Fast Shock-to-Detonation Transition in Tube with Converging-Diverging Nozzle for PDE Applications

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The future of air-breathing pulse detonation propulsion depends to a large extent on the solution of the fundamental problem of detonation initiation via deflagration-to-detonation transition at very short distances within a very short time. Several possible approaches to this challenging issue have been suggested recently by Frolov (2007). The most promising approach implies the use of combined means consisting of the flame accelerating device (e.g., a Shchelkin spiral) followed by the shock focusing element (e.g., a curved tube segment). In this case, the Shchelkin spiral generates a shock wave of sufficient intensity ahead of the accelerating flame and DDT is attained due to transition of this shock to a detonation in a curved tube segment due to gasdynamic focusing phenomena. This paper describes the experimental data on shock-to-detonation transition (SDT) in a new focusing element – a converging-diverging (CD) nozzle.

The experimental setup was a tube – nozzle – tube assembly 4.5 m long comprising two straight segments of circular smooth-walled tube 52 mm in internal diameter connected via flanges to the DC nozzle from both sides. At one end of the assembly, a solid-propellant shock wave generator with a bursting diaphragm was attached. The other end of the assembly was open to the atmosphere. The DC nozzle contained a shaped conical converging section 30 mm long and straight conical diverging section 450 mm long. The nozzle throat section had a diameter of 28 mm and was located at a distance of 2130 mm from the bursting diaphragm. The shape and length of the converging section was the same as that obtained computationally by Semenov et al. (2008) whereas the length of the diverging section was considerably increased to ensure reliable detonation transition. All experiments were performed with the stoichiometric propane – air mixture at normal atmospheric conditions. The shock wave velocity was measured using 9 high-frequency pressure transducers PT1 to PT9 with PT1 serving as a triggering unit.

It has been proved experimentally that the critical velocity of the shock wave at the nozzle entrance required for SDT was 720 ± 20 m/s (Fig. 1). Figure 2 shows the pressure records corresponding to the run with the near-critical incident shock velocity. In this case, detonation arose about 1.7 m downstream from the nozzle throat due to secondary explosion in the wake of the transmitted shock. At incident shock velocities on the level of 1000 m/s, the detonation was registered at the nozzle exit. The experimental configuration under study can be considered promising for air-breathing PDEs.

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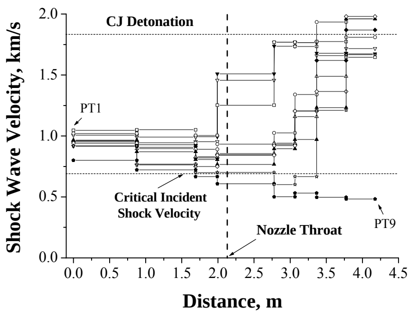

Fig. 1 Measured shock wave velocities at different measuring segments in a tube with a DC nozzle filled with the stoichiometric propane – air mixture (symbols denote positions of pressure transducers PT1 to PT9 and are used for indicating different runs).

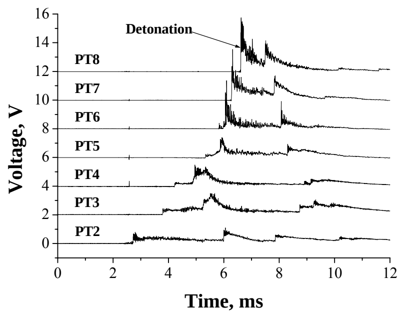

Fig. 2 Pressure records by transducers PT2 to PT8 in the run with the critical incident shock velocity of 720 ± 20 m/s.