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ScienceDirect

Procedia Engineering 211 (2018) 306–314

Procedia Engineering

www.elsevier.com/locate/procedia

2017 8th International Conference on Fire Science and Fire Protection Engineering
(on the Development of Performance-based Fire Code)

# Experimental research on the Characteristics of Hydrogen-Air Explosion Pressure in Spherical Vessel—Pipe

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**Abstract:**

In this paper, the spherical vessel-pipe gas explosion test system is developed to study the effects of initial pressure, vessel volume and pipe length on the explosion of hydrogen-air premixed gas. The experimental system consists of an explosive device, an ignition device, a data acquisition device and an automatic gas distribution device. The explosive device consists of a 113 L or 22 L spherical vessel connected with pipe. The experimental results showed that, the maximum explosion pressure in the spherical vessel connected with pipe decreases with pipe length, the hydrogen maximum explosion pressure at the end of the pipe decreased when the spherical vessel is connected. The maximum explosion pressure in the isolated spherical vessel and the isolated pipe terminal increased linearly with the initial pressure. In the spherical vessel connected with pipe, the maximum explosion pressure in the spherical vessel and pipe terminal increased with the initial pressure, but there is no linear relationship between the maximum explosion pressure and the initial pressure. In the spherical vessel connected with pipe, the change in maximum explosion pressure in the spherical vessel is small, and the maximum explosion pressure at the pipe terminal clearly increased as the volume of the vessel increased. When a hydrogen explosion occurs in the spherical vessel connected with pipe, there is a significant oscillation in the spherical vessel and terminal of the pipe. The maximum explosion pressure rising rate in spherical vessel increases with the vessel volume, The maximum explosion pressure rise rate at the pipe terminal decreases with the vessel volume. The maximum hydrogen explosion pressure rising rate at the pipe terminal increases with the pipe length, the maximum hydrogen explosion pressure rising rate in the large spherical vessel decreases with the pipe length. In the spherical vessel connected with pipe, the maximum explosion pressure in the spherical vessel decreases with the pipe length. The maximum hydrogen explosion pressure in the pipe terminal increased with the pipe length. When the spherical vessel is connected with the three-section pipe, the maximum hydrogen explosion pressure in the pipe terminal reaches 1.78 MPa, which is a quasi-detonation state.


Peer-review under responsibility of the organizing committee of ICFSFPE 2017.

*Key words:* spherical vessel-pipe, hydrogen explosion, oscillation, $dp/dt_{max}$

## 1. Introduction

Hydrogen is a clean energy source, and its usage amount is increasing. During the process of using hydrogen, many factors can lead to hydrogen leakage, which leads to the occurrence of an explosion accident. In the industrial production of hydrogen, a spherical vessel connected with pipe is often formed. For example, the structure between the raw material storage tank and the transportation pipe is a spherical vessel connected with pipe. Thus, the study on hydrogen explosion characteristics in the spherical vessel connected pipe has a very practical significance. Currently, many experts and scholars have studied the hydrogen explosion. For example, Bartknecht [1] studied gas explosion in a container and proposed the famous "cube law " of gas explosion. Hidenori Matsui et al. [2] explained and summarized the explosion characteristics of the hydrogen-air mixture and discussed the effect of initial temperature on the stoichiometric hydrogen mixture explosion pressure characteristics. He found that the knocking characteristics of hydrogen were very similar to that of acetylene. Kanchan Raiet et al. [3] studied the flame propagation of hydrogen-air premixed gas under 1 atm atmospheric pressure, and they found that the flame at the initial stage of flame propagation has unstable properties and the flame of the non-

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1877-7058 © 2018 The Authors. Published by Elsevier Ltd.
Peer-review under responsibility of the organizing committee of ICFSFPE 2017
10.1016/j.proeng.2017.12.017

homogeneous hydrogen-air mixture is also unstable. Tanaka [4] studied the safety of a hydrogen fuel cell vehicle during the hydrogenation process and carried out the dispersion and explosion experiments. He concluded that the overpressure generated after the hydrogen leakage had a significant correlation with the ignition time and ignition distance. Battersby et al. [5]studied the influencing factors of hydrogen explosion. They found that hydrogen explosion suppresses the effect of diluted nitrogen, and water mist is better than any of them alone. In addition, they also found that the hydrogen maximum pressure rise rate was decreased in the water mist environment. Dorofeev et al. [6] proposed a simple assessment method of explosion effect and unrestricted hydrogen explosion safety distance. They found that the hydrogen explosion effect was largely dependent on the amount of released hydrogen. Mogi [7] studied the phenomenon of spontaneous combustion and explosion in the high-pressure hydrogen emission process. Nget al. [8] evaluated the safety parameters of hydrogen explosion. Middha et al. [9] studied the influence of container size and geometric dimension on detonation of hydrogen explosion.

In summary, experts and scholars have carried out many in-depth studies on the explosion and safety of hydrogen, but they have only studied the explosion characteristics and hazards of hydrogen in a single container. There is little research about the influencing factors of hydrogen explosion in a spherical vessel connected with pipe. Therefore, the present paper studied the influencing factors of hydrogen explosion in a spherical vessel connected with pipe. It is hoped that the results of this study will provide reference for safety technology of hydrogen explosion protection in the spherical vessel connected with pipe.

## 2. Experiment

### *2.1 Experiment System*

As is illustrated in Fig.1, the experimental system is made up of the explosion system, data acquisition system and auto gas distribution system.

#### 2.1.1 Explosion System

The explosion apparatus consists of a large spherical vessel, a pipe, and a smaller spherical vessel. The large spherical vessel is 113 liters in volume and 600 mm in diameter. The small spherical vessel is 350 mm in diameter and 22 liters in volume. Each cylindrical pipe is 2000 mm in length and 60 mm in internal diameter. There are flange connections at both ends of the pipe. The end of the pipe can be covered by blind plate. The pressure sensor and ignition device interface were set on the vessels and pipe, which can be blocked when it is not in use. The ignition system in the experimental system consists of an ignition gun and high-voltage spark plugs and uses a capacitive electrical ignition source for the high-voltage spark plugs. The ignition energy of the ignition device is 5 J[10].

#### 2.1.2 Data Acquisition System

The data acquisition system consists of a pressure transducer and a data acquisition device. The pressure transducer model is HM 90-H3-2 with a range and measurement accuracy of 0-10 MPa and ± 0.3% FS, respectively. In addition, the frequency response of the pressure transducer is 200 kHz.

A DEWE-43 multi-channel data acquisition device is adopted to collect synchronous data through eight acquisition channels. The resolution of the data acquisition device is 24-bit, and the sampling rate is 200 kHz. The data acquisition instrument comes with the analysis software DEWE Soft X2, which has the data storage, export, analysis, reporting, oscilloscope and FFt functions.

#### 2.1.3 Auto gas distribution system

The auto gas distribution system consists of a distribution system and a vacuum circulating pump. The distribution system model is RCSC2000-B, and it consists of the distribution box, control box, computer control platform, hydrogen gas cylinder, and air compressor. The gas distribution system can provide multiple gas distribution modes to complete qualitative and quantitative experimental studies. The automatic air distribution system host is connected with the latest communication cable and achieves dynamic process automatic gas distribution ultimately through controlling the flow of gas or concentration of the components using a high-precision mass flow controller. The vacuum pump model is 2X-8GA, and its pumping rate can be up to 0.008 $m^3/s$.