Detonation-bubble interaction: methods and scoping tests

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Introduction

Detonation behaviour under limit conditions is influenced by multi-dimensional instabilities along the detonation front. In regular mixtures, where instabilities are weaker, it is driven largely by adiabatic shock compression across the entire detonation front. In irregular mixtures, stochastic localized hotspots appear to play an much more important role in sustaining propagation. It is unclear if detonation limits are governed by the bulk characteristics of the mixture or by local hotspots [1, 2]. The goal of the research is to inject bubbles into a detonation channel. These bubbles aim to create localized hotspots that can focus the shock wave or change induction zone length, providing insight into detonation limits. A novel injector was designed to create bubbles of a desired diameter ejected with precise timing.

Experimental methods

The detonation apparatus is a thin rectangular channel (203 mm $\times$ 19 mm) with a visualization section to enable high-speed shadowgraph imaging. Precision regulators and choked flow orifices are used to mix the reactants in real-time and fill the apparatus, with an in-line static mixer to ensure mixedness. The bubble injector consists of two coaxial tubes: the outer tube contains the bubble fluid solution, while the inner tube carries the bubble gas from a small tank premixed with the desired bubble gas. The opening and closing of two solenoids on either side of another choked flow orifice downstream of the small tank is carefully timed over two phases. During the first phase, a bubble is formed on the injector, and the second phase is used to detach the bubble from the injector.

Preliminary Results

Extensive testing and improvements of the injector has yielded a method to reliably inject bubbles into the detonation channel. Figure 1 displays the injection process of a N_2 bubble. Figure 2 displays shadowgraph images of the interaction of a detonation with a 17 mm bubble. The test was conducted in $2\,H_2 + O_2 + 2\,N_2$ bath gas at 10.1 kPa. To determine the overall effect of the bubble film on the detonation as a control experiment, the bubble also contained bath gas.

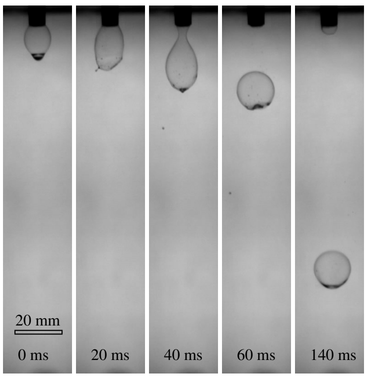

Figure 1: Bubble injection process

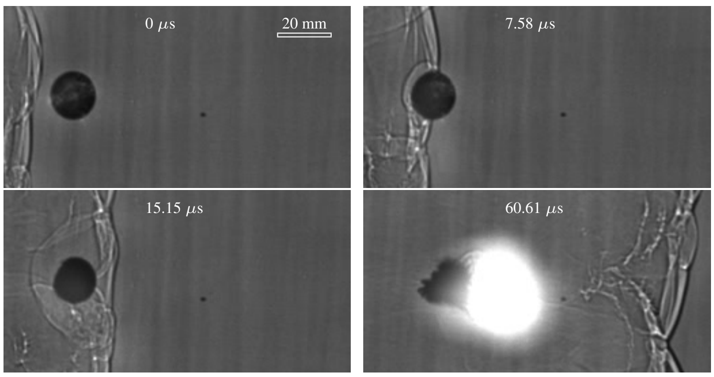

Figure 2: Shadowgraph images of the detonation interacting with a bubble

Planned Work

Further control tests will be conducted to understand the effect of the bubble film. Then, the bubble composition will be varied first by changing the reactivity (*e.g.* ozone addition), and second by changing the density of the bubble gas (*e.g.* xenon dilution), thereby focusing the frontal shock. Both of these methods are expected to create hotspots to study detonation limits. 1D and 2D simulations are also underway.

References

[1] M. I. Radulescu and B. Borzou, "Dynamics of detonations with a constant mean flow divergence," *Journal of Fluid Mechanics*, vol. 845, pp. 346–377, June 2018.

[2] J. H. S. Lee, "Detonation Phenomenon," Cambridge University Press. Section: 1.1 Deflagrations and Detonations.

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