

Study on the coal mixing ratio optimization for a power plant

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Abstract. For coal-fired power plants, the application of blended coal combustion has been a great issue due to the shortage and rising prices of high-rank coal. This paper describes the optimization of blending methods between Xing'an lignite coal, Shaltala lignite coal, Ura lignite coal, and Inner Mongolia bituminous coal. The multi-objective decision-making method based on fuzzy mathematics was used to determine the optimal blending ratio to improve the power plant coal-fired economy.

1. Introduction

In recent years, blending different types of coal at pulverized coal-fired power plants are becoming increasingly common in China because of the uneven distribution of resources and transportation difficulties [1]. In power plants, different types of coals can be blended out-furnace or in-furnace [2,3]. This paper describes the mathematical analysis of the blending strategy of different coal types to find the optimized coal blend ratio.

2. Determination of the coal mixing ratio

Main coals used in a 350 MW supercritical combustion power plant are shown in table 1. Xing'an coal, Ura coal, and Shaltala coal are lignite coals, while Inner Mongolia coal is bituminous one. Design coal of the 350 MW power plant is lignite coal.

Table 1. Main coals used in a 350 MW power plant.

Coal No.	Coal Origin/Grade	Mt (wt%)	Mad (wt%)	Aar (wt%)	Vdaf (wt%)	Qnet, ar MJ/kg
1	Inner Mongolia	21.8	13.9	17.88	37.54	20.05
2	Xing'an	13.1	4.92	37.07	48.39	14.22
3	Ura	26.8	16.86	6.14	47.83	17.54
4	Shaltala	30.2	9.64	18.25	48.34	13.42
5	Design coal	27.8	9.27	12.06	45.09	17.34

Properties of coals used in 350 MW supercritical combustion power plant are shown in table 2.

Xing'an coal, Ura coal and Shaltala coal are lignite coal. They are characterized by high volatile content, easy to catch fire, low calorific value and softening temperature are lower than 1192°C, easy to get slag. While Inner Mongolia bituminous coal has lower volatile content, not easy to catch fire, and its low calorific value is higher than the design coal. The softening temperature of Inner Mongolia bituminous coal is greater than 1500°C, so it is not easy to get slag. The volatile content of Ura lignite



is 52.24%, the volatile content of design coal is 45.09%, and the volatile content of Inner Mongolia bituminous coal is about 37%. The low calorific value of boiler design coal is 17.34 MJ/kg, the low calorific value of the main burning Xing'an coal, Ura coal and Shaltala coal are less than the designed coal. Therefore, a certain amount of Inner Mongolia bituminous coal should be mixed into lignite coal to meet the boiler operation requirements. The power plant has six coal mills, 5 for running and 1 for backup. Two different coal types were ground in different mills because they have different grinding coefficients. In the in-furnace blending method, different coal types were fed into the furnace from separate burners and burned together in the furnace. Three kinds of lignite and bituminous coal blending schemes were used to find the optimal blending ratio by using the multi-objective decision-making method based on the fuzzy mathematics. Blending schemes for Ura lignite coal and Inner Mongolia bituminous coal are shown in table 3.

Table 2. Properties of coals used in a 350 MW power plant.

Coal No.	Coal Origin/Grade	Cdaf (wt%)	Hdaf (wt%)	Odaf (wt%)	Ndaf (wt%)	DT(°C)	ST(°C)	FT(°C)
1	Inner Mongolia	78.86	4.95	14.43	1.76	1340	>1500	>1500
2	Xing'an	75.75	5.13	16.7	2.42	1120	1130	1140
3	Ura	74.65	3.62	19.51	2.22	1180	1190	1200
4	Shaltala	75.32	3.82	18.6	2.26	1160	1180	1190
5	Design coal	78.18	5.81	14.69	1.32	1100	1110	1130

Table 3. Ura and Inner Mongolia bituminous coal blending schemes.

Option	Ura lignite	Inner Mongolia bituminous coal
1	1	4
2	2	3
3	3	2
4	4	1

Thus, the set of evaluation schemes is:

$$U = \{ I, II, III, IV \}$$

It can be seen from the previous text that the factors affecting the mixed coal mainly include the ignition characteristics of coal, the low calorific value of coal, the slagging characteristics of coal and the price factor of coal. Therefore, the evaluation index is:

- volatile coal content;
- low coal calorific value;
- comprehensive slagging index of mixed coal;
- mixed coal prices;

According to the industrial analysis of coal, ash comprehensive index R and coal prices, according to the four coal blending program to calculate the coal price in accordance with the ratio of linear addition to calculate the indicators as shown in table 4:

Table 4. Indicators of mixed coal.

Factors	Unit	Scheme 1	Scheme 2	Scheme 3	Scheme 4
Volatile content	f1 %	40.48	43.42	46.36	49.3
Low calorific value	f2 KJ/kg	18760	17470	16180	14890
Slagging index	f3 1	1.02	1.09	1.12	1.23
Price of coal	f4 yuan	534	489	442	396

The set of four evaluation factors is:

$$V = \{f_1, f_2, f_3, f_4\}$$

The four factors of each factor index matrix F are:

$$\Delta = \begin{pmatrix} 40.48 & 43.42 & 46.36 & 49.3 \\ 18.76 & 17.47 & 16.18 & 14.89 \\ 1.02 & 1.09 & 1.12 & 1.23 \\ 534 & 489 & 442 & 396 \end{pmatrix}$$

The weight of the four factors can be obtained according to the actual operating experience of the power plant. Because of the relatively low heat generation and slagging characteristics of the coal plant in the actual operation process, the weight of the power plant is relatively large, and its weight is relatively large in price and volatile The weight set A is:

$$A = (a_1, a_2, a_3, a_4) = (0.2, 0.3, 0.3, 0.2)$$

Next, we apply the weighted relative deviation distance to the minimum method for decision making. According to the factors of each scheme, the optimal index of each factor of each scheme is taken as the standard vector of matrix F, so the standard vector of matrix F is:

$$f^0 = \{49.3, 18.76, 1.02, 396\}$$

Make

$$\delta_{ij} = \frac{|f_i^0 - f_{ij}|}{f_{i\max} - f_{i\min}}$$

The fuzzy matrix of the relative deviation of each factor is derived as follows:

$$\Delta = \begin{pmatrix} 0 & 0.24 & 0.48 & 1.0 \\ 1.0 & 0.54 & 0.38 & 0 \\ 1.0 & 0.53 & 0.18 & 0 \\ 0 & 0.25 & 0.50 & 1.0 \end{pmatrix}$$

According to the weighted relative deviation distance formula,

$$d_j = d_j(u_j, f^0) = \frac{1}{a} \sqrt{\sum_{i=1}^n (a_i \cdot \delta_{ij})^2}$$

Inferred

$$d_j = \{0.67, 1.85, 0.86, 1.06\} \quad i = 1, 2, 3$$

The minimum method of weighted relative deviation distance is based on the smallest value as the optimal solution of the matrix. Therefore, the program is the optimal solution, that is to say when Ura coal and Inner Mongolia bituminous coal ratio is 4: 1, it is the best ratio program. In the same way, the optimal ratio of Xing'an coal, Tara coal and Inner Mongolia bituminous coal is studied by using multi-objective decision-making method in fuzzy mathematics.

Different proportions of coal are obtained by fuzzy mathematics in tables 4 and 5.

Table 5. Xing'an coal and bituminous coal blending program.

	Xing'an coal: Inner Mongolia bituminous coal				Best option
	1:4	2:3	3:2	4:1	
d_j	1.32	1.02	0.86	1.26	3:2

Table 6. Tara coal and bituminous coal blending scheme.

	Tara: Inner Mongolia bituminous coal				Best option
	1:4	2:3	3:2	4:1	
d_j	1.03	0.79	0.98	1.12	2:3

3. Numerical simulation analysis of blended coal

Finally, the analysis of coal blending is performed, and the results are shown in table 7.

Table 7. Analysis of coal blending.

Industry Analysis					
		Unit	Option I	Option II	Option III
Moisture	Mt	%	20.42	13.42	24.22
Ash	Aar	%	19.76	30.55	8.7
Volatile	Var	%	24.69	24.43	30.85
Fixed carbon	FCar	%	35.13	31.6	36.23
Low calorific value		kJ/kg	17398	16552	18042
Elemental analysis					
		Unit	Option I	Option II	Option III
Carbon	Cdaf	%	77.44	76.99	75.49
Hydrogen	Hdaf	%	4.5	5.06	3.89
Oxygen	Odaf	%	16.1	15.79	18.49
Nitrogen	Ndaf	%	1.96	2.16	2.13

4. Conclusion

Based on the multi-objective decision-making and multi-level evaluation model in fuzzy mathematics, the volatiles, low calorific value, coking index, water, and coal price standard were determined. When the Ura coal and Inner Mongolia bituminous coal mixed combustion, their best blending ratio is 4: 1. When the Shaltara coal and Inner Mongolia bituminous coal mixed combustion, their best blending ratio is 2: 3. When the Xing'an coal and Inner Mongolia bituminous coal mixed combustion, their best blending ratio is 3: 2. So coal power plant can be blended in accordance with the proportion of this research in the actual combustion process, to achieve the best coal-fired economy.

Acknowledgments

This project "Improving the Combustion Mode and Security Running Control Strategy to Decrease the Pollution in Northeast of China" (UK-CIAPP\201) was supported by the Royal Academy of Engineering under the UK-China Industry-Academia Partnership Programme scheme. The authors are grateful for the support of the Royal Academy of Engineering and the UK Government's Newton Fund. This project was supported by the China Scholarship Council (No. 201706175069).

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