

Shock-to-detonation transition in hydrogen mixtures with repeated obstacles

Maria Camila Restrepo, Hiroaki Watanabe, Ashwin Chinnayya, Vincent Rodriguez
Institut PPRIME - UPR 3346 - CNRS - ISAE-ENSMA - Université de Poitiers, France

Shock-to-detonation transition (SDT) in hydrogen–oxygen mixtures results from the coupling of chemistry with shock dynamics. When a shock reflects from a rigid boundary, three ignition regimes can follow: (i) Strong ignition is a prompt, nearly planar bulk reaction that couples to the reflected shock within a few microseconds [1]; (ii) Weak ignition, characterized by a delayed onset in which independent flame kernels grow and coalesce [2]; and (iii) Weak-bifurcation ignition, where ignition is facilitated by the bifurcated reflected-shock structure and begins inside the stagnation bubble near triple points [3]. Although single shock–obstacle interactions have been extensively studied [4, 5], the combined effect of repeated obstacles in rectangular shock tubes and the conditions under which they promote or suppress SDT remain underexplored.

Experiments are performed with a stoichiometric $2\text{H}_2 + \text{O}_2$ mixture in the driven section at initial pressures $P_1 = 15$ kPa to 20 kPa. The 4 m-long shock tube has a 50 mm square cross-section that contracts over the last 0.36 m to a 50 mm \times 10 mm slot. Incident shocks are generated by a 3 m-long driver filled with either stoichiometric $\text{C}_2\text{H}_4/\text{O}_2$ or Ar-diluted H_2/O_2 . Pressure ratios derived from the Brown & Thomas [4] correlations for the chosen driver–driven gas pairs are expected to yield incident Mach numbers of approximately $M_s \approx 2.5$ – 3.5 in the test mixture. The corresponding post-reflection states—pressure P_5 and temperature T_5 —are expected to fall within the SDT window reported in the literature: shock velocity $U_s = 1.5$ km s⁻¹ to 2.0 km s⁻¹, $T_5 = 1000$ K to 1600 K and $P_5 = 500$ kPa to 2000 kPa [1, 5]. A removable train of equally spaced flat obstacles is positioned within the optical section allowing systematic variation of spacing and blockage to quantify how repeated obstacles modify the reflected-shock dynamics. The overarching goal is to determine how such perturbations shift the balance among strong-ignition, weak-ignition, and weak-bifurcation ignition modes. Preliminary runs already indicated critical flow conditions for SDT, and forthcoming tests will refine these limits; results will be shared as work-in-progress.

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References

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