Shock Waves Generated in the Presence of Barriers in Gas Explosions

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ABSTRACT

This paper examines conditions that generates shock waves in a gas explosion through experiment. The result shows that the presence of barrier and thin film, which is simular to air door and stopping in underground coal mines, is very important for the generation of shock waves in a gas explosion. When there are physical barriers, the speed of transmission would be very fast and shock waves will result in the process; when the film is destroyed in gas explosion, shock waves will also appear which would result in an increase in explosion power. Therefore, in order to weaken the gas explosion and prevent the generation of shock waves, the number of barriers should be reduced, and the air door and stopping in tunnels should be strengthened in coal mines. The result of research is very important to prevent gas explosion and decrease the power of such explosions.

KEYWORDS

Barrier, Explosion, Film Destruction, Methane Concentration and Shock Wave.

INTRODUCTION

The gas explosion is one of the most serious accidents in underground coal mines and it is a very complex phenomenon. From the scenes of gas explosion in underground coal mines, it is an evident that gas explosion can produce very great power and result in serious destruction in a very short time. However, it is still unclear if this serious destructional force is related to the shock wave. It is the intent of this paper to study the shock wave producing conditions in a gas explosion, which is critical toward the prevention of such explosions from happening in underground coal mines.

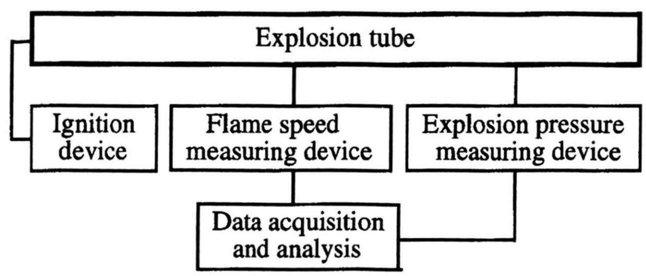

Figure 1. The experimental gas explosion system.

EXPERIMENTAL METHOD AND EQUIPMENT USED

Figure 1 illustrates the experimental gas explosion test device which consists of five components: gas explosion tube, data acquisition and analysis, flame speed measuring system, explosive pressure measuring system and igniting device.

The Gas Explosion Tube

This 24 m long square explosion tube (80 mmby 80 mm) is composed of several small segments with varying lengths (0.5 m, 1 m, 1.5 m and 2.5 m), as shown in Figure 2. There are holes in the tube wall for tapping pressure measuring instruments, temperature, flame and igniter sensors. The tube is made of 16 Manganese steel and has a pressure-resistance value of over 20 MPa.

The Data Acquisition and Ayalysis System

This system is Type CS20186-32; it has 32 channels with sampling rate of 20 M/sec., sampling precision of 10 bit, and memory length of 1 M /channel. It can meet the requirement of a data-sampling rate of 1 point/sec as shown in Figure 3.

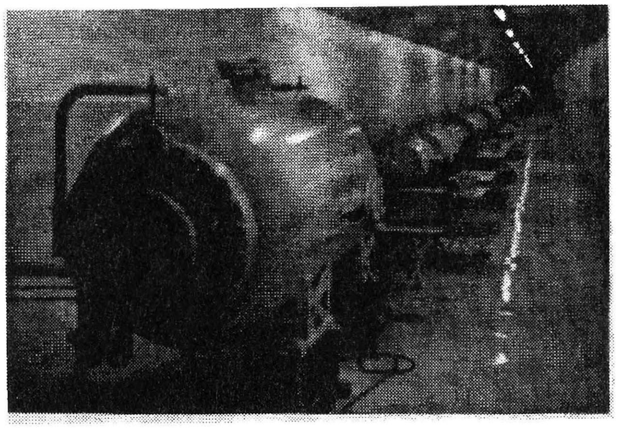

Figure 2. Photograph showing the gas explosion tube.

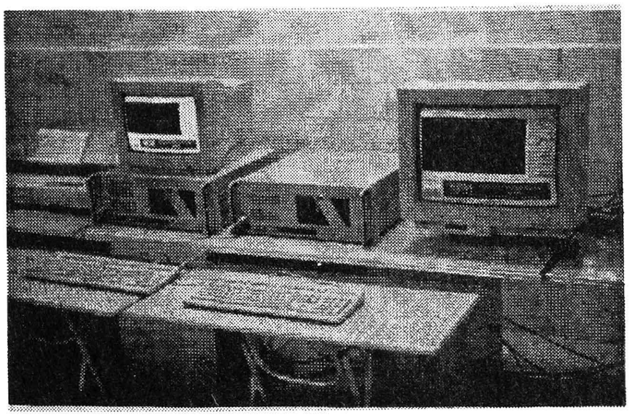

Figure 3. Data acquisition system.

The Flame Speed Measuring System

Phototriode is used as the sensor in this system; it can sample the flame signal of gas burning with weak light. The sampling rate can reach 1 point/ms.

The Explosive Pressure Measuring System

A model YD205 of sensor with piezoelectric quartz crystal is used in this system. It has very high frequency and the sampling rate can reach 1 point/s.

The Ignition Device

This device is a simple igniter using electric spark with energy reserves of capacitance. The output power can be between 20~100 J.

For the experiment, some 8%~ 10% concentration of methane gas were first released into the gas explosion tube segment. Depending on the experiment, 2, 4, or 6 barriers can be placed in the explosion tube as shown in Figure 4. Methane gas is ignited using the igniting device after data acquisition system is turned on.

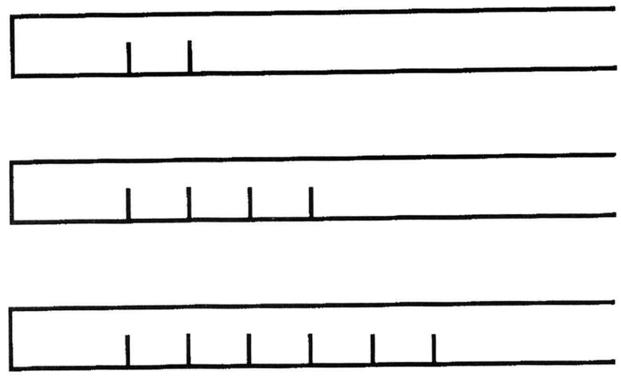

Figure 4. Vairous numbers of arriers in gas explosion tube used in the experient.

EXPERIMENTAL RESULTS

Explosion Shock Wave Induced by Barriers

Results of flame transmission and explosion wave can be seen in Tables 1 and 2.

Table 1. Flame transmission in gas explosons.

Test No.	# Barriers	Distance S (L/D)	Speed m/sec
1	no	20	97.7
2	no	36	73.2
3	no	50	36.1
4	no	60	30.6
5	no	70	14.2
6	2	20	139.8
7	2	36	111.3
8	2	50	98.7
9	2	60	76.5
10	2	70	37.8
11	4	20	177.1
12	4	36	125.0
13	4	50	119.8
14	4	60	96.4
15	4	20	58.6
16	6	36	280.0
17	6	36	230.0
18	6	50	240.0
19	6	60	222.0
20	6	70	201.0

The transmitting curve of gas explosion without barrier and six barriers are shown in Figures 5 and 6.

Table 2. Experimental results during gas explosions under various conditions.

Test No.	Distance S (L/D)	Max. Pressure (MPa)	Speed (m/sec)	Mach #	# Barriers
1	11	0.303		< 1	no
2	46	0.210		< 1	no
3	74	0.137		< 1	no
4	90	0.192		< 1	no
5	118	0.168		< 1	no
6	158	0.187		< 1	no
7	11		987	2.9	2
8	46	0.401	447	1.3	2
9	74	0.192	207	0.6	2
10	90	0.226	379	1.1	2
11	118	0.200	703	2.1	2
12	158	0.253	402	1.2	2
13	11	0.139	659	1.94	4
14	46	0.179	447	1.32	4
15	74	0.169	413	1.21	4
16	90	0.203	410	1.21	4
17	118	0.183	781	2.30	4
18	158	0.198	402	1.18	4
19	11	0.228	1,077	3.17	6
20	46	0.315	492	1.45	6
21	74	0.271	482	1.42	6
22	90	0.283	447	1.31	6
23	118	0.231	781	2.30	6
24	158	0.262	429	1.26	6

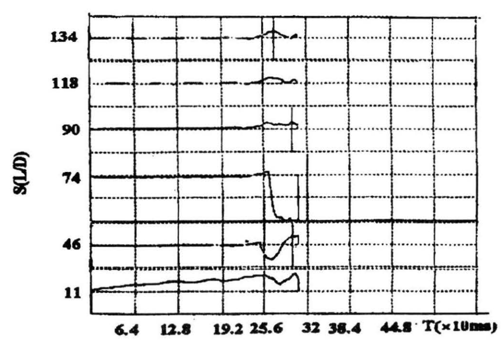

Figure 5. Transmission of explosion waves without barriers during an explosion.

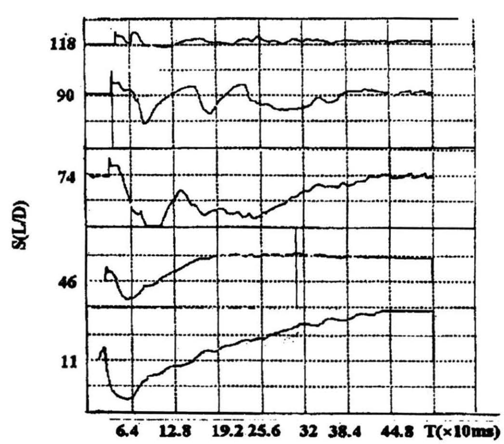

Figure 6. Transmission of explosion waves with six barriers in the explosion tube.

Data indicate that barriers are very important to transmission of explosion wave in a gas explosion. When there are no barriers, fluctuating values of explosion wave are not large in gas explosion and the sudden change of explosion wave boundaries doesn't appear, the Mach number is below 1, and shock wave can not appear (Emanuel, 1986). However, when the sudden changing boundary of explosion wave appear and the Mach number exceeds 1, there will be shock waves.

When there are barriers in the explosion tube, fluctuating values of explosion wave will increase very quickly in a gas explosion, this rapidly fluctuating boundary of explosion waves will appear in the position at 46 times the L/D from the beginning the tube, where L is the length of the gas explosion tube and D is the diameter of the tube. This will result in a Mach number of more than 1, which will result in shock wave. The destruction of neighboring structure can increase significantly with the emergence of shock wave. So, in order to decrease the destruction force, the emergence of shock wave could be prevented through decreasing the number of barriers in underground coal mine airways.

Explosion Shock Wave Induced by Thin Films

The air door and stopping in underground coal mines is analogous to a thin film placed in the explosion tube. Several tests are conducted in order to study the action of film in a gas explosion. For this experiment, methane with 8%~10% concentration is released into the front portion of the test tube, where it is divided into two section by a thin film. Two conditions were conducted, one without barriers while the other, barriers were placed in front section of the explosion tube.

Experimental results show that when there are no barriers in the tube, the shock wave will not appear because of strength of the gas explosion is weakened and the film cannot be distracted. When there are barriers in the explosion tube, the strength of the explosion can be enhanced greatly, result in a rapid increase in super-pressure, and the film can be distracted. The sudden changing explosion wave boundary appeared and the Mach number is more than 1, which will result in the emergence of shock wave, its result is shown in Figure 7.

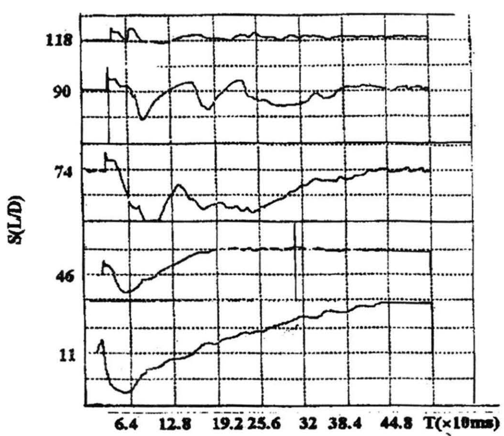

Figure 7. Transmission of explosion shock waves when thin files were used.

Comparing Figure 6 with Figure 7, it can be seen that the value of super-pressure can be increased in gas explosion when there is film introduced in the tube. Therefore, the possibility of shock wave generation can be greatly increased when films are present.

Air doors and stoppings in underground coal mines can prevent transmission of explosion wave only when their strength is large enough to resist force of action in gas explosion, if the strength is not enough, the power of destruction can be increased when the film is destroyed. So, in order to prevent the phenomenon of film destruction in underground of coal mine, the strength of air doors and stoppings must be large enough to resist force of gas explosion.

CONCLUSIONS

1. Barriers are very important to the transmission of explosion waves in a gas explosion. When there are no barriers, fluctuating value of transmission of explosion wave is not large and sudden changing boundary of an explosion wave has not emerged, the Mach number is less than 1, and the shock wave can not be produced. When there are barriers present, fluctuating value of transmission of explosion wave increases very quickly, suddenly changing boundary of explosion wave can easily emerge and the Mach number is larger than 1, and the shock wave will likely be produced. The emergence of shock wave and increasing fluctuating value of explosion wave would greatly increase the destruction of structure in underground coal mines.
2. The possibility of shock wave generation can be greatly increased when there are thin films in a gas explosion. In order to prevent this *film* destruction phenomenon in underground coal mine, the strength of an air door and stopping must be large enough to resist the force of a gas explosion.

REFERENCE

Emanuel, George, 1986, *Gasdynamics: Theory and Applications*, American Institute of Aeronautics and Astronautics, Inc., pp. 52~60.