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Research on the combustion characteristics of anthracite and blended coal with composite catalysts

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ABSTRACT

Composite catalysts composed of different proportion of chemical reagents and steel industrial wastes were used as coal-burning additives. The effects of additives on combustion characteristics of anthracite coal and blended coal were studied by thermogravimetric analysis (TGA). The results showed that appropriate amount and proportion between chemical reagents and waste slag used as composite catalysts had good performances on the characteristics of coal combustion including ignition temperature, burnout temperature and burnout index, this will improve the coal combustion efficiency and also facilitate the comprehensive utilization of steel industrial waste slag.

1. Introduction

In China, the coal-dominated energy structure pattern is difficult to change in a period of time, while most of coal are still used in traditional way and combustion efficiency of coal stays at a low level, as the result, most pollutions were generated from coal combustion, therefore, to achieve national sustainable development strategy, it is necessary to improve coal combustion efficiency and reduce the pollutions emission. Many investigators have found that alkaline metals, alkaline earth metals and transition elements oxides were useful for catalytic combustion [1–3], techniques has been applied through adding chemical substances (CaO, FeO, MnO etc.) to solve the coal burning problems such as difficult to ignite and combustion incompletely [4,5]. However, the industrial applications were limited due to the high costs of these chemical substances.

Recycling of solid waste is one of the major themes of world environmental protection [6,7]. China, as the largest producer of iron and steel industry country, the annual production of steel industrial waste slag was amazing big [8]. However, the main utilization of steel industrial waste slag in China stays at a low value, low levels such as used as cement substitutes, building materials, etc. Most of steel industrial waste slag contains a lot of alkaline metals, alkaline earth metals and transition elements oxides. Compared with chemical substances, steel industrial wastes are cheap and very easy to obtain. Steel industrial wastes as coal burning additives will not only improve coal combustion efficiency, but also provides a high value-added way to utilize steel industrial wastes [9,10].

In this work, composite catalysts which were composed of different proportions between chemical reagents and waste slag were used as coal-burning additives. The catalytic effects were discussed by TGA. Ignition temperature, burnout temperature and burnout index were determined to evaluate coal combustion reactivity in this research. The results can be used to provide a useful basis for further applying coal with high efficiency.

2. Experimental

2.1. Composite catalysts

Considering the factors of effect and cost as well as improving the coal burner adaptability, the research of composite catalysts was necessary. Based on the previous studies of single coal combustion additive [11,12], two kinds of chemical reagents ($NaClO_4$ and MnO_2) and

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Table 1
Ultimate and proximate analysis (w %) of coal sample.

No.	Ultimate analysis, daf					Proximate analysis, ad			
	C	H	O*	N	S	M	A	V	FC
1	88.98	0.58	9.38	0.45	0.61	2.47	22.84	8.23	66.46
2	80.75	2.99	14.38	1.20	0.68	1.33	24.45	14.29	59.93

Notes: *By difference; 1, raw coal from Jiangxi; 2, raw coal from Wuhan.

Table 2
The chemical composition of coal ash and slag (w %).

No.	Na_2O	MgO	Al_2O_3	SiO_2	SO_3	K_2O	CaO	TiO_2	Fe_2O_3
1	1.60	1.41	34.83	48.71	5.57	1.04	4.56	0.80	1.50
2	1.72	1.81	33.04	53.85	2.33	0.95	2.57	0.6	3.16
3	0.97	3.32	15.02	16.95	5.34	0.13	47.81	0.42	7.22
4	0	0.75	1.46	0.73	0.26	0.025	0.025	0.18	95.48

Notes: 1, raw coal from Jiangxi; 2, raw coal from Wuhan; 3, steel slag; 4, red iron oxide of cold rolling.

two kinds of waste slag (steel slag and red iron oxide of cold rolling) were chosen in this work. Steel slag was generated in the process of steelmaking, contained Ca, Fe, Al etc. and red iron oxide of cold rolling was generated in the process of striping the surface of hot rolling steel before cold rolling, which was rich in Fe_2O_3. All of the coal combustion additives were grounded to 80 meshes according to TGA.

Before work, the waste slag were dealt with acid, the purpose was to remove the useless components and solve the problem of hard to grind, specific methods were as follows: waste slag (150 g in this work) were weighted which were composed of 2 copies of steel slag and 1 copy of red iron oxide of cold rolling. Some HCl solution was added to the waste slag and made them fully dissolve, then some NaOH solution was added to balance out and the PH was controlled at 6.5. At last, the mixture was filtered and the filtered liquid was put into a dry oven, after drying, the rest solid wastes were taken as effective components.

The proportions between solid waste and chemical reagents were as follows: $NaClO_4$: MnO_2: solid waste = 1:1:4 (code name A); $NaClO_4$: MnO_2: solid waste = 1:1:6 (code name B). The additive amounts were 0.3‰ and 1‰ respectively relative to the coal sample.

2.2. Coal samples

Many power plants use blended coal (composed of anthracite and bitumite) instead of anthracite to avoid the problem of hard to ignite and combustion incompletely. In this work, the coal samples were collected from Jiangxi Shengta (anthracitic coal) and Wuhan Steel Electric Co., Ltd (blended coal, Wuhan for short), all of them were grounded to 80 meshes according to TGA. The properties of the coal sample were listed in Table 1, chemical composition of the coal ash and slag were listed in Table 2. The catalytic samples were prepared with 0.3‰A, 1‰A, 0.3‰B and 1‰B respectively relative to the coal sample.

2.3. Thermoanalysis

The combustion characteristics of coal with or without composite catalysts were studied in a Netasch STA 409PC thermogravimetric analyzer. In a nitrogen flux of 30 ml/min and oxygen flux of 10 ml/min, the shielding gas was nitrogen and the flux was 10 ml/min. Coal sample (30 mg) was placed in an Al_2O_3 ceramic crucible and burned under a simulative air atmosphere at a heating rate of 10 K/min from the ambient temperature to 1000 °C. The weight of sample was monitored continuously as a function of temperature.

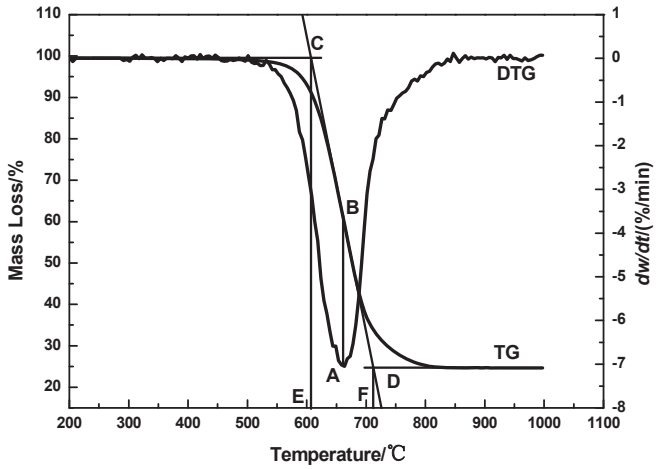

Fig. 1. Definition of ignition and burnout temperature.