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Characteristics of flame velocity of gas explosion with obstruction in pipeline☆

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Summary The velocity of flame propagation caused by gas explosion is very difficult to be measured in experiment. A new image processing method is applied to calculate the velocity based on correlation coefficients of images. Experiment of gas explosion with 9.5% gas is carried out. The images photographed during the experiment are processed by the new method. And the change law of velocity of flame propagation is calculated. The results show that the velocity and structure of the flame are both unstable when it propagates in the pipeline. The propagation of flame is not away in acceleration state, but acceleration and deceleration are mutual alternation. And the velocity is in shock statement till the flame extinct during the whole flame propagation. The results also show that the metal wire mesh in the pipeline can accelerate the velocity of flame propagation but reduce the damage caused by gas explosion. And this method also covers the shortage of experimental method.

Introduction

Gas explosion is one of the severest disasters which can cause property damage and casualties in coal mine. In China, 21 fatal accidents of gas explosion and coal dust and gas explosion happened which cause over one hundred deaths since 1949. In recent years, as the development of research on gas explosion and standardization of production management, gas explosion seldom occurs. But it occurs

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occasionally in high gas coal mines. The research on flame propagation velocity and temperature field of gas explosion can help to design the device for reducing the damage caused by gas explosion.

The gas explosion process in a container was studied and results show that the ignition location and the gas concentration have a great effect on the explosion intensity (Phylaktou and Andrews, 1993). The gas explosion propagation when placing obstacles in tubes was researched and the results show that flame propagation through the vessels, up until flame front venting, is found to be substantially laminar, with significant overpressure only being generated in the later stages of explosions(Salzanoa et al., 2002; Fairweather et al., 1999). Experimental trials in three different pipes (single bend, *U*-shaped and *Z*-shaped) were performed and the results show that the explosion strength was significantly enhanced because of the turbulence induced by increasing the number of turns (Chuanjie Zhu et al., 2010, 2011). Nie Baisheng researched the explosion flame propagation characteristics in empty pipe and in the presence of Al_2O_3 and SiC foam ceramics were experimentally investigated. The two-dimensional temperature distribution field of premixed gas explosion flame based on the radiation thermometry was calculated and flame propagation velocity was researched through experiment (Nie et al., 2011). Nie Baisheng simulates and theory analyzes the overpressure transmission rule when gas explosion takes place in different type of roadways and explosion flame propagation characteristics in empty pipe and in the presence of Al_2O_3 and SiC foam ceramics were experimentally investigated and the results show that Al_2O_3 and SiC foam can hinder the propagation of the flame caused by gas explosion (Nie et al., 2014; Yan et al., 2011).

Currently, photoelectric conversion method and particle image velocimetry (PIV) are used to measure velocities of dynamic flames with images photographed by high speed camera (Hirasawa et al., 2002; Stella et al., 2001; Dong et al., 2002). Zhou Huai-chun et al. developed a calculation method of monochrome image temperature field based on the reference point by means of radiation law and attained temperature field by comparing monochrome images with radiation strength of one reference point in images (Zhou et al., 1996). Researchers use image processing method to reveal the propagation rules of methane explosion. However, current measurements and computational method (Wang, 2001, 2006; Na'inna et al., 2013) merely focus on velocity of flame front other than areas after flame front.

The experiment of gas explosion in pipeline with obstruction

The experimental system

Schematic diagram of experimental system is as shown in Fig. 1. The experimental system includes pipeline system, pre mixed gas system, ignition system, synchronous control system, high speed photography system, data acquisition system and so on. The section shape of pipeline is square and size is 80 mm × 80 mm. The pipeline consist two shout pipelines which are connected by flange. And metal wire mesh is installed in the flange which separate two short pipelines. The two side faces are transparent organic glass with high strength. Safety valve is installed in the up side to guarantee the safety of the experiment.

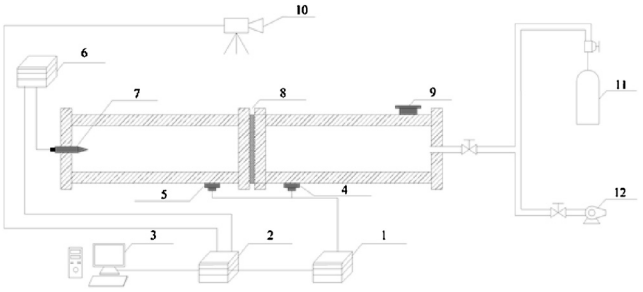

Figure 1 Schematic diagram of experimental system. 1 — High speed data acquisition instrument, 2 — PLC synchronous controller, 3 — computer system, 4 — 2# air pressure sensor, 5 — 1# air pressure sensor, 6 — high energy ignition device, 7 — ignition electrode, 8 — metal wire mesh, 9 — pressure relief, 10 — high speed camera valve, 11 — pre mixing tank, 12 — vacuum pump.

The volume fraction of the pre mixed air is 9.5% methane and 90.5% air. The ignition energy is 5 J. And the initial temperature and pressure are 300 K and 1.013 × 105 Pa separately.

Experimental procedure and method

(1) Injecting air into the pipeline to check the air tightness of the experimental system. The next step can be carried out till the air tightness is good.
(2) Evacuating the pipeline till the vacuum degree is 0KPa. And then premixed air with 9.5% methane is injected into the pipeline.
(3) Open all the data acquisition software and control system. Triggering ignition electrode after all the works are ready.

Experimental results and analysis

The frame rate is 2000 and some images of flame propagation shot by high speed camera are as shown in Fig. 2.

It can be seen from Fig. 2 that the velocity and structure of the flame are both unstable when it propagate in the pipeline. The propagation of the flame is affected by shock waves greatly. So the law of propagation of flame is similar with that of propagation of shock wave. The velocity accelerates firstly and then decay when it arrive the metal wire mesh. When the flame arrives another side of the pipeline, the flame front propagates reversely due to it is reflected by another side of pipeline.

It also can be seen from Fig. 2 that the color of the flame varies greatly in different time. In the beginning, the flame is blue and the shape of flame is cone with a fairly smooth front. This is because the propagation velocities on edges are obviously smaller than those in the middle as a result of friction of pipe wall and cohesion of gas. The temperature of flame which passes the metal wire mesh is lower than the temperature of flame before the metal wire mesh.