Experimental study on the detonation propagation behaviors through a single orifice plate in hydrogen-air mixtures

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Abstract

In this study, the regimes of detonation transmission through a single orifice plate were investigated systematically in a 6-m length and 90-mm inner diameter round tube. A single obstacle with different orifice size (d) from 10 to 60 mm was adopted to study the effects of the induced perturbations on the detonation propagation. Here, particular attention was paid to the cases for which the blockage ratio (BR) is greater than 0.9, i.e., the cases of small hole diameter of $d<25$ mm. Because it is a more practical and important problem in industrial safety. Detonation velocity was determined from the time-of-arrival (TOA) of the detonation wave recorded by eight high-speed piezoelectric pressure transducers (PCB102B06). Detonation cellular size was obtained by the smoked foil technique. The characteristic of detonation velocity evolution were quantitatively analyzed after it passes through a single obstacle. The experimental results showed that with the increases of BR from 0 to 0.96, the effect of BR on the upper limit of detonation propagation is more serious. Once the detonation wave fails in the fuel-rich side, it is difficult to be re-initiated due to the larger sound speed of products. As the BR values are further increased to 0.972 and 0.988, no detonation wave can be observed, indicating the perturbation induced by orifice plates has exceeded the critical condition of detonation formation. Of note is that the detonation is easier to be produced in the fuel-lean side when the BR values are greater than 0.802. This can be explained and the specific reasons are as follows: Firstly, the stronger shock wave is easier to be formed at the fuel-lean side due to the smaller products speed of sound. Secondly, the hydrogen-air mixture is unstable with highly irregular detonation cellular structures, which is easier to induce a detonation wave. Finally, the disturbance is sharply enhanced in the larger BR cases, which facilitates the fast mixing of combustible gases. Moreover, the critical condition for detonation propagation through an orifice plate can be quantified as $d/\lambda>1$ where λ is the detonation cell size.

Keywords: Detonation, perturbation, propagation mechanism, critical condition.