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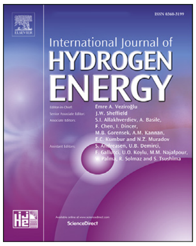

Explosion venting of hydrogen-air mixtures from a duct to a vented vessel

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ABSTRACT

Experiments were conducted on the vented explosion of hydrogen–air mixtures from a 150-cm-long duct to a cylindrical vessel with a vent at the center of its side wall to investigate the effects of vent burst pressure and an obstacle in duct on the process of explosion venting. Turbulent pressure oscillation owing to a pressure wave moving back and forth in a duct and vessel was observed for unvented explosions. For explosion venting from duct to vessel, flame acceleration in duct much increases the explosion overpressure in vessel. The maximum explosion in duct is always higher than that in vessel, and both of them increase with an increase in the vent cover thickness. An obstacle installed in duct significantly affected the explosion overpressure, which first increased and then decreased with an increase in the blockage ratio. Three pressure peaks were distinguished in the external pressure-time histories, which were resulted form different pressure waves formed outside the vessel.

Introduction

Nowadays, explosion venting is extensively employed to protect equipment against excessive internal hydrogen-air explosion pressures by means of effective pressure relief. The effectiveness of explosion venting is affected by the parameters of ignition position [1–11], the location, number, area of the vents [1–8,12], hydrogen concentration [1–5,8–10,12], vent burst pressure [1,2,13], the presence of obstacles [4–6,14–16], pre-ignition turbulence [1,2,8,9,17], hydrogen concentration gradient [4,18], etc. Recently, Liang [19] investigated the effect of igniter type and number of igniters on vented deflagrations and found that the maximum combustion overpressure increases with an increase in the number of igniters.

In most previous research, only a single vessel or duct was used to investigate the phenomena of vented hydrogen–air

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deflagrations. However, vessels interconnected by pipes are very common in the industry, and the fact that flames can spread from one vessel to another through the pipes was observed to significantly affect the maximum internal overpressure. Holbrow et al. [20] investigated explosion venting of dust in two vessels with different volumes connected with a pipe and observed that the passage of flames from the primary ignition vessel resulted in a secondary explosion that produced a much higher pressure than expected from a vented single vessel and that the pressure enhancement was greatest when the primary ignition occurred in the larger of the two vessels. Zhang et al. [21] investigated the vented explosion of methane–air mixtures in a confinement similar to that of Holbrow [20], and their experimental results demonstrated that explosion transmission from a large vessel to a small vessel caused a poorer venting effect and the longer is the pipe, the larger is the peak pressure. Liang [22–24] investigated vented lean hydrogen–air deflagration in rectangular vessels configured with single and multiple chambers, and higher overpressure was measured for the tests involving more chambers.

Although explosion of dust [20] and methane [21] in interconnected vented vessels have been investigated, the flame behavior and pressure build-up of vented hydrogen–air deflagration are not well understood, and the effectiveness of explosion venting is not well known. Hydrogen-air mixture is more reactive and more prone to accelerate, resulting in higher overpressure and even worse cause a transition from deflagration to detonation under suitable conditions [25,26]. In this study, experiments of vented hydrogen–air deflagration from a 150-cm-long duct to a vented vessel were performed to investigate the flame behavior and pressure build-up within and outside the confinement. In some tests, an orifice plate fitted in the duct was used to simulate the effect of a valve installed in pipes, which connect vessels, on explosion venting.

Experimental

Fig. 1 shows the test enclosure, sketch of the experimental layout and obstacles used in current tests. The cylindrical vessel had two 10-cm-long necks at its waist; one end was connected to a 150-cm-long duct constructed from three 0.5-m-long flanged sections, and the other open end was used as vent. The inner diameter and length of the cylindrical vessel was 25 cm, and the square cross section of the necks and ducts was 7 × 7 cm. Quartz windows were fitted into the cylindrical vessel and duct as shown in Fig. 1 to allow optical access necessary for a Schlieren system.

The hydrogen–air mixture was ignited at the end of the duct using an electric spark generated by an ignition plug mounted at the end of the duct, and the ignition energy was maintained at approximately 500 mJ. The measuring systems and experimental procedures were quite similar to our earlier work [13]. The flame images were captured by a high-speed Schlieren system. Three piezoelectric pressure sensors, PS_1–PS_3, were employed to record pressure histories, as shown in Fig. 1. PS_1 was mounted in the duct 60 cm from the ignition plug, PS_2 was flush with the inner surface of cylindrical vessel, and PS_3 was mounted on the axis of vent at 60 cm from the vent cover to measure the pressure evolution outside. And pressure sensors were coated with a thin layer of silicon grease to avoid thermal effects on the pressure measurements.

Our focus was the effects of vent burst pressure and an obstacle fitted 50 cm from the ignition plug on explosion venting. Experiments with vents sealed by a blind flange

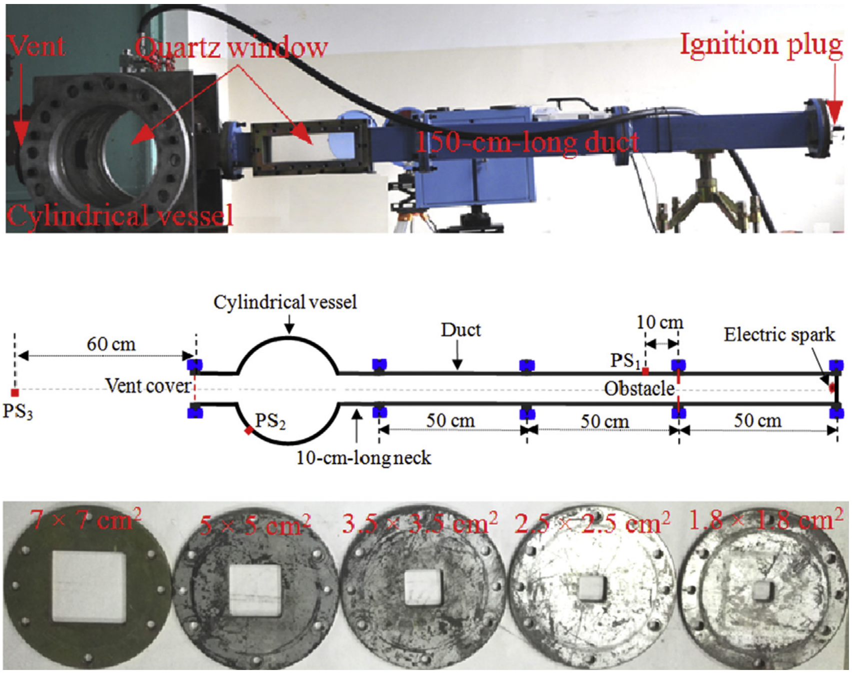

Fig. 1 – Test enclosure (top), sketch of experimental layout (middle) and obstacles (bottom).