EXPERIMENTAL STUDIES OF FLAME PROPAGATION AND PRESSURE RISE ALONG THE SYMMETRY LINE IN A 1:54 SCALE COAL MINE MODEL

A. R. GREEN & N. NEHZAT

The University of New South Wales,

School of Safety Science, Sydney 2052, Australia.

ABSTRACT

Gas explosion is a major hazard for many industries, especially for the coal mines, chemical or petrochemical industries, onshore or offshore. Some data are presented in this paper for propane/air explosions in a 1:54 coal mine model in which the ignition position along the symmetry line is varied. Detailed pressure and flame development were recorded. Comparison between two ignition source position were made and it was concluded that the flame propagation and pressure rise in the model is highly dependent on the ignition position. Faster flame propagation and pressure rises were recorded when ignition occurred further away from the vent areas and no substantial effects due to buoyancy was observed in the early stages of flame propagation.

INTRODUCTION

Explosion in confined spaces, particularly those occurring in hazardous industries such as coal mines, have been a matter of real concern [1-4]. The complexity of gas explosion phenomena and the scarcity of the experimental results hinder a quantitative understanding of the phenomena. Assessment of individual geometries is essential if the effects of the hazards are to be mitigated. However there is little experimental data available which can be used in validating computer codes that are used as prediction tools for loss prevention [5,6].

The present work was aimed at providing experimental data relevant to the explosion protection for the coal mines. The study investigates the underlying mechanisms of the phenomena. The initial aim is to identify the important factors in explosion development and determine major influences such as the ignition position, strength, acoustics, wall surface roughness on the flame propagation and use the experimental results for validating the code EXPLODE 2.2 [7,8].

In this paper we report the effects of buoyancy and also change of ignition source position along the symmetry line on the flame development and pressure build-up within the coal model which has sections with cross flows.

EXPERIMENTAL SET-UP

A schematic of the experimental set-up is shown in Figure 1. The length of the roadways and cross cuts are 2.3m and 0.93m respectively and their average width and height are 0.135m and 0.048m with a total volume of 40 litre. The premixed propane/air mixture enters the model at different positions and is vented through two valves positioned near the vent areas. The enclosure is filled with a uniform fuel/air mixture. The fuel concentration was monitored by an Infrared gas analyser (Horiba Model PIR-2000), calibrated against standard gases of known compositions. A standard spark plug igniter was used as the ignition source. The right end of the model, which is referred to as the "vent" end was open to atmosphere. The vents are initially covered with cling film while filling the model occurs.
The pressure was monitored by six piezoresistive pressure transducers (shown on the figure) with a range to 2 bars gauge (Honeywell Microswitch, 185PC30AT). Transducers were calibrated against a Druk DPI digital pressure indicator. The power supply for the transducers was 8 volt DC and data acquisition board was a National instrument, NB-MIO-16X card.

Flame development are recorded with a high speed video camera (NAC, Model HSV-400) operating at 200 frames per second. The camera was set at f1.8 with an open shutter and recording was started manually prior to ignition.
The model is secured against the wall and with this configuration it is possible to study the effects of buoyancy on the flame propagation. For the experiments reported here, the fuel, vent failure pressure and initial fuel/air mixture were kept constant.

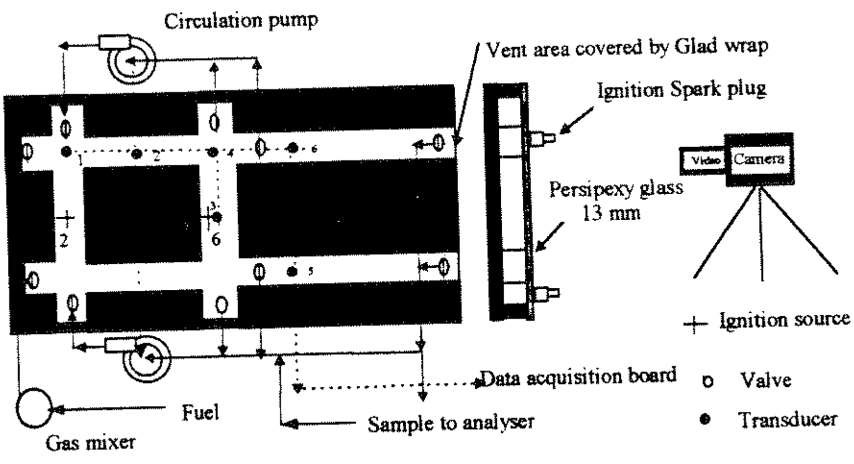

Figure 1 Test set-up for the 1:54 scale coal mine model

RESULTS AND DISCUSSIONS

Flame propagation for two ignition sources along the symmetry line 2 and 6 are given by Figures 2-3. After ignition the burnt gases expand into the unburnt gas, causing turbulence and local distortions of the flame front. The distorted flame front has a greater surface area and this increases the reaction rate. The process is self accelerating. The higher the reaction rate, the greater the flame velocity and pressure, the higher the turbulence, the greater the reaction rate. The observed peak pressures are proportional to the reaction rate and higher reaction rate will produce higher peak pressures. These results show that opposition to the self accelerating mechanism in the model reduces the severity of the explosion in terms of peak pressure and peak pressure time.

Flame propagation along the symmetry line in the early stages of explosion is symmetrical and depending on the ignition position, flame duration within the coal mine model changes from 80 ms to 400 ms, as shown by Figures 2-3. This variation in flame development also can be seen from the pressure time histories for the same sample point given by Figure 4.

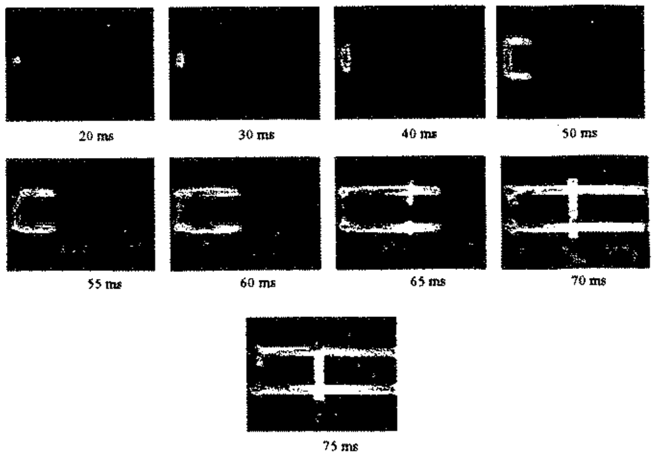

Figure 2 Flame propagation for the ignition positions 2 along the model's symmetry line

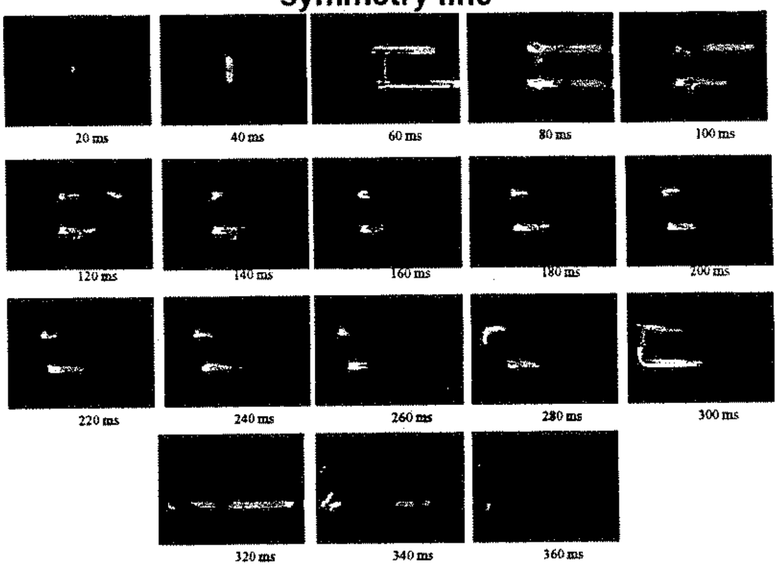

Figure 3 Flame propagation for the ignition positions 6 along the model's symmetry line

CONCLUSIONS

In the present study, an attempt has been made to examine the flame propagation in a 1:54 scale coal mine model. The major conclusions obtained in this study are as follows:

1. Flame propagation and pressure development within the model are inter-related and consistent .
2. Flame duration within the model is dependent on the ignition position.
3. Flame propagation for the ignition along the symmetry line is symmetrical in the early stages and no effects due to the buoyancy is observed.

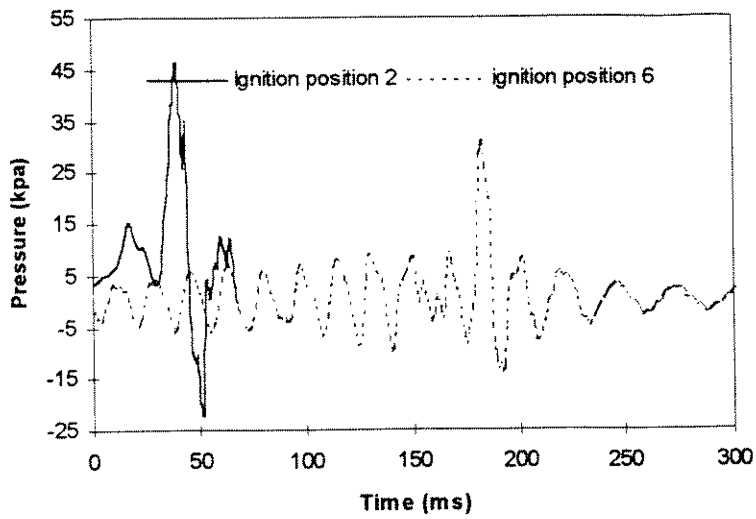

Figure 4 pressure time histories of the same sample point for two ignition position along the model's symmetry line

REFERENCES

1. Maremonti, M., Russo, G., Salzano, E. and Tufano, V. " Numerical Simulation of gas explosions in linked vessels", *J. Loss Prev. Process Ind.*, No.**12**, pp. 189-194, 1999.
2. Holbrow, P., Lunn, G. A. And Tyldesley, A., "Dust explosion protection in linked vessels: guidance for containment and venting", *J. Loss Prevention in the Process Industries*, No.**12**, pp. 227-234, 1999.
3. *"Mine Explosion tests"*, Lake Lynn Experimental Mine, US Bureau of Coal Mines.
4. *Explosion at the Endeavour Colliery at 28 June 1995, Summary of Investigation*, Department of Mineral Resources, New South Wales, MDG No. 1007, May, 1996.
5. Green, A., Nehzat, N., "An integral length scale model for simulating gas explosions", *Proceedings of The Second Asia-Pacific conference on combustion (ASPACC-99)* in Taiwan, pp. 583-585, May 1999.
6. Green, A. R., Piper, I. and Upfold, R. W., "Numerical simulation of gas deflagration using massively parallel processing", *25th Int. Conference Safety in Mines Research Institutes*, 1993.
7. Piper. I., "*Computer simulation of explosions in coal mines using massively parallel processing*", PhD thesis, University of wollongong, 1993.
8. Nehzat, N., *"Gas explosion modelling for the complex geometries"*, PhD. Thesis, The University of New South Wales, Sydney, Austalia, (1998).