Exhaust Gas Compositions and Hazardous Effect of Coal Dust Explosion

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1 Introduction

Coal dust and gas explosion accidents in coal mines caused a large number of deaths, injuries and property losses [1]. Scholars have conducted a lot of research on the reaction mechanisms of coal dust and gas explosions through experiment and numerical simulation[2-8], which provided theoretical basis and test methods for further research on hazardous effect of coal dust and gas explosion. Liu Zhentang studied the solid and gaseous products after coal dust explosion, and analyzed the gaseous products variation with coal dust concentration[9-14]. However, there are still relatively few studies on the gaseous products composition and its hazardous effects. The coal dust and gas explosion consumes a lot of oxygen, and the toxic and harmful gases produced threaten the personnel safety. Therefore, it has highlighted the significance of revealing the main compositions and hazardous effects of explosion gaseous products.

In this article, 14 coal samples with different metamorphic grade such as anthracite, bituminous coal, lignite explosion experiments were carried out by the self-designed pipeline explosion experimental system, the composition and concentration of explosion gaseous products were analyzed quantitatively by gas chromatography, which are instructively important for accident prevention and control.

2 Experimental Testing System

The experimental testing system mainly includes dust dispersion system, ignition system, data acquisition system and gaseous products analysis 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. Firstly, the coal dust samples with the concentration of 200 g/m^3 are dispersed evenly in the pipeline through the dispersing system, then ignited by electric spark. Finally, gaseous products were collected and analyzed further by gas chromatography. The pipeline layout is shown in Figure 1.

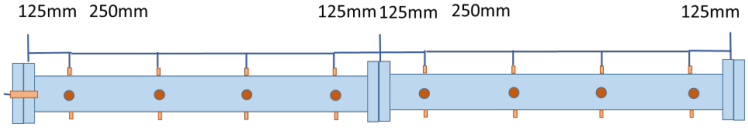

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Figure 1: Pipeline layout Diagram

3 Results and Analysis

3.1 Composition and Content of Coal Dust Explosive Gaseous Products

After coal dust explosion in pipeline, the main gaseous products consist of N_2, O_2, CO_2, CO. In addition, there are a small amount of methane, ethane, ethylene, acetylene and other gases. Figure 2 shows the change of three main gas compositions after each coal sample explosion. It can be seen that the concentration of N_2 is about 80%, the concentration of O_2 is generally lower than 16%, and the concentration of CO_2 ranges from 3.89% to 8.63%, which is higher than the value 0.5% of the air flow in the mining face according to the coal mine safety regulations. Among all coal samples, anthracite such as SH, GZ, DSC, HL or bituminous coal with high metamorphic degree have higher oxygen content in the explosion gaseous products than bituminous coal and lignite with low metamorphic degree. That is, the oxygen consumption of coal dust with higher coalification degree is lower than that of lower coalification degree during explosion. In terms of CO_2, bituminous coal with high metamorphic degree such as GC and DSC produces less CO_2 than bituminous coal and lignite with low metamorphic degree such as HM, WJP and DY.

Table1: Species and concentration of post-explosion gaseous products for different coals

NO.	Coal Sample	O_2 %	N_2 %	CO_2 %	CH_4 ppm	CO ppm	C_2H_4 ppm	C_2H_6 ppm	C_2H_2 ppm
1	SH	9.704	82.73	6.893	1350	100	12720	0	0
2	GZ	13.4	81.38	4.776	2645	922.7	7496	172.6	48.2
3	DSC	14.26	80.64	4.228	6298	179.9	0	1191	0
4	YQXJ	14.96	79.32	4.484	9963	142.9	6485	0	0
5	SY	10.17	81.26	6.89	921.1	2557	16370	0	0
6	HL	16.03	83.15	3.885	2509	137.1	0	0	0
7	PX	10.56	83.25	4.709	1668	3813	10660	209.9	42.62
8	TS	10.36	79.95	6.393	2941	6477	11560	482.1	86.35
9	LNC	9.429	80.16	6.009	1758	3916	12630	298.7	61.58
10	HM	7.804	79.1	8.625	2785	7934	15780	852.2	75.79
11	GC	9.594	80.4	8.113	2157	1826	14050	349.1	51.18
12	WJP	8.871	81.13	8.48	3195	1052	19520	69.85	0
13	DY	10.59	83.81	5.946	2317	8449	0	345.1	25.12
14	BF	9.356	82.8	8.05	2342	6613	0	1145	152.7

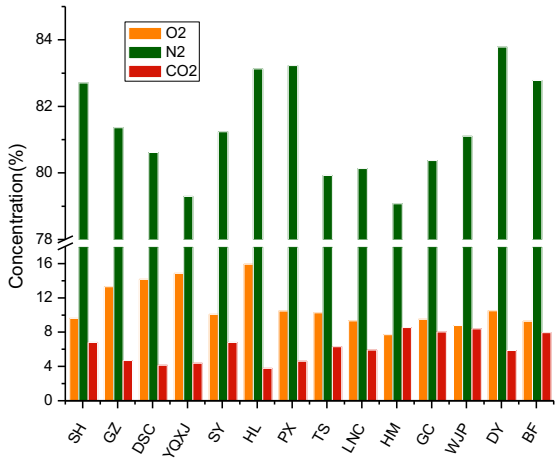

Figure 2: Concentration of O_2, N_2 and CO_2 in post-explosion gas

It is shown in Figure 3 that ethylene content is the highest. However, some coal samples such as DSC, HL, DY have not detected ethylene. With the increase of coalification degree, the CO content produced by low-grade bituminous coal and lignite explosion is more than that of anthracite and high-grade bituminous coal. Bituminous coal releases flue gas during combustion, which contains a large amount of CO. These smoke-forming substances are mainly side chains and functional groups in the coal molecular structure.

From Figure 4, it can be seen that ethane and acetylene are not detected in some coal samples, and the content of ethane in the two gases is obviously higher than that of acetylene.

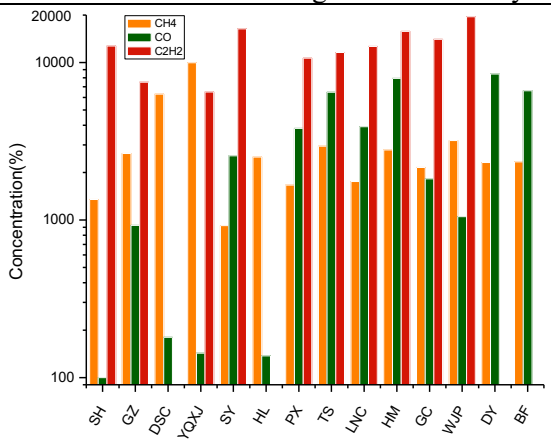

Figure 3: Concentration of CH4, CO and ethylene in post-explosion gas

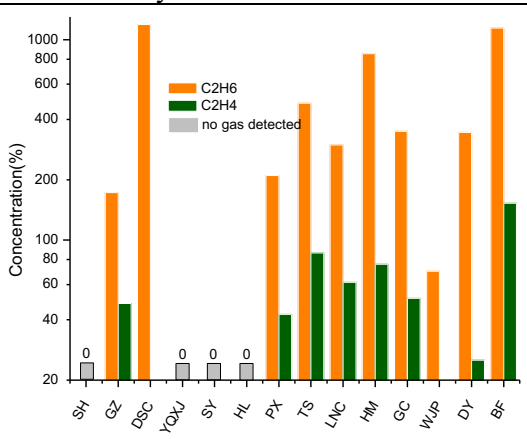

Figure 4: Concentration of ethane and acetylene in post-explosion gas

3.2 Analysis of Toxic and Harmful Gases after Coal Dust Explosion

After coal dust explosion, people are exposed to anoxic environment. Furthermore, there exists the CO poisoning risk. Based on the above test results, the lowest CO concentration after explosion is 100 ppm, and the highest CO concentration is 8449 ppm. According to the coal mine safety regulation, the maximum allowable concentration of CO in the air is 24 ppm. While the lowest CO concentration after coal dust explosion in the pipeline is far higher than the specified value, whose concentration threshold is much higher than the human body can withstand. On the other hand, a large amount of O_2 is consumed after explosion,

which makes the concentration of O_2 significantly lower than the normal value. The lowest oxygen concentration is 7.804% and the highest is 16.03%, which is difficult for people to breathe if they are exposed to this environment. Moreover, there is a large amount of CO_2, which also inhibits normal breathing.Therefore, in order to reduce the personal injury caused by coal dust explosion, it is important that reduce the CO generation and provide fresh air flow in the first time of accident.

4 Conclusion

In this article, composition and concentration of residual gases are obtained through collection and analysis of coal dust explosion residual gas in pipeline, and the hazardous effect of toxic and harmful gases is discussed. A number of conclusions can be obtained.

1) After coal dust explosion, the main gas compositions are N_2, O_2, CO_2, CO. Meanwhile, there are a small amount of methane, ethane, ethylene, acetylene and other gases. Among them, the concentration of N_2 is about 80%, the concentration of O_2 is generally lower than 16%, and the concentration of CO_2 ranges from 3.89% to 8.63%. The oxygen consumption of coal dust particles with higher coalification degree is lower than that of coal dust particles with lower coalification degree during explosion.

2) After coal dust and gas explosion in pipeline, the lowest CO concentration is 100 ppm and the highest is 8449 ppm, which is far beyond the human body's endurance level.

Acknowledgements

This work was financially supported by the Open Fund of Key Laboratory of Mine Disaster Prevention and Control in Hebei Province, North China Institute of Science and Technology (Grant No. KJZH2017K01), Leading Talents in Science and Technology Innovation under the Ten Thousands Program (Grant No. W02020049).

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