Journal of the Energy Institute xxx (2017) 1–9

Contents lists available at ScienceDirect

Journal of the Energy Institute

journal homepage: http://www.journals.elsevier.com/journal-of-the-energy-institute

Characteristics of gasoline–air mixture explosions with different obstacle configurations

Guoqing Li [a], Yang Du [a,*], Jianjun Liang [a,b], Shimao Wang [a], Bo Wang [a], Sheng Qi [a]

[a] Chongqing Key Laboratory of Fire and Explosion Safety, Logistical Engineering University, Chongqing 401311, China
[b] School of College of Power Engineering, Chongqing University, Chongqing 400030, China

ARTICLE INFO

Article history:
Received 13 November 2016
Received in revised form
22 December 2016
Accepted 4 January 2017
Available online xxx

Keywords:
Gasoline–air mixtures
Obstacles
Overpressures
Flame speeds

ABSTRACT

The effects of obstacle distance from ignition point, the blockage ratio of obstacle (BR) and the separation distance of obstacles on the characteristics of gasoline–air mixture explosions have been examined by a series of contrast experiments in a semi-confined organic glass pipe (with a square cross section size of 100 mm*100 mm and 1000 mm long, $L/D = 10$, $V = 0.01\ m^3$). It was shown that before the flame fronts propagated to the obstacle, the flame fronts remained regular shape and spread in a low speed, while passed across the obstacle, the flame fronts could be sharply accelerated and became distorted. And it was obvious that the shorter the distance between obstacle and ignition point, the earlier the flame was accelerated, and eventually led to a higher maximum flame speed. Meanwhile, the maximum overpressures and maximum rates of overpressure rise were obtained at $L_i = 400$ mm, and the shorter the distance between the obstacle and ignition point, the shorter the time taken to reach the maximum overpressure. Three kinds of blockage ratios (BR = 36.4%, 49.8%, 71.7%) were tested, and it was found that the maximum flame speeds, maximum overpressures, average rates of overpressure rise and maximum rates of overpressure rise increased with the growth of blockage ratio. It was also discovered that the maximum effect of the combined obstacles on flame acceleration behavior could be obtained at an obstacle separation distance of 1 time to 4 times the length of pipe diameter. And the time taken to obtain the maximum overpressures became shorter with the growth of the obstacle separation distance, while the maximum overpressures and maximum rates of overpressure rise were obtained at an obstacle separation range from $D_i/D = 3$ to 5 (or 300 mm–500 mm).

1. Introduction

It is well known that flammable gas explosion is a frequently occurring accident in the process industry, such as chemical plant, coal mines, oil depots etc. [7,21]. Once explosion occurs in these places, it would led to serious injuries, death, destruction of equipment and downtime, especially in some cases when gas explosion happens in a space containing solid obstacles or congested areas that can be treated as a large porous structure [9]. The interaction of the explosion induced unburnt gas flow with obstacles results in the generation of turbulence downstream of the obstacle and the acceleration of the flame when it reaches this turbulence. Extremely fast explosion flames can be generated by this mechanism giving rise to severe overpressures. Therefore, it is essential to understand and predict these phenomena in process industries, and particularly to assess the risks and design suitable protection and mitigation measures against vapor cloud explosions.

Former studies have been performed to gain an insight into the effect of obstacle on the propagation characteristics of flammable gas explosions, and great attention has been paid to the studies of the effect of the structure of obstacles, the number of obstacles, the cross-wise location of obstacles, the blockage ratio (BR) of obstacles etc. on the flame forms, flame speeds and overpressures change rules [2,6,9–13,15,18]. Moreover, with the development of advanced test technologies and computing technologies, schlieren technology, PIV

* Corresponding author.
E-mail address: duyang58@163.com (Y. Du).

http://dx.doi.org/10.1016/j.joei.2017.01.001

Nomenclature

L (mm)	pipe length
L_i (mm)	obstacle distance from ignition point
D (mm)	pipe diameter
D_i (mm)	obstacle separation distance
D_i/D	dimensionless separation distance
BR (%)	obstacle blockage ratio
R (mm)	obstacle hole radius
H (mm)	obstacle width
V (m^3)	pipe volume
S_f (m/s)	flame speed
x_n (m)	flame front position
Δt_n (s)	the arrival time difference of two adjacent flame fronts
P_{max} (kPa)	maximum overpressures
$(dp/dt)_{ave}$ (kPa/ms)	average rates of overpressure rise
$(dp/dt)_{max}$ (kPa/ms)	maximum rates of overpressure rise

technology and LES-based CFD simulation have been applied by some researchers in order to deeply investigate the mechanisms that correlate flame dynamics and result in overpressures in flammable gases explosions, and great progress has been made [2,3,6,8,16].

However, most of the previous investigations on flammable gases explosions in an obstructed vessel were about hydrogen, methane, propane, ethylene [1,5,9,11,16]. Few of them were about gasoline vapor, which is also a hazardous explosive gas and extensively used fossil fuel, and once mixed with air or other oxidant, a potential explosive atmosphere might be formed, which can lead to a destructive explosion and form damaging overpressures and high temperature [7,17,19,20]. In the former studies, Zhang and Li investigated the gasoline–air mixture explosions characteristics both in a closed straight pipe and a closed pipe with a T-shaped branch structure, and they found the existence of T-shaped branch structure had significant effect on overpressure and flame behaviors [7,20]. Du investigated suppressions of the gasoline–air mixture explosion by non-premixed nitrogen in a closed tunnel [4]. Qi studied the effect of vent size and concentration in vented gasoline–air explosions and the effects of concentration, temperature, humidity, and nitrogen inert dilution on the gasoline vapor explosion. However, most of the former studies on gasoline–air mixture explosions were experimentally studied using a long closed pipe, a constant volume container, or a non-obstructed vented chamber, and there were no reports on the effects of obstacles on the characteristics of gasoline–air mixture explosions.

In this paper, a series of explosion experiments on gasoline–air mixtures were carried out in a semi-confined pipe under the initial gasoline vapor concentration of 1.70% [7], taking account of 17 different kinds of obstacle configurations. The work of this paper aims at investigating the effects of obstacles on the overpressures and flame behaviors of gasoline–air mixture explosions, therefore providing reference for explosion safety protection of oil and gas industry.

2. Experimental

2.1. Experimental system and apparatus

The experimental equipment applied in this article as shown in Fig. 1 consisted of a semi-confined organic glass pipe (with a square cross section size of 100 mm*100 mm and 1000 mm long, L/D = 10, V = 0.01 m^3), a dynamic data testing system, a high-speed camera, a

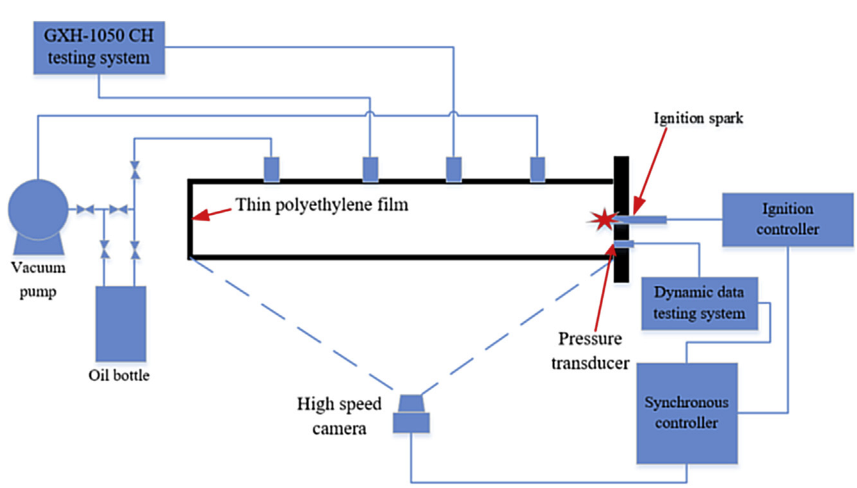

Fig. 1. Schematic of experimental system.

Please cite this article in press as: G. Li, et al., Characteristics of gasoline–air mixture explosions with different obstacle configurations, Journal of the Energy Institute (2017), http://dx.doi.org/10.1016/j.joei.2017.01.001