Explosion Characteristics of Coal Dust with Different Metamorphism Degrees

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1 Introduction

Coal dust and gas explosion accidents in coal mine caused great casualties and property loss[1]. Due to the special mine underground environment, most gas explosion accidents involve coal dust. Therefore, it has highlighted the significance of preventing and reducing accident losses of coal dust and gas explosion accidents, which focuses on revealing the propagation characteristics of coal dust and gas explosion.

For coal dust and gas explosions, a large number of scholars have conducted a lot of research on the reaction mechanisms of coal dust and gas explosions mainly using 20 L spheres and various sizes of pipelines[2-10].The reaction mechanisms and explosion characteristic parameters of coal dust and gas explosion are analyzed and summarized from experiment and numerical simulation, which provides theoretical basis and test methods for further research on the influence factors of coal dust and gas explosion.

The mixing uniformity degree of coal dust is vital to the test of coal dust explosion. In this article, a total of 19 coal samples with different coal ranks distributed in northwest, north and northeast China were selected, which includes two kinds of anthracite, thirteen kinds of bituminous coal and four kinds of lignite. Many coal dust and gas explosion experiments were carried out by self-designed pipeline system, which focus on testing the characteristic parameters of coal dust and gas explosion. The propagation law of coal dust and gas explosion was analyzed comprehensively, which provides theoretical basis for the prevention of coal dust and gas explosion accidents in coal mines.

2 Experimental Testing System for Coal Dust and Gas Pipeline Explosion

The self-designed pipeline explosion experimental system mainly includes dust dispersion system, ignition system and data acquisition and control system. The explosion pipeline inner diameter is 88 mm, 108 mm in outer diameter, and 10 mm in thickness. Four photoelectric sensor interfaces, four pressure sensor interfaces and four dust nozzle interfaces are arranged on the same cross-section. The experimental system is shown in Figure 1. Coal dust passed through 200 mesh sieve. The ignition energy was 3J by methane air mixture with 7% volume concentration.The layout is shown in Figure 1.

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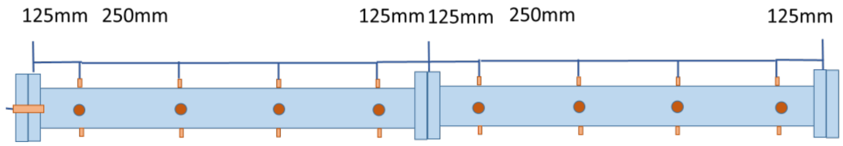

Figure 1: Diagram of pipe size and sensors distribution

PCB piezoelectric sensors are used for pressure measurement and the sensitivity are shown in Table 1.The flame arrival time was recorded by CKG100 photoelectric sensor. The spectral response range was 450-980 nm, the response time was less than 100μs, and the output impedance was 10 kΩ.

Table 1: Position and sensitivity of PCB pressure sensors

NO	2#	3#	4#	5#	6#	7#	8#
Distance from ignition end (m)	0.375	0.625	0.875	1.105	1.355	1.605	1.855
Sensitivity (V/MPa)	1.478	1.424	0.7265	1.416	1.452	1.424	0.7248

3 Results and Analysis

3.1 Explosion pressure distribution characteristics of different ranks coal dust and gas

As shown in Figure 2, for most coal samples, the pressure reaches maximum value about 1.6 m from the ignition end, and then the maximum pressure decreases significantly. Meanwhile, the maximum explosion pressure of the measuring point at the distance of 0.87 m from the ignition end is lower than that of the previous one. With the decrease of coal rank, the maximum pressure of each measuring point increases. This means that, the explosion pressure of low metamorphic coal dust is higher than that of high metamorphic coal dust under the same conditions.

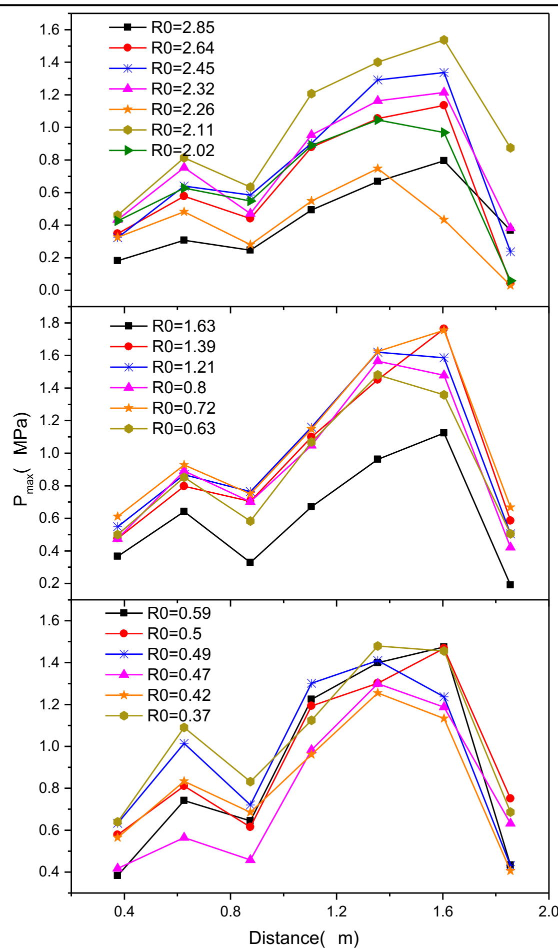

Figure 2: Relationship between P_{max} distribution and vitrinite reflectance of coals

3.2 Maximum Pressure of Coal Dust and Gas Explosion in Pipeline

In Figure 3, the maximum explosion pressure of lignite is lower than that of bituminous coal, and the maximum explosion pressure of bituminous coal is higher than that of anthracite. From lignite to anthracite, the volatiles of coal dust decreases gradually, but the maximum explosive pressure of bituminous coal is the highest, because the coal dust explosive reaction is not only related to the volatiles of coal, but also to the pyrolysis gas during the thermal decomposition of coal dust. It is concluded that the maximum explosion pressure of each measuring point present increases first and then decreases along the pipeline direction.Table 2 shows the relationship between coal samples vitrinite reflectance and maximum explosion pressure and flame propagation velocity.

Table 2: Relationship between vitrinite reflectance and explosion parameters

Number	sample name	category	Vitrinite Reflectivity R_0 (%)	maximum pressure (MPa)	Maximum Flame Propagation Velocity (m/s)
1	DY	anthracite	0.37	1.45	12.14
2	MTG	anthracite	0.42	1.26	9.32
3	WJP	meagre coal	0.47	1.29	10.64
4	GC	meagre coal	0.49	1.41	10.92
5	HM	meagre coal	0.50	1.47	9.43
6	CC	meagre coal	0.59	1.47	7.99
7	LNC	meagre coal	0.63	1.48	13.97
8	TS	meagre coal	0.72	1.75	20.66
9	FL	coking coal	0.80	1.57	20.16
10	ML	coking coal	1.21	1.62	15.43
11	PX	fat coal	1.39	1.76	12.19
12	HL	gas coal	1.63	1.12	5.21
13	YW	gas coal	2.05	1.05	10.87
14	SY	gas coal	2.11	1.54	13.44
15	YQXJ	candle coal	2.26	0.75	6.46
16	DSC	lignite	2.32	1.21	11.21
17	GZ	lignite	2.45	1.34	6.93
18	ZX	lignite	2.64	1.14	2.56
19	SH	lignite	2.85	0.79	1.73

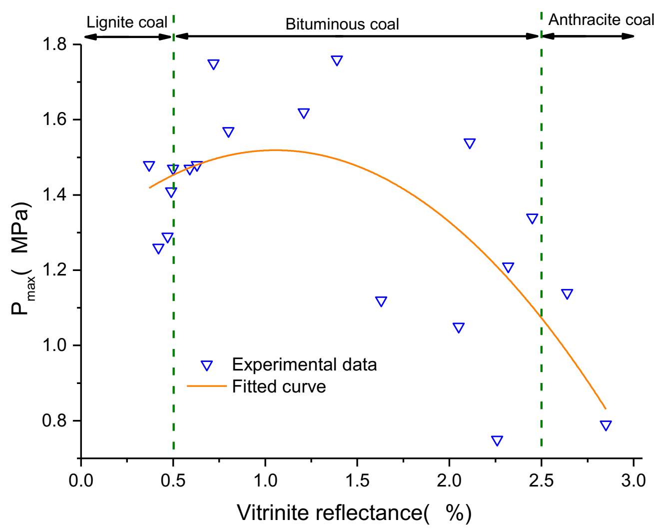

Figure 3: Relationship between maximum pressure and vitrinite reflectance of coals

3.3 Pipeline Coal Dust Explosion Velocity Distribution Characteristics

According to the position of each photoelectric sensor and the time from ignition to flame detection, the flame propagation velocity between two measuring points were calculated. It is shown in Figure 4 that the maximum flame propagation velocity reaches the maximum at the second flame measuring point with the increase of the propagation distance. Then the flame propagation velocity begins to decrease, while the bituminous coal and lignite will increase slightly at the distance of 1.105 m from the ignition end, and finally decrease gradually.

In Table 2, for anthracite, it is found that the higher coalification degree, the lower the maximum flame propagation velocity. For bituminous coal, the maximum flame propagation velocity decreases with the coalification degree increase. Because lignite has a lower coalification degree, the maximum flame propagation speed has little relationship with the coalification degree.

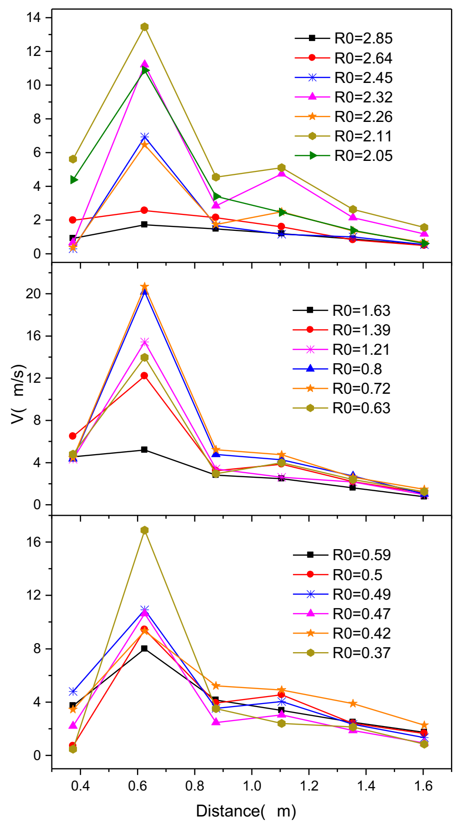

Fig. 4 Relationship between maximum flame speed distribution and vitrinite reflectance

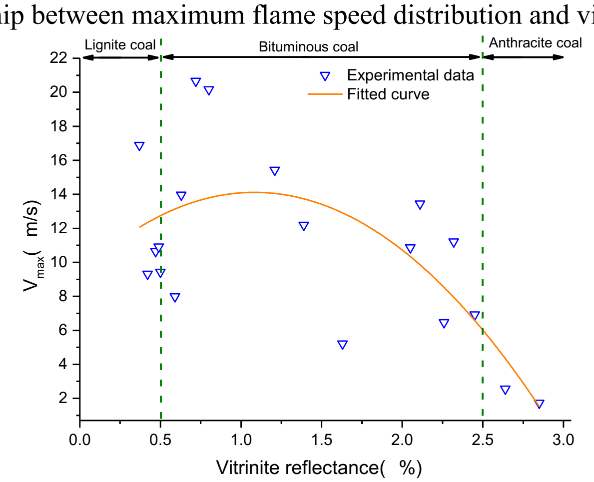

Fig. 5 Relationship between maximum flame speed and vitrinite reflectance of coals

4 Conclusion

Through the experimental system of coal dust and gas explosions in pipelines, the explosion pressure and propagation speed of coal dust with different metamorphic degree and gas in pipeline was analyzed. It can be concluded that coal rank influences the explosion pressure and propagation speed. Coal dust with high metamorphism degree has lower volatile matter, the reaction is slow at the initial stage of explosion. With the decrease of coal rank, the explosive reactivity of coal dust is improved, which is reflected in the increase of flame propagation speed and pressure rise rate. From lignite to anthracite, the maximum explosion pressure and flame propagation velocity first increase and then decrease, the maximum explosive pressure of anthracite dust is the lowest, and that of bituminous coal is the highest, followed by lignite.

Acknowledgements

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