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Effect of burst pressure on vented hydrogen-air explosion in a cylindrical vessel

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ABSTRACT

Effect of vent burst pressure on internal pressure and flame evolution is experimentally investigated during explosion venting of rich hydrogen-air mixtures with equivalence ratio of 2 in a cylindrical vessel with a neck. Experimental results show that four pressure peaks are observed at the vessel exit under low vent burst pressures, corresponding to the following four successive stages: the vent failure, the venting of the burned gases, the maximum production rate of burned gas in vessel and the suction of gases into vessel. But under high vent burst pressure, the second and third pressure peaks disappear and the first one becomes dominant. The fourth pressure peak due to suction is kept around several kilopascals. The pressure in vessel is always characterized by single pressure peak which increases with the increase of the vent burst pressure. Under low vent burst pressures, the oscillation of internal flame due to flame-acoustic interaction results in oscillation of pressure rise rate in about 2000 Hz, and the oscillation nearly disappears under high vent burst pressures. The external flame speed does not decrease monotonously as the increase of distance away from the vent, and the maximum length of external flame is nearly independent of vent burst pressure.

Introduction

In hydrogen safety community, hydrogen explosion hazard is extremely important and has been extensively focused due to its wide flammable range, low ignition energy and high burning rate, etc. Actually, explosion venting is an effective method commonly used to prevent or minimize the damage to vessels caused by internal explosion. The key point in explosion venting lies in the appropriate setting of venting parameters to maintain effective pressure relief, which is extremely important for combustible gas mixtures with high rate of pressure rise, such as hydrogen-air mixture, and at the same time, secondary disasters resulted from explosion venting should be avoided.

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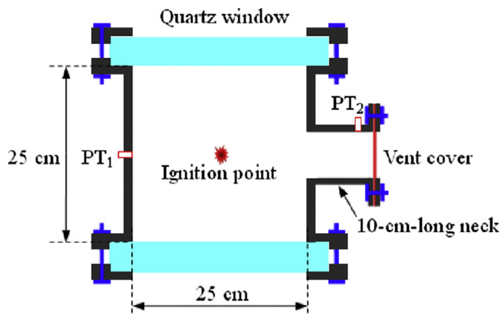

Fig. 1 — Schematic of vented vessel.

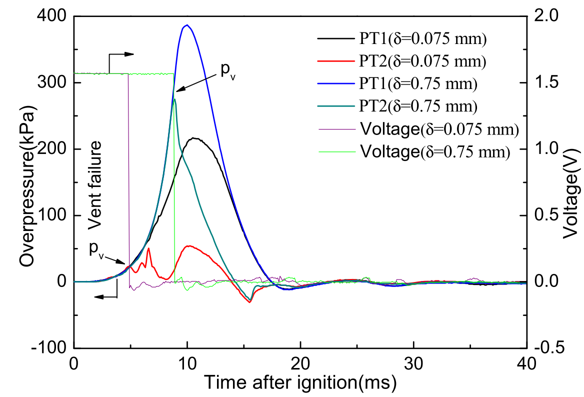

Fig. 3 — Determination of vent failure time t_b and vent burst pressurep_v.

Generally, vent burst pressure (p_v) is one of the most important venting parameters affecting explosion venting of hydrocarbon-air mixtures [1–6]. For example, McCann et al. [1] investigated the explosion venting of methane-air mixtures in two kinds of cubical vessel with size of 18 cm and 38 cm, respectively, and found that two pressure peaks appear when p_v exceeds a critical value. They also observed the time interval between two pressure peaks decreases with the increase of p_v. Four pressure peaks are discovered by Cooper et al. [2], and two particular pressure peaks become dominant when p_v increases. Chow et al. [3] found that dominant pressure peaks depend on the initial conditions besidesp_v. Molkov [4] observed that peak pressure increases with the increase of p_v when p_v< 200 kPa, but decreases whenp_v becomes higher. On the contrary, Ponizy and Leyer [5] found that the maximum pressure increases with the increase of p_v. However, no consistent trend of the influence of p_v on maximum pressure is found by Kasmani et al. [6,7].

In spite of the above mentioned investigations about explosion venting of hydrocarbon fuels, comprehensive experimental examination is still necessary for hydrogen, which is far more reactive and diffusive, since hydrogen may not follow the rules obtained from explosion venting of hydrocarbon fuels. For example, Kasmani [8] found that there was no significant difference among the maximum pressures whenp_v = 9.8, 17.8 and 20.9 kPa, respectively; however, the maximum pressure decreases as p_v reaches to 42.4 kPa for hydrogen-air mixture ignited at the center of a cylindrical vessel. Obviously, this trend is different from the results obtained from methane-air mixtures.

Apart from the works of Kasmani [8], many aspects of the effect of p_v on explosion venting of hydrogen-air mixtures have not been studied yet. For example, how does the maximum pressure vary along with higherp_v? How does the internal and external flame propagate before and after vent failure? In order to address these problems, explosion venting of rich hydrogen-air mixtures in a cylindrical vessel with a neck was experimentally investigated to, firstly, clarify the effect of p_v on the maximum internal pressure and pressure rise rate, and secondly, make clear the behaviors of the internal and external flames before and after vent failure, especially the flame speed and the flame length.

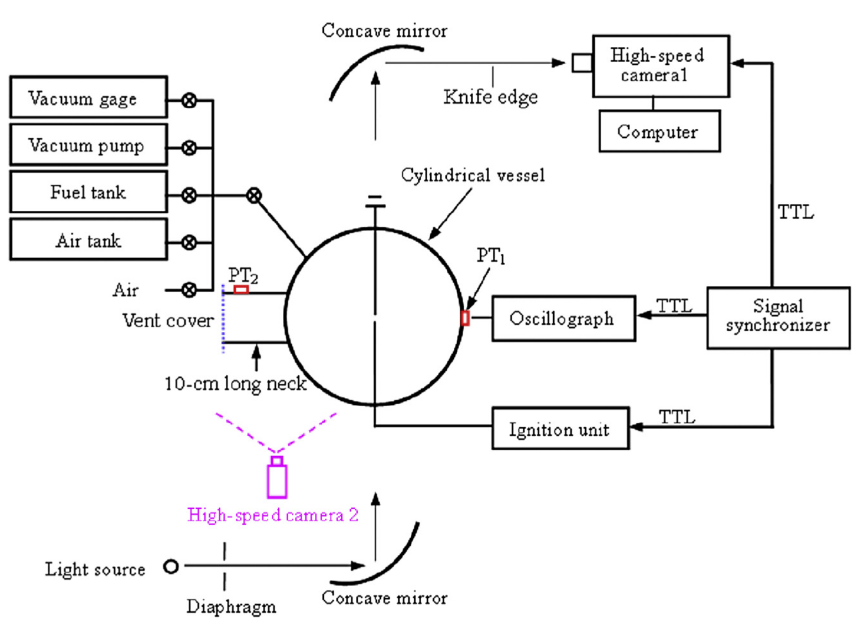

Fig. 2 — Experimental layout.