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Suppression of methane/air explosion in pipeline by water mist

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ABSTRACT

In this study an experiment system was built to explore the suppression of methane/air explosion in pipe via water mist. And droplet size of water mist and pipe size were investigated to shed light on their influence on explosion. It was found that for water mist droplet diameter of 45 μm and 100 μm it was impossible to suppress the explosion. Instead it promoted the explosion and the larger the diameter, the more easily the gas exploded. But it was effective to suppress the explosion with the presence of fine water mist with droplet more than 160 μm in diameter and the larger the ratio of the pipe length to its diameter, the better its effectiveness in decreasing flame propagation velocity and suppressing gas explosion. This study can provides theoretical foundation for the designing of water mist explosion suppression system in different industry occasions.

1. Introduction

Gas power generation technology is currently a gordian technique in promoting gas utilization, but low concentration gas explodes easily once encountering a spark in its pipeline, and it is very dangerous. Practice shows the presence of fine water mist in the pipeline can ensure safe delivery of low concentration gas.

Previous studies have done a lot of work on the suppression of methane/air explosion in pipeline by water mist. One of such alternative mitigation measures is the use of water mist sprays or fogs. When transported into the flame reaction zone, water mist droplets will evaporate, extracting heat from the flame, reducing the rate of reaction and the burning velocity(Thomas go, 2002; Yang and kee, 2002). However, sometimes an explosion-enhancing effect is noticed. It has been established that the main reason for explosion enhancement is turbulence generation in gas mixture by water sprays. (Teresa et al., 2004; Wingerden et al., 1995a,b; Brenton and Thomas, 1994; Kim et al., 1998); Doing their experiments in transparent rectangular cavity, Qin Wenqian pointed out that gas explosion pressure and the wave propagation speed significantly reduced with the increase of superfine mist (Qin Wen-qian et al., 2012); Gu, Holborn using a small scale experiment platform examined water mist particles in different sizes and found that the super fine water mist could effectively lower the gas explosion temperature and prolong the delay time (Gu Rui et al., 2010; Holborn and battersby, 2013); Zhang Pengpeng reported that the super fine water mist could suppress the gas explosion to a certain extent, and with the increase of the spray time, it could suppress the explosion more effectively (Zhang Pengpeng et al., 2014); Yu Minggao et al. argued that appropriate amount of water mist could effectively restrain explosion propagation velocity in the pipeline and reduce the flame temperature (Yu Minggaoa et al, 2011); But when the gas concentration is higher or the mist flux insufficient, it could not suppress gas explosion, instead promoted the generation of gas explosion by combustion. (Boeck L R et al., 2015, 2014; Battersby P N et al., 2012; Ingram J M et al., 2012; Vollmer K G et al., 2012) proposed that droplet size distribution could influence the premixed combustible gas explosion flame, when water mist was under certain concentration state. Modak found that the smallest droplet diameter with effective suppression power was 10 μm and reducing the droplet diameter does not change its explosion suppression effect significantly (Modak, explosion, 2006).

The above researches show that water mist has certain suppression effect on gas explosion with its filling rate and diameter as parameters. But with inappropriate parameters, it will be ineffective and event promotes the possibility of explosion. Yet the range of particle size effective in explosion suppression is still not very clear, and the factor of pipe sizes was rarely involved in the previous

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studies. In this study an experiment system was built to explore the suppression of methane/air explosion in pipeline by water mist. And then the particle size of water mist and pipeline size were investigated to shed light on their influence on explosion suppression. It can provide theoretical foundation for the designing of mist spray explosion suppression system in different industry occasions.

2. Experiments

2.1. Experiment facility

The experiment system of water mist explosion suppression is shown in Fig. 1; it is mainly consisted of the blast pipe, gas with tracheal road, igniter, pressure sensor, high-speed camera and nozzle injector. The cross section of the blast pipe is square, placed horizontally and is made of organic glass, so that the high-speed camera can operate dynamically in the flame propagation process of gas explosion. To study the effect of pipe geometry size, three sizes pipes are adopted, and their internal size of 150 × 150 × 1700 mm, 150 × 150 × 1000 mm and 250 × 250 × 1000 mm and with their right ends sealed with flanges and stainless steel plate and their left ends with film seal, as pressure relief surface in the explosion experiment. Three kinds of pipeline spray nozzles are installed in the middle of the pipe, with their distance to the ignition source being 840 mm, 490 mm and 490 mm respectively. The gas distribution pipe routing is composed of compressed methane, compressed air and two mass flow controllers. The gas concentration and the volume are controlled by two mass flow controllers. The mixed gas gets into the pipeline through the right gas inlet. Gas ignition is a self-designed electronic igniter installed in the center 10 mm from the right end and with its working voltage of 5 v powered by the regulated power supply.

2.2. Experimental methods

Explosion pressure is measured by a PR - 23 type high-frequency pressure sensor made by Swiss Keller company installed on the right end plate, the measurement range is 0–0.1 MPa and the response time is 0.2 ms, measuring the overpressure signal near the igniter. A Phantom series high-speed camera by U.S. Vision Research is used to capture the explosion flame shape and position of flame front in the dynamic propagation of gas explosion flame at a speed of 500 frames per second. The FS-N18N photoelectric sensor made by Japanese KEYNCE Company is employed to collect the igniter light signal; the photoelectric sensor is placed pointing to the ignition to trigger acquisition card and high-speed camera after the ignition. So that the acquisition of pressure signal in the explosion process and the dynamic high speed camera for the explosion flame can operate at the same time to obtain accurate firing time. The water mist in the pipeline is produced by the spray nozzle installed on the pipe wall. The nozzle is made by IKEUCHI CO., LTD. The inlet water pressure and flow rate for nozzles are shown as in Table 1. The size distribution was measured by laser scattering (LS2000).

The experiment process is roughly divided into three stages, in the first stage, the mixture gas of methane and air was taken to the intake pipe from pipe right end, and each gas flow was controlled via two mass flow controllers. At the same time, in order to ensure pressure was the atmospheric pressure in the pipe, a vent was settled near the left side of the pipe. At the same time as the pipe

Table 1
The table of nozzle performance parameters.

Model	Pressure (MPa)	Flow/(l/hr)	Average diameter of droplet/(μm)
KB80063N	0.7	2.0	45
K010N	0.7	9.0	100
J010N	0.7	9.0	160

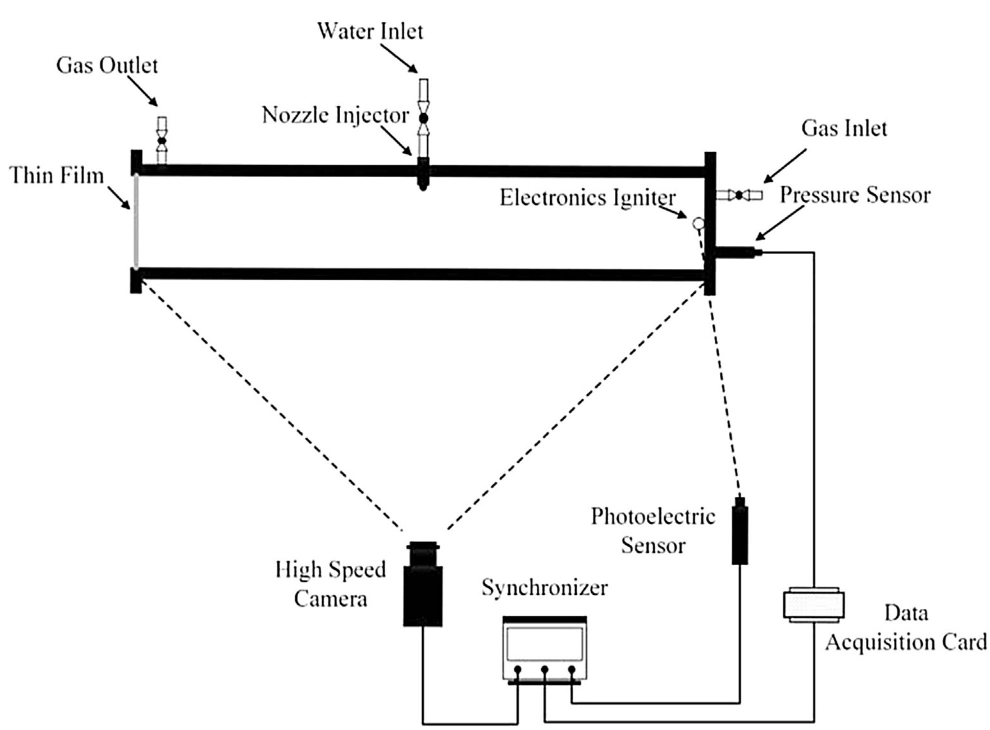

Fig. 1. Schematic diagram of the experiment system.