Relationship Between Coal Powder and Its Combustibility

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Abstract: *Coal' s volatile component, ash and fixed carbon content have different functions in different stages of a combustion process, but the traditional coal classification can precisely show its combustion property. In this experiment coal' s evaluation indexes (ignition index D_i), (burn off index D_f) were used to qualitatively show the ignition property and combustion ending property of coal samples. Meanwhile, considering actual heating circumstances in calciner (in cement plants), this thesis established the relationship among the ignition index, burn off index and coal' s industrial analysis value, which makes it possible for the user to predict the quality of coal before using it and is very valuable in practice.*

Key words: *coal powder*; *combustion property*; *coal*

1 Introduction

We have studied two important parameters that show coal' s combustion property in calciner' s working process[1]: ignition temperature and ignition dynamic parameters; burn off index combustion ending time and combustion ending dynamics parameter. When we did derivative calculations and experiment tests on them, we found that there was a great variance in these parameters for different coals. That is to say, each coal has its own combustion property. But is there a principle relationship between coal and its combustion property? If the relationship does exist and has been found, we can use it to predict coals' combustion property and resolve the difficult problems of how to evaluate coals' quality and how to determine the design parameters of calciners. Obviously, it is very valuable.

2 Experimental

In this experiment, we studied 11 coal samples from cement plants. Coals' industrial analysis values were obtained by national standards, the elements C, H, N in the samples were determined by an elementary analyzer made by PE Corporation in American, the element S in the samples was analyzed by SC-132 sulphur determiner made by LECO corporation. The results are shown in Table 1. The characteristic curve of weight loss was obtained by analysis the weight loss of coal combustion under the experiment temperature condition. The weight loss of coal combustion was analyzed by a weight loss analyzer. According to the calciner' s working property, we supposed each sample' s experiment temperature varies from room temperature to 880℃.

In cement' s production process, the heat absorbed by $CaCO_3$ decompose reaction and the heat released from coal' s combustion process come to a thermal balance[4], so the temperature in calciner almost keeps stable, then we can think that coals are burned under an invariable environment temperature condition. So we should give up the traditional way that chooses temperature as a parameter[5], but choose time as a parameter to determine the combustion index of calciner. That is to say, when we determine the ignition index, we should consider the effect of the heating time that is spent to heat the coal until burning, the maximal speed of combustion, the time point that the speed of combustion reaches the maximum. Similarly, we should also consider the effect of the maximal speed of combustion, the time point that the speed of combustion reaches the maximum, the time interval that the coal comes to combustion ending on the burn off index. So we work out two relational expressions to determine the ignition index D_i and burn off index D_f:

$$D_i = (dw/dt)_{max}/t_0 t_m \qquad D_f = (dw/dt)_{max}/\Delta t_{1/2} t_m t_f$$

where $(dw/dt)_{max}$ is the maximal speed of combustion, $(dw/dt)_{mean}$ is the mean speed of combustion, t_0 is the time that is spent from heating to ignition, t_m is the time point that the speed of combustion reaches the maximum, $\Delta t_{1/2}$ is the time interval that the speed of combustion comes to a half of the maximal speed of combustion, t_f is the time interval from ignition to combustion ending.

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Table 1 The Results of Coal Samples' Industrial Analysis and Elementary Analysis/%

Coal sample	Industrial analysis				Elementary analysis				
	M_{ad}	V_{ad}	A_{ad}	F_{Cad}	C_{daf}	H_{daf}	N_{daf}	O_{daf}	S_{daf}
No.1	1.06	7.70	23.86	67.38	69.55	2.19	1.02	1.83	0.49
No.2	1.09	10.44	22.39	66.08	69.11	2.82	1.23	2.96	0.40
No.3	1.67	22.18	41.24	34.91	46.00	2.99	0.77	6.87	0.46
No.4	0.20	24.49	23.93	51.38	59.62	3.55	1.18	11.09	0.43
No.5	1.80	20.53	34.97	42.70	54.94	3.16	1.05	2.92	1.16
No.6	0.82	9.83	26.81	62.54	64.31	2.73	1.36	1.32	2.66
No.7	0.85	15.45	19.19	64.51	72.31	3.48	1.46	2.35	0.36
No.8	1.33	15.46	21.69	61.52	67.16	3.33	1.38	4.46	0.65
No.9	1.21	20.96	32.08	45.75	56.20	3.47	1.31	5.31	0.43
No.10	2.33	26.32	20.98	50.37	68.84	3.10	1.53	2.48	0.74
No.11	0.89	12.12	27.33	59.66	66.46	4.11	1.63	0.00	0.34

3 Results and Discussion

3.1 The index of coal's combustion property

The characteristic curve of weight loss was obtained by analysis the weight loss of coal combustion under a high temperature condition. Analyzing the characteristic curve, we get the ignition index D_i and burn off index D_f of the coal samples. They are shown in Table 2.

3.2 Relationship between coal's combustion index and its industrial analysis value

First, we analyze the relationship between coal's ignition index D_i, burn off index D_f and its water, volatile component, ash, fixed carbon content respectively. With a plenty of experiments and data handling, generally considering coal's industrial analysis value, we find that there is a linear relationship between coal's ignition index and Vad × Cad, coal's burn off index and Vad2 × (Cad + Aad)0.5, which are shown in Fig.1 and Fig.2. By linear the data in Fig.1 and Fig.2, we get the relational expressions between coal's ignition index D_i, burn off index D_f and its' industrial analysis value:

$$D_i = 0.023 \cdot V_f \cdot C_f - 7.39 \quad (1)$$

$$D_f = 0.0038 \cdot V_{ad2} \cdot (C_{ad} + A_{ad})0.5 + 3.17 \quad (2)$$

From (1), (2), we can calculate the ignition index D_i, burn off index D_f of each coal samples, they are shown in Table 2.

3.3 Discussion

In order to show the relationship clearly, we fill the experiment results and calculation results in Table 3 with the traditional coal classification.

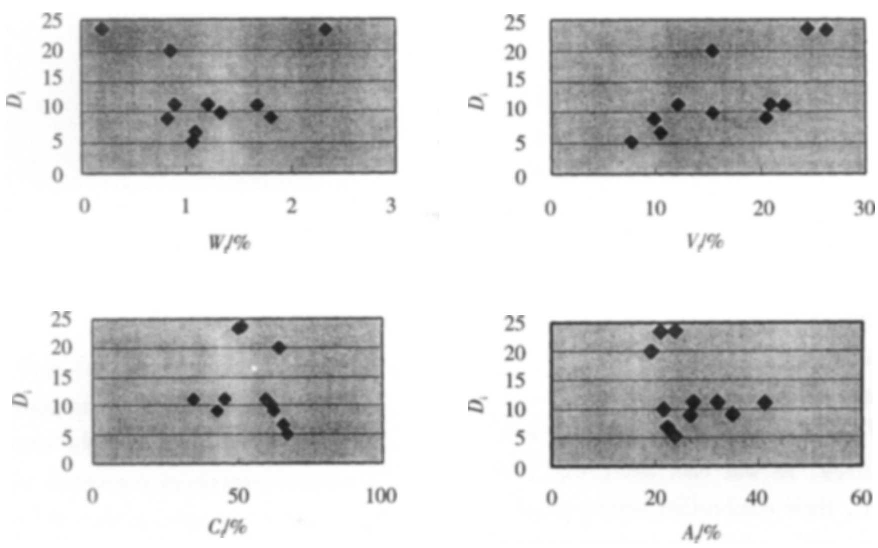

Fig.1 The relationship between coal's ignition index D_i and industrial analysis values

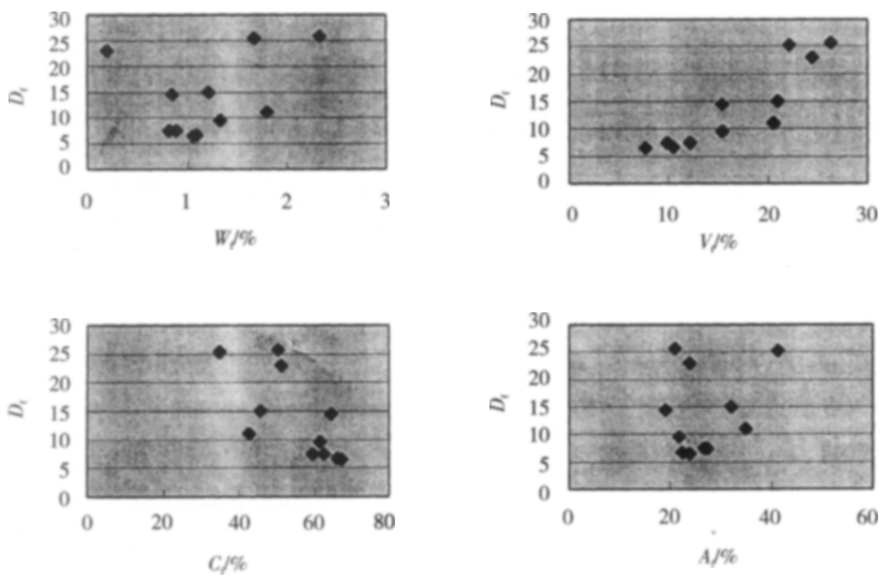

Fig.2 The relationship between coal's combustion ending index D_f and industrial analysis values

Table 2 Comparison of the Ignition Index D_i and Burn off Index D_f of Coal Samples

coal's classification	Anthracite			Lean coal			Bituminous Coal(soft coal)			
coal sample	No1	No2	No6	No11	No8	No7	No3	No5	No9	No4	No10
$D_{i.cal}/10^{-4}$	4.4	8.41	6.69	9.17	14.39	15.43	10.34	12.68	14.57	21.42	22.97
$D_{i.exp}/10^{-4}$	5.20	6.75	8.97	11.27	9.97	20.00	11.10	9.10	11.21	23.53	23.40
$D_{f.cal}/10^{-6}$	5.30	7.01	6.64	8.38	11.46	11.47	19.49	17.29	17.90	22.95	25.41
$D_{f.exp}/10^{-6}$	6.40	6.70	7.35	7.45	9.52	14.40	25.30	11.06	14.95	22.98	25.71
$t_{max} - t_0$/s	28	28	22	30	18	16	24	23	20	15	16

Comparing the experiment results of D_i, D_f by the thermogravimetric analysis and the calculation results of D_i, D_f, we find that the experiment results and calculation results are very similar, and show a regularity, except for few samples. By dynamic burning experiments, we get the time that coal samples come to smooth burning, which also shows the regularity of coal's ignition property and the thermogravimetric analysis results are almost concerted. All these show the rationality of this experiment method and calculation results to a certain extent. By analysis the data in Table 3, we can find that: the ignition index D_i and burn off index D_f of soft coal No10, No4 are larger than 20, and the time that they come to smooth burning is 15s and 16s respectively, which show that they have a fine ignition property and combustion ending property. The combustion property of soft coal No5, No9, No3 and lean coal No7, No8 are average, as soft coal No5, No9, No3 have a high ash content, their combustion ending properties are better than lean coal's, while the ignition properties are worse than lean coal's, which can be proved by the time that coal samples come to smooth burning. The time for No5, No9, No3 samples is longer than lean coal samples'; the ignition index D_i, burn off index D_f of lean coal No11 and anthracite No2, No6, No1 are much lower, and the time that coals come to smooth burning is rather long, which shows that their combustion properties are poor.

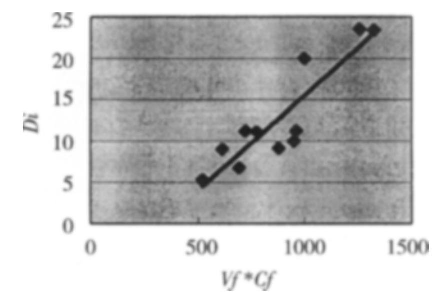

Fig.3 The linear relationship between coal's ignition index and $V_f \times C_f$

From the analysis above, we can find that coal's volatile component, ash and fixed carbon content have different functions in different stages of the combustion process. Coal's volatile component content is very important to its combustion, for example, anthracite's combustion property is much worse than soft coal's, ash and fixed carbon also have an effect on the combustion. The ash content has a great effect on coal's ignition process, for example, soft coal No3, No5, No9, though their volatile component content is rather high , their ignition property

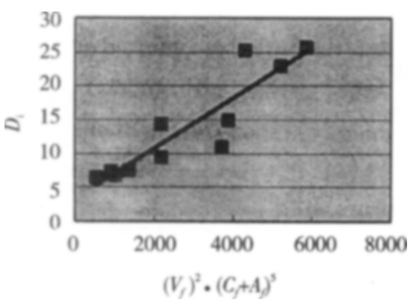

Fig. 4 The linear relationship between coal's combustion ending index and $V_f^2 \times (C_f + A_f)^{0.5}$

is not as good as lean coal's. The fixed carbon content has a great influence on the combustion ending process, for example soft coal No5, No9, No3 and lean coal No7, No8. Fixed carbon contents are low in No5, No9, No3 and are rather high in No7, No8, but we can find that soft coal No5, No9, No3 have a fine combustion ending property. Of course, these are the analysis results from phenomena; we will discuss the mechanism of ignition and combustion ending in the combustion process in other thesis.

4 Conclusions

a) There is a linear relationship between coal's ignition index and $Va \cdot C_f$, so is coal's burn off index and $V_f^2 \cdot (C_f + A_f)^{0.5}$.

b) The relational expressions between coal's ignition index D_i, burn off index D_f and its industrial analysis value are shown as follows:

$$D_i = 0.023 \cdot V_f \cdot Cad - 7.39 \quad (1)$$

$$D_f = 0.0038 \cdot V_f^2 \cdot (C_f + A_f)^{0.5} + 3.17 \quad (2)$$

c) Coal's volatile component, ash, and fixed carbon content have different functions in different stages of the combustion process. Coal's volatile content is very important to its combustion, anthracite's combustion property is much worse than soft coal's; the ash content has great effect on the coal's ignition process, while the fixed carbon content has a great influence on the combustion ending process.

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