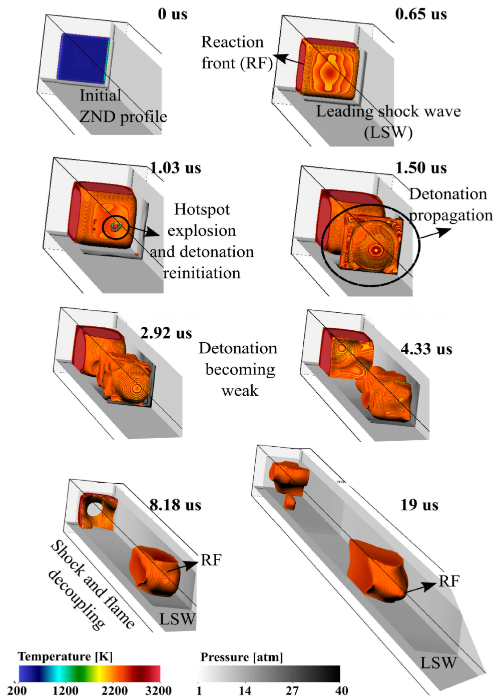

Figure. Temperature isovolumes and pressure slices for a 3D simulation of a quenching detonation in a stoichiometric mixture of ethylene and air. The detonation is initiated with a blast at the entry. The channel diameter was ~ 1/50th of the cell size. 0 μs: initiation. 0.65μs: initial decoupling of shock and reaction front. 1.03 μs: hot spot explosion at centerline. 1.50 μs: detonation formation; 2.92 μs: detonation weakens. 8.18 μs: quenched detonation and flame propagation.

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