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Analysis and Research of Explosive Coal Explosivity in Coal-fired Power Plants

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Abstract. According to the explosion of pulverized coal system in a coal-fired power plant in Shandong, this paper analyzes the explosivity of the coal. According to the explosive index, the coal can be divided into the most explosive coal, the more explosive coal, explosive coal and normal coal. According to the proximate analysis and net calorific value of coal this paper fitted linear formula of explosive index by the method of least squares, and the error of coal prediction explosive index was analyzed. The formula could be used to predict explosive index of coal.

1. Introduction

Since 2016, due to adjustment of the coal market and coal policies, the coal quality of some coal-fired power plants in Shandong Province deteriorates. This has led to problems such as explosions in the milling system, excessive environmental indicators, and abnormal combustion[1]. Especially, the explosions in boiler milling systems happen frequently. At present, the evaluation criteria for coal powder explosivity are mainly the volatile matter of coal, industrial index(*Bc*), explosive index (K_d), thermogravimetric ignition temperature, pulverized coal flow ignition temperature[2], etc. The industrial index(*Bc*) is the explosion index calculated from factors such as volatile matter, sulfur content, fixed carbon content, moisture and ash of coal[3]. The explosive index (K_d) is the result of considering the combined effects of volatile matter, ash, calorific value and fixed carbon. The pulverized coal flow igniting temperature can represent the influence of pulverized coal moisture, pulverized coal fineness, concentration and temperature on the pulverized coal explosion characteristics. According to the explosion of the milling system in a power plant in Shandong Province, this paper used a new method to classify the explosion characteristics of the pulverized coal. Based on the industrial analysis and calorific value of coal, the pulverized coal explosion index prediction model was established.

2. Analysis of coal explosivity

This paper selects the explosive index (K_d) of coal powder as the classification criterion for judging the explosion of coal powder. The calculation formula is calculated according to the standard of performance test for pulverizers and pulverizing systems of power station.

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2.1. Coal as fired explosion analysis

The coal as fired from 2015 to 2016 of the coal-fired unit was analyzed. Compared with the annual data, it was found that the explosive index of coal as fired fluctuated greatly on November 19, 2016. And the explosive index of coal as fired exceeded six frequently, as shown in Figure 1.

The unit's milling system exploded on December 6, 2016. According to coal quality in the first three months before the explosion, the average explosive index of coal as fired from September to November was about 4.85, and the average explosive index of coal as fired rose to 5.36 in December.

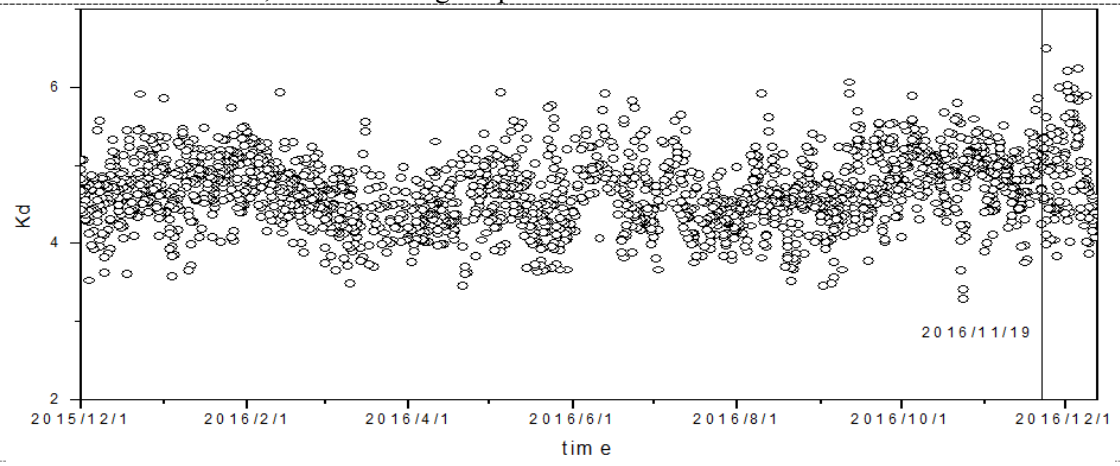


Figure 1. Explosive index of coal as fired.

2.2. Coal as received explosion analysis

In 2016, there were a total of 1,179 samples of coal as received, and the explosive index (K_d) was between 1.7 and 8.1. According to the source of coal, the coal samples from the same source are combined into one coal sample, and the coal samples from different sources are numbered sequentially. Maximum and minimum values of explosive indices for different coal types were shown in Figure 2 to 4.

Since the designed coal type of the unit is explosive coal with high volatile content, the volatile matter content of most coals purchased by power plants is generally high. If the classification is carried out according to the requirements of the national standard, most coals are explosive coals, which have no guiding significance for the blending of coal into the furnace. In this paper, detailed classification of explosive coals was carried out to facilitate the classified storage and management of coal types with different explosive characteristics. According to the explosive index of coal as received, the coals were divided into four grades: the most explosive coal ($K_d \geqslant 7.0$), the more explosive coal ($5.5 \leqslant K_d < 7.0$), explosive coal ($3.0 \leqslant K_d < 5.5$) and non-explosive coal types ($K_d < 3.0$).

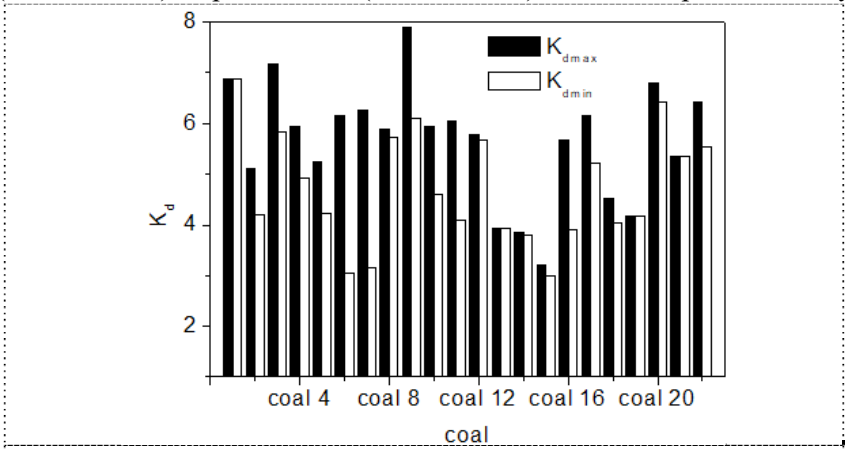


Figure 2. Explosive index of coal as received 1.

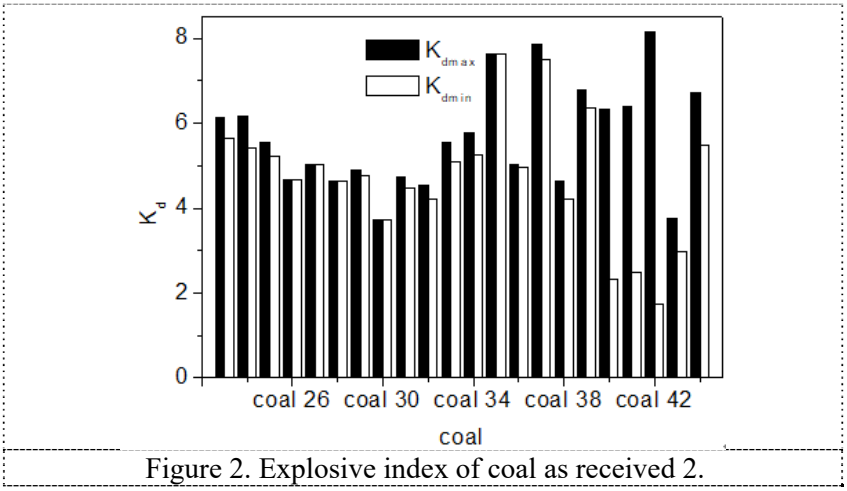


Figure 2. Explosive index of coal as received 2.

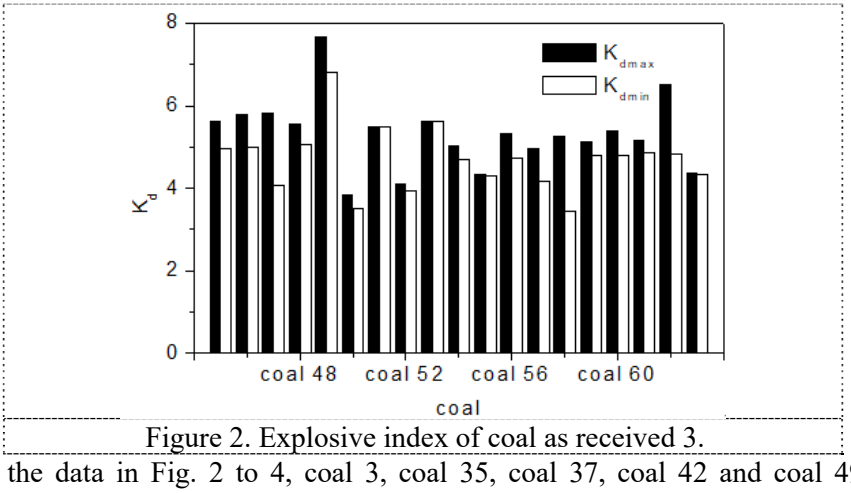


Figure 2. Explosive index of coal as received 3.

Analysis of the data in Fig. 2 to 4, coal 3, coal 35, coal 37, coal 42 and coal 49 are the most explosive coals. The coal 1, coal 8, coal 9, coal 12, coal 20, coal 22, coal 23, coal 24, coal 39, coal 44 and coal 53 are more explosion coals. The explosive indices of coal 4, coal 7, coal 10, coal 11, coal 17, coal 40, coal 41, coal 47 and coal 62 fluctuate greatly.

3. Explosive index prediction model for explosive coals

Based on the relationship between coal calorific value and coal moisture, ash, volatile matter and other influencing factors[4], some papers have proposed a variety of simple and predictive calorific value calculation models[5, 6]. However, there are few studies on the explosive index prediction model[7, 8]. The explosive index of pulverized coal is very important for the coal quality management and coal blending of coal-fired power plants. The existing calculation method involves many parameters, and it is necessary to perform multiple analyses on the coal sample, that increases the workload of the inspector. In order to avoid these difficulties, this paper fitted linear formula of explosive index by the method of least squares according to the proximate analysis and net calorific value of coal[9, 10].

$$K_d = 0.12472 \times M_{ad} - 0.01134 \times A_{ad} + 0.19492 \times V_{ad} + 0.15211 \times Q_{net,ar} - 3.90325 \quad (1)$$

Mad —— Moisture of air dry, %.

Aad —— Ash of air dry, %.

Vad ——volatiles of air dry, %.

Qnet,ar —— net calorific power of as received, %.

The coal explosive index was calculated by the prediction formula and compared with the actual explosive index, the absolute error is within 0.5. For coal samples with an explosive index greater than

3, the relative error is less than 5%. For coal samples with an explosive index of less than 3, the relative error is less than 15%, this is mainly due to its small explosive index. To further investigate the accuracy of the prediction formula, the average absolute error (MAE), the average relative error (AAE) and the average offset error (ABE) are introduced. The three errors are calculated as follows:

$$\mathrm{MAE} = \left(\sum_{i=1}^{N}|e_i|\right)/N \quad (2)$$

$$\mathrm{AAE} = \left(\sum_{i=1}^{N}(|e_i|/M_i) \times 100\%\right)/N \quad (3)$$

$$\mathrm{ABE} = \left(\sum_{i=1}^{N}(e_i/M_i) \times 100\%\right)/N \quad (4)$$

This paper analyzes the predicted values of the explosive index according to formulas 2, 3 and 4. The predicted average absolute error (MAE) is only 0.104, the average relative error (AAE) is 2.42%, and both MAE and AAE are smaller. The average offset error (ABE) is -0.199%, and the predicted value offset is small. It seems that the prediction model has less error in the prediction of the explosive index and the prediction value is accurate.

Table 1. Comparison of coal explosivity.

Coal	V_{daf}（%）		K_d		Bc		K_d（fitted value）			
	Value	Grade	Value	Grade	Value	Grade	Value	Grade	Absolute error	Relative error (%)
Shan xi coal	39.68	Most explosive coal	7.76	Most explosive coal	49.44	Most explosive coal	7.49	Most explosive coal	0.27	3.51
E er duo si coal	36.22	Most explosive coal	6.72	More explosive coal	38.94	Most explosive coal	6.49	More explosive coal	0.23	3.43
Zao kuang coal	41.8	Most explosive coal	4.67	Explosive coal	37.79	Most explosive coal	4.81	Explosive coal	0.14	3.10

This paper collected coal quality data from other parts of the coal mine, calculated coal industry index and explosive index, and calculated the coal explosive index by using prediction model. The calculation results are shown in Table 1. According to the new classification method, the coal classification is more detailed and accurate, which is convenient for the classification, storage and management of coal. The absolute error of the explosive index fitted value and the true value is within 0.3, and the relative error is within 3.6%.

4. Conclusion and suggestion

The explosive coal can be classified according to coal quality and equipment conditions. The most explosive coal and more explosive coal must be stacked and managed separately, and the proportion of blending into the coal as fired should be strictly controlled.

For the coal with large fluctuations in explosive index, real-time explosion characteristics analysis of coal as received is required, and the coal is classified and stacked according to explosion characteristics.

According to the proximate analysis and net calorific value of coal this paper fitted linear formula of explosive index by the method of least squares, and the error of coal prediction explosive index was analyzed. The prediction model has less error in the prediction of the explosive index and the prediction value is accurate.

In view of the fact that the coal with the dry and ash free volatiles greater than 25% (or an explosive index of coal greater than 3.0) is often used in some boilers, the flue gas recycling of the milling system shall be carried out[11]. Furthermore, the flue gas recirculation system shall be equipped with the oxygen measuring equipment at the outlet of coal mill or the oxygen content at the output of coal mill can be estimated according to the gas flow of the flue gas recirculation circuit and the air quantity of primary air. If the real-time monitoring of oxygen is not possible, the oxygen can be estimated by the correlation test between the opening of flue gas recirculation dampers and the oxygen at the outlet of coal mill[12]. When the flue gas recirculation system is in normal operation, the oxygen concentration at the exit of the coal mill is controlled at 14~16%[13]. During the start and stop of the coal mill, the oxygen concentration of the coal mill outlet is controlled at 12~14%.

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