International Journal of Mining Science and Technology 24 (2014) 23–29

Contents lists available at ScienceDirect

International Journal of Mining Science and Technology

journal homepage: www.elsevier.com/locate/ijmst

Propagation law of shock waves and gas flow in cross roadway caused by coal and gas outburst

Zhou Aitao [a,b,*], Wang Kai [a], Wu Zeqi [a]

[a] School of Resource & Safety Engineering, China University of Mining & Technology, Beijing 100083, China
[b] State Key Laboratory Cultivation Base for Gas Geology and Gas Control, Henan Polytechnic University, Jiaozuo 454003, China

ARTICLE INFO

Article history:
Received 12 May 2013
Received in revised form 9 June 2013
Accepted 15 July 2013
Available online 4 January 2014

Keywords:
Coal and gas outburst
Shock waves and gas flow
Propagation law
Cross roadway

ABSTRACT

In order to study the propagation law of shock waves and gas flow during coal and gas outburst, we analyzed the formation process of outburst shock waves and gas flow and established the numerical simulation models of the roadways with 45° intersection and 135° intersection to simulate the propagation of outburst gas flow and the process of gas transport. Based on the analysis of the simulation results, we obtained the qualitative and quantitative conclusions on the characteristics and patterns of propagation and attenuation of outburst shock waves and gas flow. With the experimental models, we investigated the outburst shock waves and gas flow in the roadways with the similar structures to the simulated ones. According to the simulation results, when the angle between the driving roadway and the adjacent roadway increased, the sudden pressure variation range in adjacent roadway and the influencing scope of gas flow increased and the sudden pressure variation duration decreased. The intersection between the driving roadway and the adjacent roadway has no effect on airflow reversal induced by the shock waves and gas flow.

1. Introduction

Coal and gas outburst is the most serious disaster in the underground mining production. During an intense outburst, ejection of millions tons of coal or rock and cubic meters of gas with high kinetic energy can cause death or injuries and even destroy underground facilities [1–11]. Therefore, it is necessary to thoroughly study the propagation characteristics of outburst gas flow and shock waves. Currently, there is little report of site measurement data, theoretical analysis and experimental research information about the outburst shock waves and gas flow. There is only available of brief theoretical analysis as well as qualitative summarization of the propagation characteristics of outburst shock waves and gas flow in the straight roadways [12–16]. However, crossed roadways widely distributed in underground mines, and the propagation and attenuation of outburst shock waves and gas flow in crossed roadways largely differed from that in straight roadways. This paper simulates the propagation of outburst gas flow and the process of gas transport. Then, similar experimental models could be used to investigate the outburst shock waves and gas flow at the roadways with the similar structures to the simulated ones.

2. Analysis of formation process of outburst shock wave and gas flow

In the intensive process of coal and gas outburst, high-pressure gas instantly flows into roadway and expands, and then air in the roadway is shocked and compressed [17–20]. At the moment, it forms a series of small compression waves, which changes the parameters of the gas behind the compression wave. When the high-pressure gas in outburst area constantly expands, compression wave formed later moves more quickly than that previously formed. When the former catches up with the latter, it can produce air shock wave and make physical parameters of air rapidly change. A section of compressed air area which is also called high-speed shock wave and gas flow area will appear behind the shock wavefront. For the speed of gas convective mass transfer is lower than the speed of airflow, dense gas flow area appears behind the shock wave and gas flow, as shown in Fig. 1. The shock wave is in the front of gas flow, indicating that shock wave enters into region of gas flow. After all the high-pressure gas rushes out from the outburst area, the intensity of shock wave and gas flow is likely to reach the maximum value in the event of little attenuation. The shock wavefront formed by a series of superimposed compression waves may propagate with a speed which surpasses the local sound velocity in the undisturbed roadway, depending on the outburst intensity and the expansion energy of gas.

* Corresponding author. Tel.: +86 15210567636.
E-mail address: cumtbzat@126.com (Z. Aitao).

2095-2686/$ - see front matter © 2014 Published by Elsevier B.V. on behalf of China University of Mining & Technology.
http://dx.doi.org/10.1016/j.ijmst.2013.12.005

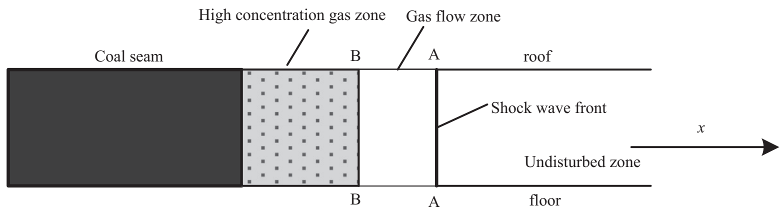


Fig. 1. Schematic illustration of the process of an outburst.

3. Analysis of propagation law of shock wave and gas flow in cross roadway

3.1. Establishment of the geometric model

Fig. 2 shows the geometric model of angle between the driving roadway and the adjacent roadway (45° and 135°). The outburst cavity is a cube (10 m × 10 m × 10 m). The driving roadway is 50 m long. The length of roadway above the driving roadway is 100 m. The length of roadway below the driving roadway is 50 m. All the roadways are 4 m wide and 3 m high. The cross-section $B - B'$ is the inlet of the airflow and cross-section $C - C'$ is the outlet of the airflow.

3.2. Analysis of simulation results

3.2.1. Pressure comparison of shock waves and gas flow

Fig. 3 shows the pressure variation of the cross-section $A - A'$ in the distance of 50 m from driving roadway.

As can be seen from Fig. 3, the pressure of 45° crossing roadway reaches the maximum 146287.6 Pa in 0.18 s and the pressure of 135° crossing roadway reaches the maximum 225605.5 Pa in 0.16 s.

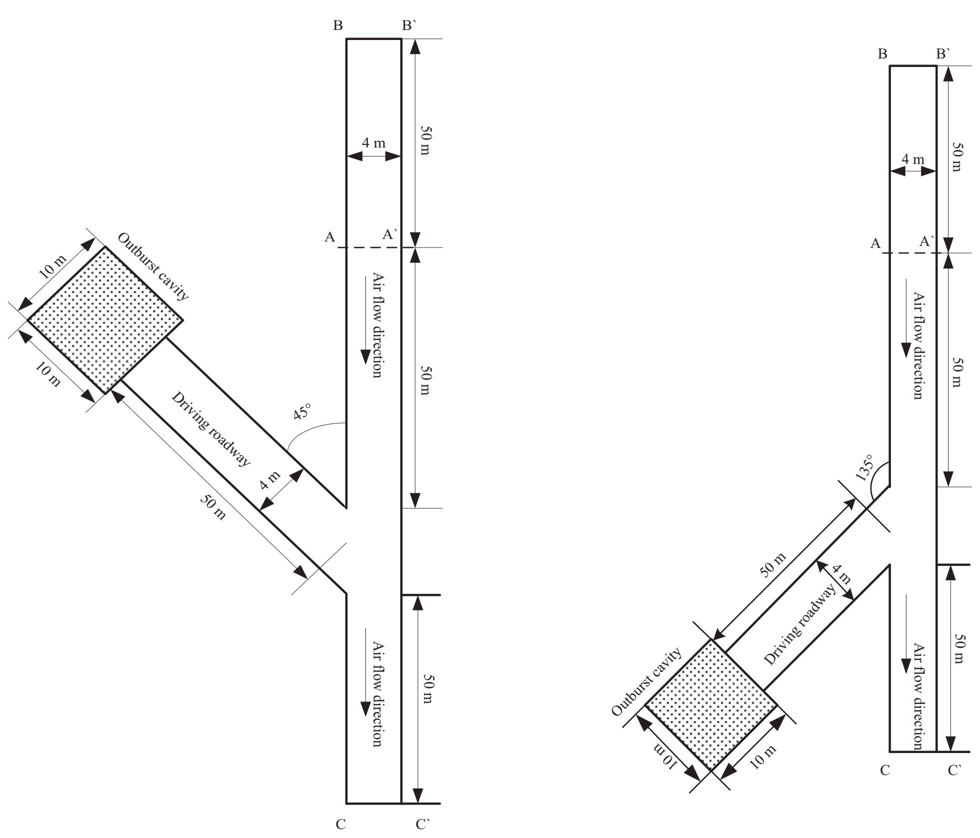
Fig. 4 shows the pressure comparison of the different regions in the two models when the shock waves and gas flow reaches the observation area.

As shown in Fig. 4, the range of pressure variation in the outburst roadway is between 74,400 and 149,000 Pa. The greater the angle between outburst roadway and adjacent roadway is, the higher the pressure of the shock waves and gas flow is.

3.2.2. Velocity comparison of the shock waves and gas flow

Fig. 5 shows the velocity variation of the cross-section $A - A'$ in the distance of 50 m from driving roadway.

As noted in Fig. 5, the velocity of 45° crossing roadway reaches the maximum 236.58 m/s in 0.18 s and the velocity of 135° crossing roadway reaches the maximum 392.36 m/s in 0.16 s.



(a) Geometric model of 45° intersection roadway (b) Geometric model of 135° intersection roadway

Fig. 2. Two models with the angle 45° and 135° between driving roadway and adjacent roadway.