Effect of particle size of coal dust on explosion pressure

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Abstract: The effect of the particle size of coal dust on explosion pressure and the rising rate of explosion pressure is studied. Three coal dusts from Lingan Coal Mine in Canada and Datong Coal Mine in China are selected to test. The influence of particle size on the maximum explosion pressure P_{max} and maximum pressure rising rate $(dp/dt)_{max}$ of each coal dust was tested experimentally. The results indicate that with the decrease of particle size of coal dusts, explosion pressure increases on condition of the same concentration. If the concentration of coal dust is different, the maximum explosion pressure appears at the concentration of 500 g/m^3. The smaller the particle size of coal dusts, the larger the rising rate of explosion pressure of coal dust. When the concentration of coal dust is 500 g/m^3, the rising rate of explosion pressure of each coal dust is the maximum.

Key words: coal dust; explosion pressure; explosion pressure rising rate; dust explosion; particle size

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0 Introduction

In spite of significant research worldwide, the coal dust explosion hazard has not been eliminated. From Ref. [1], it could been known that many primary coal mines in China have explosibility. There have been serious explosion incidents in coal mines. According to statistical data, the deaths caused by gas or coal dust explosions accounts for 71% of the full death amount cause by all industry accidents[2]. For example, methane and coal dust explosion occurred in Xishui Coal Mine in Shuozhou City, China in 2005, and 72 workers were dead. In 2007, the same explosion took place in Hongtong Coal Mine in Linfen City, China, and 105 workers were dead. Therefore, it is very necessary to study the explosion characteristics of gas and coal dust.

In industrial explosion accidents, metal dust explosion accidents account for a significant proportion, especially coal dust explosion. At present, some research has focused on the characteristics of coal dust explosion, especially the explosion characteristics of combustible gas or coal dust[3-7], but not the effect of particle size of coal dust on its explosion pressure.

This paper investigates the effect of particle size of coal dust and the rising rates of explosion pressure on explosion pressure. Three coal dusts from Lingan Coal Mine in Canada and Datong Coal Mine in China are selected to test. The influence of particle size on the maximum explosion pressure P_{max} and maximum pressure rising rate $(dp/dt)_{max}$ of each coal was tested experimentally.

1 Cold dust explosion test

The explosibility characteristics of coal dust are often measured in closed volume chamber. The 20 L chamber is used for explosibility measurements, including maximum explosion pressure and maximum pressure rising rate[8]. An example of a 20 L laboratory test chamber designed by Siwek R[9] is widely used. The schematic diagram of the chamber and its auxiliary equipment is shown in Fig. 1.

The spherical test chamber is made of stainless steel with a maximum allowable working pressure of 2 MPa. The vessel is surrounded by a water jacket,

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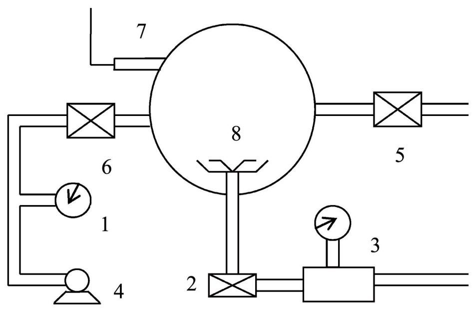
which is used to control the initial temperature of the test chamber. The top access cover is fitted with ignition leads. Chemical ignitors are connected to the ignition leads. Different ignitors are used for different ignition energies[10].



1—pressure gauge; 2—solenoid valve; 3—dust storage chamber; 4—vacuum pump; 5—exhaust valve; 6—vacuum valve; 7—pressure transducer; 8—rebound nozzle

Fig. 1 Schematic map of 20 L Siwek chamber

Prior to each run, the coal dust with required mass was placed in a tube located beneath a nozzle housed in the chamber bottom. Dust dispersion through the nozzle was achieved by an air blast from a 1 L reservoir pressurized to 1.38 MPa. Also before each run, the explosion vessel was evacuated to 0.053 MPa so that the dispersion pulse raises the vessel pressure to 0.1 MPa at the time of ignition. Ignition was started by a chemical ignitor with a stored energy of 5 kJ, centrally mounted in the chamber. The use of these energetic ignitors was justified on the basis of being relevant to the industrial settings where primary explosions of methane have initiated coal dust explosions.

A fixed time delay of 400 ms between the commencement and the ending of dust dispersion, followed by a 10 ms delay before ignition, was used in all test. The computer opens the solenoid valve between the dust storage chamber and the test chamber through a rebound nozzle to raise the chamber pressure. Pressure development during an explosion was measured by a piezoelectric transducer mounted flush with the interior of the vessel. An IBM PC was used to record the pressure time data from which the values of P_{max} and $(dp/dt)_{max}$ were obtained. The PC was also used to control the dust dispersion and ignition sequence by opening and closing the solenoid valve shown in Fig. 1.

The pressure-time trace can provide the maximum overpressure, and the maximum pressure rising rate for a given test.

2 Coal dust samples

Coal samples were obtained from Lingon Coal Mine in Canada and Datong Coal Mine in China. Each coal dust was grinded and sieved to produce the fractions with the same size for test. Each coal dust sample was withdrawn for particle size measurements based on the principle of laser diffraction or light scattering. Particle size analysis of all the coal dusts are shown in Table 1.

Table 1 Particle size analysis of coals

Particle size (μm)	wt (%)		
	Lingan 1	Lingan 2	Datong
<125	100	100	100
<75	87	98	100
<45	65	83	98
<20	41	53	78

According to Table 1, the particle sizes of the coal dusts from Lingan1, Lingan 2 and Datong are 125, 75 and 45 μm, respectively. Proximate analysis is given in Table 2. The values shown are the average of three analyses done for each of the three dust sample. To present excessive loss of volatiles and surface oxidation, the coal dust was kept in an inert atmosphere over the duration of testing.

Table 2 Proximate analysis of coals

Cold dust	Proximate analysis (%)			
	Fixed carbon	Moisture	Ash	Volatiles
Lingan 1	49.5	0.2	18.4	31.9
Lingan 2	52.9	0.3	15.1	30.7
Datong	60.7	0.8	11.6	26.9

3 Results and discussion

To determine the influence of particle size on overpressure and pressure rising rate of coal dust explosion, the pressure-time trace is tested with 5 kJ chemical ignitors. Many times experiments were conducted. Fig. 2 is a typical P-t curve of coal dust explosion.

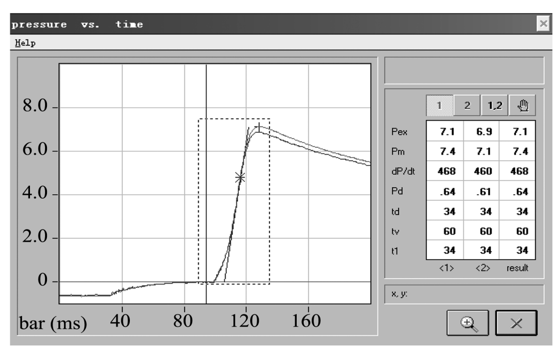


Fig. 2 *P-t* curve of Datong coal dust explosion

The data for coal dust are shown in Tables 3 and 4. It can be found that the explosion pressure of coal dust is affected by the particle size of coal dust. With the decrease of the particle size of coal dust, explosion pressure increases on condition of the same concentration. When the concentration of coal dust is different, the maximum explosion pressure appears at the concentration of 500 g/m^3.

Table 3 Explosion pressure of coal dusts

Concentration of cold dust (g/m^3)	P_{max}(MPa)		
	Datong	Lingan1	Lingan2
250	0.70	0.57	0.64
500	0.74	0.65	0.66
750	0.69	0.63	0.65
1 000	0.59	0.61	0.62

Table 4 Rising rate of explosion pressure of coal dusts

Concentration of cold dust (g/m^3)	$(dp/dt)_{max}$(MPa/s)		
	Datong	Lingan1	Lingan2
250	33.9	8.6	13.2
500	46.8	12.9	14.6
750	46.3	13.0	14.9
1 000	38.5	13.1	14.8

The data in Table 4 indicate that the rising rate of explosion pressure of coal dust varies with the different particle sizes of coal dusts. The smaller the particle size of coal dust, the larger the rising rate of explosion pressure of coal dusts. When the concentration of cold dust is 500 g/m^3, the rising rate of explosion pressure of each coal dust is the maximum. In conclusion, it is very important to prevent coal dusts explosion of small particle size because they have greater explosion pressure and pressure rise rate than that of bigger particle size.

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煤粉粒子尺寸对爆炸压力的影响研究

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摘　要： 本文研究了煤粉粒子尺寸对爆炸压力及爆炸压力上升速率的影响，研究使用了来自加拿大 Lingan 煤矿和中国山西大同煤矿的具有 3 种不同粒子尺寸煤粉。通过试验测试了每种煤粉的最大爆炸压力 P_{max} 和最大压力上升速率 $(dp/dt)_{max}$。研究结果表明在相同的煤粉浓度条件下，随着煤粉粒子尺寸的减小爆炸压力增大；对于不同的煤粉浓度，最大爆炸压力出现在煤粉浓度为 500 g/m^3 时；煤粉的粒子尺寸越小，其爆炸压力上升速率越大，在煤粉浓度为 500 g/m^3 时，爆炸压力上升速率最大。

关键词： 煤粉；爆炸压力；爆炸压力上升速率；粉尘爆炸；粒子尺寸

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