Suppression effect of solid inertants on coal dust explosion

TAN Ying-xin[1], CAO Wei-guo[1], ZHANG Yun[1], CHANG Hao[2]

(1. *School of Environment and Safety Engineering, North University of China, Taiyuan 030051, China*;
2. *PLA Unit 63961, Beijing 100012, China*)

Abstract: The effect of solid inertants like rock dust on explosion suppression was experimentally tested. By adding solid inertants with different concentrations into three kinds of coal dust, the maximum explosion pressure P_{max} and the rate of explosion pressure rise$(dp/dt)_{max}$ were acquired. Based on this, the suppression effect of rock dust on coal dust explosion was analyzed. The experimental and analytical results show that there are two major factors that play an important role in explosion suppression: composition of solid inertant and particle size of solid inertant. The higher the concentration of solid inertant and the smaller the particle size of solid inertant, the better the suppression effect. In addition, the smaller the particle size of coal dust, the larger the amount of rock dust.

Key words: coal dust explosion; explosion pressure; solid inertants; rock dust

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0 Introduction

Coal is a combustible black or brownish-black sedimentary rock underground being used as an energy resource. Coal dust is sedimentated everywhere in tunnel during coal mining. Yu, et al. indicated that all the coal dust in the coal mine in China is explosive[1-2]. Once methane explodes, its flame will change suddenly[3]. Afterwards, gas detonates and produces shock wave[4], which leads to the tunnel full of coal dust and consequently causes its secondary explosion. According to statistics, gas explosion accidents account for 71% of all serious accidents resulting in more than 10 deaths one time[5]. For example, the gas explosion accident happened in Xishui Coal Mine in Shuozhou City of Shanxi Province led to 72 workers died on March 19, 2005. Another gas explosion accident in Ruizhiyuan Coal Mine in Linfen City of Shanxi Province led to 105 deaths on December 5, 2007. Therefore, it is necessary to prevent gas or coal dust explosion. There exist many methods for control coal dust explosion. The basic methods in coal mine include spreading solid inertant, ventilating tunnel and eliminating fire resource. Because spreading solid inertant can absorb burning heat[6] and prevent secondary explosion, it is very important to study its characteristics.

Currently, there have been three methods to prevent coal dust explosion from further diffusing: spreading rock dust in coal mine, passive explosion-proof and automatic explosion-proof, of which spreading rock dust in coal mine is an effective measure. According to *the safety production rule of coal mine*, rock dust must be spread in all the transport tunnel and air-return tunnel[7]. In fact, it plays an important role in safe production in coal mine and the researchers at home and abroad have paid much attention to it[8], i.e. Amyotte, et al. have researched into the application of solid inertant in preventing or reducing coal explosion[9-10]. In our work, by adding solid inertants into three kinds of coal dust, the effects of solid inertants on explosion pressure and the rate of explosion pressure rise were experimentally investigated and the maximum explosion pressure P_{max} and the rate of explosion pressure rise$(dp/dt)_{max}$ were acquired. Furthermore, the suppression effect of rock dust on coal dust explosion was analyzed.

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Corresponding author: TAN Ying-xin(13934240901@163.com)

1 Key factors affecting suppression effect

In order to prevent coal dust explosion, it is necessary to cover the surface of mine tunnel with solid inertant that has characteristics such as high specific heat, low density, being insoluble in water, low humidity absorption, nontoxicity, being odourless, stable chemical property, non-ignitibility, light color, good reflectivity, easy flying, and so on.

There were two major factors that influence the suppression effect of solid inertants: particle size and chemical composition. Generally speaking, the smaller the particle size of solid inertant, the better the suppression effect. Monoammonium phosphate (MAP) has physical and chemical suppression effects on coal dust explosion. The depression effect of sodium bicarbonate (SBC) is related to the composition of coal dust. MAP is more efficient than SBC in inerting, but SBC is more suitable for explosion depression than MAP.

The amount of rock dust mixed with coal dust is a key factor affecting the suppression effect. It is enough rock dust mixed with coal dust that can play a part in explosion suppression. In addition, the particle size of coal dust has a great effect on energy release rate of coal dust explosion. The coal particles with large size react with oxygen and then produce heat just on the surface of coal dust but the energy remained in the center of coal particles can not be released. On the contrary, the coal particles with small size can be oxidized completely and the whole heat energy can be released[11]. In this case, a great amount of solid inretant is needed. At present, rock dust is often used as solid inertant and it is also used in our experiment.

2 Experiment

2.1 Samples

Coal dust: two kinds of coal dust were taken from Prince Mine and Phalen Mine of Canada, respectively, and the other one was from Datong Mine of China. The particle sizes of three kinds of coal dust were listed in Table 1.

Table 1 Particle size analysis of three kinds of coal dust (wt%)

Coal dust	Particle size (μm)			
	<125	<75	<45	<20
Phalen	100	86	64	39
Prince	100	99	84	52
Datong	100	100	98	78

The composition analysis of three kinds of coal dust is shown in Table 2. The results were average values of three-time analytical results. To avoid matter volatilization and surface oxidation, three kinds of coal dust were reserved into inertant gas before experiment.

Table 2 Composition analysis of three kinds of coal dust(%)

Coal dust	Carbon	H_2O	Ash	Volatile matter
Prince	40.2	1.0	28.0	30.8
Phalen	50.5	1.5	14.7	33.3
Datong	60.7	0.8	11.6	26.9

The rock dust was got from Havelock Limeston, New Brunswick of Canada. According to *the safety production rule of coal mine*, the particle size of rock dust must be smaller than 0.5 mm and more than 70% of them must be smaller than 0.075 mm. The particle size of rock dust is shown in Table 3 and its composition is shown in Table 4.

Table 3 Particle size of rock dust

Particle size (μm)	<125	<75	<45	<20
Distribution(wt%)	91	76	48	28

Table 4 Component analysis of rock dust

Component	$CaCO_3$	$MgCO_3$	H_2O
content(%)	57.5	40.2	2.3

2.2 Experimental setup and method

The 20 L stainless steel vessel was used to test characteristic parameters of coal dust explosion. The data from the 20 L vessel were similar to that from 1 m^3 vessel. The experimental setup is shown in Fig. 1.

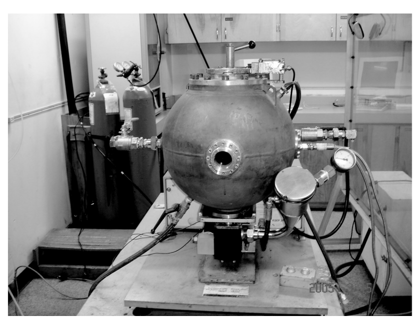

Fig. 1 20 L stainless steel vessel

Before test, coal dust was put under a spurting hole located at the bottom of the vessel whose inner pressure was 0.05 MPa. Before ignition, coal dust was blown by air inside a 1 L jar whose inner pressure inside was 1.4 MPa. After coal was blown, the inner pressure of the 20 L vessel was up to 0.1 MPa. A chemical igniter with energy of 5 kJ was used to ignite coal dust and it was fixed in the center of the vessel. Blowing coal dust taken 400 ms and there were 10 ms before igniting coal dust, thus the delay time was 410 ms in total. Coal dust explosion pressure was measured by piezoelectric sensor fixed in the vessel, and then *P-t* curve was collected by computer, finally the maximum value of coal dust explosion pressure P_{max} and the maximum rate of pressure rise $(dp/dt)_{max}$ were obtained.

3 Test result

The experiments were conducted in two cases: with rock dust or without rock dust. The test curves when adding 60% rock dust into the coal dust from Datong Coal Mine is shown in Fig. 2.

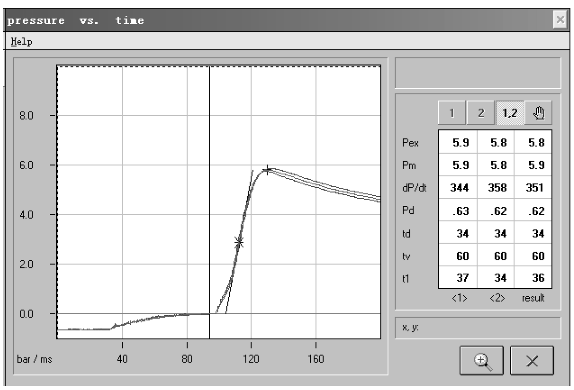

Fig. 2 Typical test curve

When coal dust density was 500 g/m^3, igniting energy was 5 kJ and delay time was 410 ms, the test data are listed in Tables 5 and 6.

Table 5 Effect of solid inertant on dust explosion pressure

Solid inertant concentration (%)	P_{max} (MPa)		
	Prince	Phalen	Datong
0	0.70	0.68	0.73
20	0.66	0.62	0.70
40	0.61	0.57	0.65
60	0.54	0.50	0.59
80	0.30	0.31	0.37

Table 6 Effect of solid inertant on the rate of pressure rise

Solid inertant concentration (%)	$(dp/dt)_{max}$		
	Prince	Phalen	Datong
0	132	110	464
20	103	85	462
40	86	68	463
60	77	59	351
80	15	7	81

It can be seen that P_{max} decreases gradually with the increase of solid inertant concentration, thus rock dust can alleviate explosion damage. When the solid inertant concentration reaches 80%, P_{max} is decreases to 50% of that without solid inertant and $(dp/dt)_{max}$ was reduced by 80%−90% of that without solid inertant. As a result, the explosion harm was greatly alleviated.

The reason is that coal dust explosion must satisfy an important condition that reaction heat release must be more than heat loss[12]. Wang, et al. studied dust explosion principle based on thermal explosion theory[13], and the conclusion is that the flame peak formed by dust burning heats the combustible dust particles of dust cloud to their burning temperature by means of radiation heat of burning particles in reaction area but by means of gas conduction because radiation heat is proportional to biquadrate of absolute temperature[14]. Based on this, temperature reduction of dust particles can stop burning. When the mixture of coal-rock dust explodes, rock dust absorbs heat from explosion flame and leads to lower temperature, and therefore flame can be crushed out. Simultaneously, rock particles shield coal particles from heat and radiation[15]. In this case, the flame does not continue burning because the flame temperature cannot rise and volatile matter cannot be produced.

4 Conclusions

1) Spreading solid inertant can play a role in the suppression of coal dust explosion, which makes P_{max} and $(dp/dt)_{max}$ greatly decrease.

2) At the same suppression level, a great amount of rock dust is needed with the decrease of particle size because it means that combustible gas increases.

3) Rock dust can prevent methane explosion from spreading. In case of methane explosion, rock dust and coal dust are blown and mixed simultaneously by strong shock and wind to form rock-coal dust cloud. Rock dust can shield heat and radiation so as to avoid the flame from burning.

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固态惰性介质对煤粉尘爆炸的抑制作用

谭迎新[1]，曹卫国[1]，张　云[1]，常　皓[2]

（1. 中北大学 环境与安全工程学院，山西 太原 030051；
2. 中国人民解放军 63961 部队，北京 100012）

摘　要： 实验研究了固态惰性介质(以石灰石为例)对煤粉爆炸的抑制作用。将不同含量的石灰石加入三种煤粉中，测得了煤粉爆炸的最大压力及最大压力上升速度。在此基础上，分析了固态惰性介质对煤粉爆炸抑制的机理。实验及分析结果表明，固态惰性介质成分和粒度是影响固态惰性介质抑爆效果的两大因素。隋性介质浓度越高、粒度越小，抑爆效果越好。此外，煤粉粒度越小，需要的惰性介质量越大。

关键词： 煤粉爆炸；爆炸压力；固态惰性介质；石灰石粉

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