Upstream Effects on Oblique Detonation Waves

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There is renewed interest in the use of oblique detonation wave (ODW) for hypersonic propulsion [1, 2]. Prior work on the study of oblique detonation waves has primarily considered waves under ideal conditions. For integrated engine systems, consideration of non-idealities on standing detonation wave dynamics remains an important area of research. For example, upstream boundary layers can lead to shorter induction lengths [3] at the initiation of the detonation front. In this work, we focus on the role of an (i) upstream boundary layer, which is relevant to wall-mounted wedge experiments, and (ii) entropic disturbances upstream of the wave. The conditions of the experiments at UCF [4] are considered.

Recent work has highlighted the role of inhomogeneity in the combustible gas mixture, such as in fuel concentration and temperature distribution, is shown to affect the morphology of standing oblique detonation waves through augmentation of the shock-detonation transition process and triple-point structures[5, 6]. This can cause instabilities in the standing detonation wave system, leading to unsteady fluctuations and the loss of performance. As an example, Iwata (2023) found varying the concentration resulted in a concave and convex shape to the ODW front over a wedge, causing the post-detonation flow to move near the wedge in fuel-lean regions and away in fuel-rich regions[7]. Furthermore, Yang et al (2021)[8] found that upstream disturbances can enhance or suppress the unstable detonation fronts, promoting the rise of trains of triple point interactions or cause triple point degeneration along the ODW surfaces. This can lead to oscillatory behavior on the detonation surfaces and is a relevant concern for air-breathing propulsion systems where intake non-uniformity and confinement effects can contribute to mixture inhomogeneity ahead of the stable detonation wave. As such, the influence of upstream effects on the quasi-stable detonation systems is not fully understood and it remains an important research topic with implications for practical engine integration.

Two-dimensional, unsteady computational fluid dynamics simulations are conducted to investigate a configuration based on Rosato et al. (2021)[4] and study upstream effects on the ODW in an H2-air mixture over a 30° wedge geometry. It is assumed the fuel-air mixture is sufficiently mixed upstream of the nozzle to approximate a premixed mixture composition; the use of the 1-step, optimized mechanism is used for the chemical kinetics[9].

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