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Thermogravimetric Assessment of Combustion Characteristics of Blends of Lignite Coals with Coal Gangue

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Abstract. In this paper, the co-combustion behaviour of lignite coal with coal gangue and coal are investigated by a thermogravimetric analysis (TGA) in the temperature range from ambient temperature to 1000 ℃. The thermal characteristics and kinetics of lignite coal, coal gangue and their blends are evaluated under combustion conditions using a non-isothermal thermogravimetric method (TGA). Lignite coal is blended with coal gangue in the range of 25–75 wt. % to evaluate their co-combustion behaviour. Such attempts of Combustion characteristics index under different proportions of analysis may help to identify appropriate blend proportion for a given coal gangue and to derive some specific advantages with respect to particular combustion practice.

Introduction

The energy demand of the world is continuously increasing in parallel with population increase and industrial development [1-2]. This demand has been met by fossil fuels particularly from coal until now. Coal gangue is composed of various minerals and accretes with coal stratum [3-6].Its dominant minerals are quartz and silicate layered clay minerals. Currently, it is one of the largest emissions of industrial solid waste.

The characteristics of low calorific and limitations of the prior art combustion value fuel, which limit its large-scale use [7], but mixed combustion is an effective way to improve their combustion and combustion efficiency [8-10]. The mechanism of low calorific value of blended coal combustion was understood by the study of lignite coals and coal gangue mixed combustion dynamics, which can effectively guide the combustion process. There are many methods of the combustion process. This study that researches methods in combination with coal combustion characteristics by thermal analysis techniques, can provide strongly theoretical support for stabilizing the low calorific value fuel combustion, and offer energy use and low calorific value boiler burning some guidance significance [11-14].

Experimental

Materials

The experimental material of coal gangue was collected from Ximeng city of Inner Mongolia Province in China. The lignite coal was obtained from Erdos city of Inner Mongolia Province in China. The materials' proximate analyses are shown in Table 1. The initial coal sample was milled and sieved into less than 74 l m in diameter. The coal gangue sample was milled and sieved in less than 200 l m. The lignite coal sample was milled and sieved into less than 200 l m. Finally, lignite coal was mixed with coal gangue and lignite coal in the proportion of 25, 40, 60 and75 (wt. %) in the fuel blend. The materials were stored in the laboratory under dry conditions.

The mixture of lignite coal and coal gangue was determined in a SETARAM thermo- gravimetric analyzer. The combustible mass of the samples was kept at 10mg. In the air flux of $30mL\cdot min^{-1}$, the furnace temperature was increased from ambient temperature to 1000 ℃ at the speed of $10K\cdot min^{-}$

[1] . The weight of sample was monitored continuously as a function of temperature. The TG, DTG and DTA experiment of lignite coal, coal gangue and the mixed fuel were completed.

Table 1. Analysis parameter of coal

	M_{ad}	A_{ad}	V_{ad}	F_{cad}	V_{daf}
lignite coal	16.85	9.98	37	46.18	44.48
lignite coal : coal gangue =4:1	15.70	24.30	33.24	36.76	45.46
lignite coal : coal gangue =3:2	9.59	31.52	27.30	31.59	46.36
lignite coal : coal gangue =2:3	6.74	44.39	24.10	24.77	49.31
lignite coal : coal gangue =1:4	3.23	50.29	18.47	16.88	52.30
coal gangue	1.56	69.32	16.99	12.13	58.34

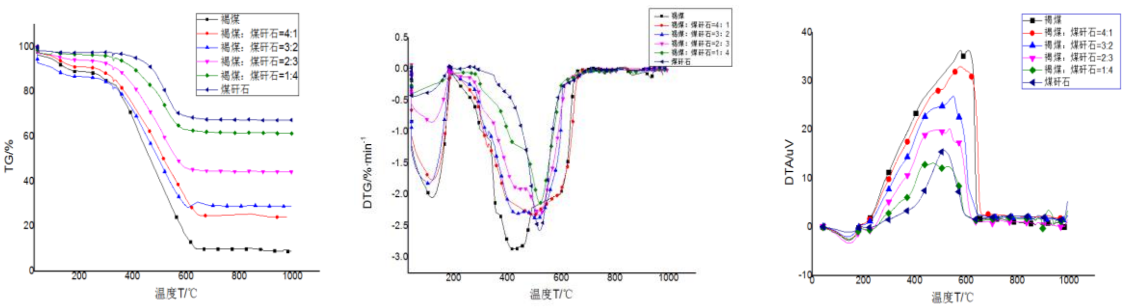
Table 2. Characteristic temperature of the sample

sample	T_i	Tmax	T_f	$(dw/dt)_{max}$
lignite coal	336	422	603	2.8696
lignite coal : coal gangue =4: 1	366	501	611	2.3179
lignite coal : coal gangue =3: 2	355	508	579	2.3865
lignite coal : coal gangue =2: 3	400	519	577	2.3275
lignite coal : coal gangue =1: 4	435	520	565	2.1408
coal gangue	444	520	577	2.5713

Table 3. Characteristics of the sample index

sample	D_i /10^{-5}	$C/10^{-5}$	H_F	C_b	S/ 10^{-8}
lignite coal	1.41	2.5363	1.9129	0.0022	3.9431
lignite coal : coal gangue =4:1	1.03	1.7241	2.3349	0.0042	4.0214
lignite coal : coal gangue =3:2	1.16	1.8927	2.3072	0.0052	5.3402
lignite coal : coal gangue =2:3	1.01	1.4547	2.2479	0.0048	3.8804
lignite coal : coal gangue =1:4	0.869	1.1314	2.1353	0.0041	2.7239
coal gangue	1.00	1.3017	2.0518	0.0033	1.9330

Effects of Blend Proportion on Combustion Process



(a) (b) (c)

Fig. 1. Combustion profiles of the blends

The co-burning profiles of different blends have been compared with the profiles of high ash coal gangue and high moisture lignite coal. As shown in Fig. 1(a), with the increase in the proportion of lignite coal, coal samples enhance the rate of weight loss. With the increase in the proportion of lignite coal, coal samples in turn enhance the rate of weight loss, the higher the ratio of lignite is, and the greater the loss of weight is. As shown in Fig. 1(b), combustion process can be divided into three stages for interpret. The temperature range of the first stage is from ambient temperature at the beginning of the test to about 200 ℃. This phase can be obtained from the DTA endothermic curve, corresponding to a loss of moisture. The second stage begins at 200 ℃ and ends in about 600 ℃. This stage exothermic reaction can be obtained from the DTA curve, which includes the devolatilization, volatile combustion and combustion of fixed carbon [15]. The third stage begins at 600℃ and ends in 1000 ℃. In this stage, the weight loss of the samples were very slight. With the lignite coal increasing, the residue yield of the samples decreases.

In the first stage and second stage, the maximum value of DTG curves of the samples increases with lignite coal increasing. Because the first stage is moisture precipitation, the high moisture content of lignite can be obtained from the table1. In the second stage, when lignite content is higher than 50% in the mixture, the curve were similar, and there are clearly two peak points; when the gangue content is higher than 50% in the mixture, there are clearly a peak point. Due to the fixed carbon combustion is associated with the degree of coal rank, the higher the coal rank is, the more carbon content is, and ignition temperature of fixed carbon is higher. By devolatile and combustion to reach ignition temperature to be fixed carbon combustion. Low coal rank coal gangue has less volatile content, but a higher degree of coalification of lignite has the large volatile content. From Fig 1. (b), the mixture of coal gangue content of greater than 50% is saw. The devolatilization and combustion peak is barely small and the fixed carbon combustion has a larger weightlessness peak; in the mixture, when the proportion of lignite content is higher than 50%, devolatilization and combustion's weightlessness loss peak is large and the weightlessness loss peak of the fixed carbon combustion is small. When considering devolatilization, combustion characteristics and combustion of fixed carbon, lignite accounted for 60% of the blend of combustion characteristics is the best, which may be due to their synergies [16-20].

Results from thermogravimetry analysis for lignite coal and coal gangue blend under different proportion. Combustion characteristic temperature table 2 obtained from Fig. 1.

As indicated in Table 2, with coal gangue increasing, T_i increases and T_f decreases. Maximum DTG tends to decrease. The coal gangue content in the sample decreases, which means that reactions are slower, if lignite coal is lower.

Combustion Characteristics Index under Different Proportions of Analysis

The following parameters characterize the combustion characteristics of Table 3 can be obtained from Table 2.

Ignition Index D_i is Determined by the Equation as Follows:

$$D_i = \frac{DTG_{\max}}{T_i \times T_f} \tag{2-1}$$

Where DTG_{max} is the maximum combustion rate. T_i is the corresponding temperature of the ignition and T_f is the corresponding temperature of the burnout. The larger the ignition index is, the better the performance of the ignition is. With the proportion of lignite increasing, the fire index increases. Mixed coal, lignite ignition index maximum amount of 60%, the proportion of mixed coal ignition is the best performance.

Flammability Index C is Determined by the Equation as Follows:

$$C = \frac{(dw/dt)_{\max}}{T_i^2} \tag{2-2}$$

where $((dw)/(dt))_{max}$ is the maximum combustion rate.T_i is the corresponding temperature of the ignition. Flammability index indicates TG curve trends from ignition point to the maximum rate of weightlessness loss point of this range may be characterized by the stability of the combustion ignition flammability index. The larger the flammability index is, the better the coal's combustibility is. With the lignite increasing, the flammability index increases. Mixed coal, lignite flammability index maximum amount of 60%, the proportion of mixed coal flammability is the best performance.

Combustion Stability Index HF is Determined by the Equation as Follows:

$$H_F = T\max\ln(\frac{DT}{DTG_{max}})10^{-3} \tag{2-3}$$

T_{max} is the maximum combustion rate corresponding temperature. DT has exothermic peak width. DTG_{max} is the maximum value of DTG. H_F is largely considered to characterize coal combustion rate after coal combustion speed and intensity of the ignition and burn performance and capable of reacting after coal ignition combustion stability. H_F is smaller, the performance of coal combustion is better .With the lignite increasing, combustion stability index increasing, mixed coal combustion is more stable than a single coal.

Burnout Characteristics Index CB is Determined by the Equation as Follows:

$$C_b = \frac{f1 * f2}{\tau_0} \tag{2-4}$$

$$f_1 = (m_0 - m_1)/(m_0 - m_e) \tag{2-5}$$

$$f_2 = (m_0 - m_2)/(m_0 - m_e) \tag{2-6}$$

f_1 is the ignition point of combustible coal sample weight loss ratio quality content and coal, the initial burn rate; f_2 is the post burnout rate; τ_0 is the burn time. C_b combines the influence factors of coal combustion stability and burnout on fire, the greater its value, the combustion performance is the better. With the lignite increasing, combustion burnout index increases. Mixed coal combustion is more complete than a single coal, especially lignite burnout index maximum amount of 60%, the proportion of mixed coal burnout is the best performance. Mixed coal's burnout characteristics are better than a single coal.

Comprehensive Behavior of Combustion Index S is Determined by the Equation as Follows:

$$S = \frac{(dw/d\tau)_{max} \times (dw/d\tau)_{mean}}{T_i^2 \times T_f} \tag{2-7}$$

$(dw/d\tau)_{max}$ is the maximum combustion rate, $(dw/d\tau)_{mean}$ is the average burn rate , T_i is the corresponding temperature of the ignition. T_f is the corresponding temperature of the burnout. Combustion characteristics index S is an integrated coal ignition and burnout characteristic index. The higher value of S indicates the better combustion characteristics of coal samples. With the lignite increasing, combustion characteristics index increases. Lignite combustion characteristics index maximum amount of 60%, the proportion of mixed coal ignition is the best performance. Comprehensive blended coal combustion performance is better than a single sample of coal.

Conclusions

The text showed the effects of blend proportion on combustion process and combustion characteristics index under different proportions of analysis. The appropriate blend proportion for a given coal gangue was 60% from the experiment .Several comprehensible differences mainly resulted from the rank differences of the materials of high ash coal gangue and high volatile lignite coal. Due to the fixed carbon combustion with coal rank, the higher the coal rank was, the more carbon content was, and ignition temperature of fixed carbon was higher. The mixed coal of the burnout characteristics、combustion stability and comprehensive behavior of combustion was better than a single coal. This study had some practical significance.

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