Study on the Influence of mixed burning Sludge on slagging characteristics of easily slagging Coal

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Abstract. In this paper, combined with experiments and theoretical calculations, the effect of urban low-calorific value sludge on the slagging characteristics of easy-slagging coals is studied. The results show that when the melting point of sludge ash is lower than that of coal ash, the ash melting point of the mixture after the two blends will be lower than the melting point of raw coal ash. When SiO_2 and Al_2O_3, which are relatively high in sludge, are used as single additives, the ash melting point of coal will first decrease and then increase. As the mixing ratio of sludge increases, coal ash slagging characteristics show a trend of gradual relief. For coals that are prone to slagging and rich in alkali metals, they can be appropriately mixed with sludge rich in silicon and aluminum compounds or additives to improve Slagging characteristics.

Keywords: Mixed burning sludge, Ash melting point, Slagging characteristics

1 Introduction

All manuscripts must be in English, also the table and figure texts, otherwise we cannot publish your paper. Please keep a second copy of your manuscript in your office. When receiving the paper, we assume that the corresponding authors grant us the copyright to use the paper for the book or journal in question. Should authors use tables or figures from other Publications, they must ask the corresponding publishers to grant them the right to publish this material in their paper. The reduction, harmlessness, stabilization and resource utilization of municipal sludge have become one of the major problems in the rapid development of urbanization [1], the moisture content of the wet sludge treated by the sewage treatment plant is generally above 80%, and the calorific value is about 0.1 ~ 3MJ/kg, and the calorific value of the dried sludge is about 6 ~ 12MJ/kg. The main components of the sludge include heavy metals, refractory trace organics, viruses, bacteria and other pathogenic microorganisms. In addition, some minerals are mainly silicate, aluminate and oxides[2].

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As complex mineral combination system, coal ash is composed of acidic oxides such as SiO_2, TiO_2 and Al_2O_3, basic oxides such as Fe_2O_3, Cao, MgO, Na_2O, K_2O, and SO_3. It is generally believed that more acidic oxides such as SiO_2, TiO_2 and Al_2O_3 can increase the fusion temperature of coal ash, while the content of basic oxides such as Fe_2O_3, Cao, MgO, Na_2O and K_2O will reduce the fusion of coal ash. but the fusion temperature of coal ash is ultimately determined by the minerals formed under high temperature[3],When a large amount of foreign substances are added, the fusion characteristics of coal ash will be affected and the slagging characteristics of coal ash will be changed.LI Ming et al.[4] found that with the increase of the proportion of sludge, the ash melting point decreased significantly , because of low temperature co-melting of minerals in coal ash sludge ash. Gao et al[5] found that the high content of hematite and anorthite in the sludge ash is the main reason for the decrease of the melting characteristic temperature of sludge/coal ash. Deng et al's[6] results show that Mullite with high temperature resistance and anorthite which can reduce the ash melting temperature can make the melting characteristics of sludge/coal ash change nonlinearly. In this paper, the effect of sludge on slagging characteristics of alkali rich coal was studied by combining experiment with theoretical calculation.

2 Introduction to the experimen

2.1 Equipment and Method

In this paper, the fusion characteristics of coal ash samples were measured by hr-4a microcomputer ash melting point tester which met the requirements of GB/T219-2008 "determination method of coal ash fusibility". The preparation method of ash sample is slow ashing method: firstly, the wet sludge is dried at 105 ℃ for 3 h, then the dried sludge or sludge pulverized coal mixture is slowly raised to 500 ℃ at normal temperature, then it is kept for 30 min, then the target temperature is reached at the heating rate of 10 ℃/min, and the ash sample is taken out and cooled to normal temperature in a drying dish, Finally, the ash melting characteristics are analyzed.

2.2 Ash Composition of Sludge and Coal

The ash composition analysis of selected coal and sludge is shown in Table 1. It can be seen from table 1 that the main components of ash in the selected sludge are Al_2O_3 and SiO_2.

Table 1. Ash Composition of Sludge and Coal

Items	Ash Composition/%									Softening temperature (℃)
	Fe_2O_3	Al_2O_3	CaO	MgO	TiO_2	SiO_2	SO_3	K_2O	Na_2O	
Coal	8.01	7.36	24.54	6.96	0.99	14.3	32.79	0.4	4.65	1360
Sludge	6.81	25.9	3.05	1.62	0.96	47.96	0.96	2.62	0.36	1266

3 Experimental results and analysis

3.1 Effect of sludge on coal ash fusion characteristics

The influence of sludge mixing ratio on coal ash fusion characteristics is shown in Fig. 1.

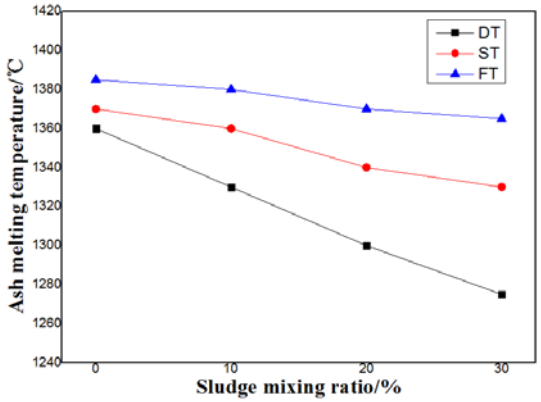

Fig.1 Influence of sludge mixing ratio on coal ash fusion characteristics

It can be seen from table 1 and figure 1 that the deformation temperature(DT), softening temperature(ST) and flow temperature(FT) of coal ash decrease with the increase of sludge mixing proportion, which indicates that mixing sludge with low melting point can significantly reduce the fusion characteristic temperature of coal ash.It can be seen from Figure 1 that with the increase of sludge mixing ratio, the temperature difference of DT, ST and FT of coal ash also increases, but it is still in the short slag area.For the above phenomenon, some studies[7,8] think that the reason is that SiO_2 in coal ash mainly exists in the form of amorphous, which is easy to form vitreous material with no fixed melting point with other metal oxides and non-metallic oxides in coal ash. This kind of material gradually softens with the increase of temperature until it begins to flow. The higher the content of SiO_2, the more amorphous vitreous body will be formed, which will lead to the temperature of ST and ft of coal ash However, SiO_2 accounts for nearly 50% of the sludge ash selected in this paper, so it will lead to this phenomenon.

3.2 Effect of main components of sludge (Al_2O_3 and SiO_2) on coal ash fusion characteristics

The influence of sludge on the ash melting point will change due to the different composition of sludge and coal ash. Through literature review, it is found that most of the sludge components are SiO_2 and Al_2O_3. Therefore, this paper discusses the influence of single additive on coal ash fusion characteristics. The single additive is SiO_2 and kaolin (Al_2O_3), and the proportion of raw coal: additive = (97:3, 94:6, 91:9). The influence of additives on the fusion characteristics of coal ash is shown in Fig. 2 and Fig. 3.

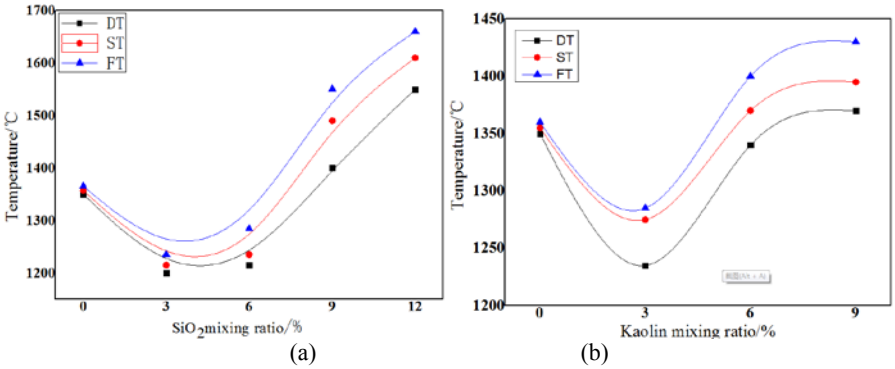

Fig.2 Variation of characteristic temperature of coal ash fusion by SiO_2 and kaolin

It can be seen from Fig. 2 (a): with the increase of SiO_2 mixing proportion, DT, st and FT temperatures of coal ash decrease first and then rise, which indicates that mixing a small proportion of SiO_2 will reduce the fusion characteristic temperature of coal ash; when the proportion of SiO_2 reaches 9%, the temperature of ST and ft of coal ash will exceed 1500 ℃.It can be seen from Fig. 2 (b): the change trend of ash fusion characteristic temperature after adding Al_2O_3 is similar to that after adding SiO_2. The temperature of DT, st and ft of coal ash decreases first and then increases. The difference with SiO2 is that when the addition ratio of Al_2O_3 reaches 6%, the fusion temperature of ash sample is close to the characteristic temperature value of raw coal ash sample The ash melting temperature can be improved when the addition ratio of Al_2O_3 is more than 6%.In addition, the difference of St temperature between 6% and 9% Al_2O_3 is only 25 ℃, which is different from that of SiO_2. This is because when the addition ratio of Al_2O_3 is 3%, the phase in the ash is mainly composed of anorthosite, Calc Huang feldspar and forsterite at high temperature, and the low-temperature eutectic formed by the three will lead to a sharp decrease in the fusion temperature of coal ash[9]. When the addition ratio of Al_2O_3 reaches 6%, the Calc Huang feldspar in the ash will be transformed into anorthite, becoming the main material in the ash and playing a "skeleton" role in high-temperature melting[9] .Based on the results of this paper and related studies, it is suggested that the additive rich in Al_2O_3 should be preferred.

3.3 Effect of sludge on slagging characteristics of coal ash

Many researchers[10,11] have studied the evaluation index of coal slagging characteristics to ensure the normal and safe operation of boilers. The commonly used indexes for predicting coal ash slagging at home and abroad mainly include slagging index "Sc", silica alumina ratio"SiO_2/Al_2O_3", alkali acid ratio "B/A", silicon ratio "G" and comprehensive discrimination index"Rz". Indexes for judging slagging tendency of coal ash are shown in Table 2.

Table 2. Indexes for judging slagging tendency of coal ash

Indexes	Calculation formula	Indicator limits			Accuracy (%)
		Slight-slagging	mid-slagging	Serious slagging	
ST	-----	>1350	1350～1260	1260	83
B/A	$\frac{CaO+MgO+FeO+Na_2O+K_2O}{SiO_2+Al_2O_3+TiO_2}$	＜0.206	0.206～0.4	＞0.4	69
G	$\frac{SiO_2*100}{SiO_2+Fe_2O_3+MgO+CaO}$	＞72	72～65	＜65	67
silica alumina ratio	$\frac{SiO_2}{Al_2O_3}$	＜1.87	1.87～2.65	＞2.65	61
Rz	1.237*B/A+0.282*SiO_2/Al_2O_3 -0.0023*ST-0.0189*G+5.145	≤1.5	1.5～1.75 1.75～2.25 2.25～2.5	≥2.5	90
Sc	2.521-0.00165*ST+0.350(B/A)	＜0.45	0.45～0.65	0.65～0.85 high ≥0.85 serious	----

The indexes for predicting the slagging characteristics of coal ash listed in Table 2 are obtained by Chinese researchers according to the ash composition of a large number of coals and their practical application in power plant boilers. He et al.[10] used the optimal segmentation model to calculate the ash and slag characteristics of more than 250 kinds of coal in China, and obtained the slagging grade boundary value of each index.Although the

slagging characteristics of coal have not been predicted completely and correctly by a single index, each of the above-mentioned items has considerable accuracy, especially the comprehensive judgment index R_Z. The accuracy of R_Z can reach 90%, which is obtained by the weighted average method based on the statistics of ash and slag characteristics of more than 90 kinds of coal by Chinese scholar Li Yongxing et al.[11].

According to the ash composition analysis results of sludge and raw coal and referring to table 2, the slagging index calculation results of sludge and raw coal can be calculated, as shown in Table 3.

Table 3 Calculation results of slagging index of sludge and raw coal

Slagging Indexes	Sludge		Raw Coal	
	Calculation results	Slagging grade	Calculation results	Slagging grade
ST	1266	medium	1360.00	slight
B/A	0.19	slight	1.97	serious
G	80.69	slight	26.57	serious
SiO_2/Al_2O_3	1.85	slight	1.94	medium
Rz	1.25	slight	4.50	serious
Sc	0.34	slight	0.97	serious

It can be seen from table 3 that although the st temperature of the selected coal is higher, many slagging indexes are serious slagging, which is consistent with the results in the actual application process. For sludge, although the st temperature is less than 1300 ℃, the calculation results of many slagging indexes are slight slagging, which shows that it is one-sided to judge the slagging characteristics of sludge and raw coal only by the st temperature of ash fusion.

Based on the analysis results of ash formation rate and ash composition of sludge, the components of coal ash mixed with different proportions of sludge are calculated, as shown in Table 4.

Table 4 Ash composition after mixing sludge and coal

Compositions	Ash of coal	Ash* of sludge	C:S**=90:10	C:S=80:20	C:S=70:30
Fe_2O_3	8.01	6.81	7.76	7.68	7.63
Al_2O_3	7.36	25.90	18.81	22.78	24.80
CaO	24.54	3.05	13.18	9.25	7.25
MgO	6.96	1.62	4.19	3.23	2.74
TiO_2	0.99	0.96	1.03	1.04	1.05
SiO_2	14.30	47.96	35.15	42.38	46.04
SO_3	32.79	0.96	15.76	9.86	6.87
K_2O	0.40	2.62	1.74	2.21	2.45
Na_2O	4.65	0.36	2.37	1.58	1.18

(Note: *The sludge involved in mixing is air dried, and the ash formation rate is calculated as 59%.**C:S means Coal:Sludge)

Combined with table 2 and table 4, the ash slagging index of the mixture can be calculated, as shown in Table 5.

Table 5 Slagging characteristics of coal ash mixed with sludge

Slagging Indexes	C:S=90:10		C:S=80:20		C:S=70:30	
	Calculation results	Slagging grade	Calculation results	Slagging grade	Calculation results	Slagging grade
ST	1330	medium	1300	medium	1275	medium
B/A	0.53	serious	0.36	medium	0.30	medium
G	58.31	medium	67.77	medium	72.32	slight
SiO_2/Al_2O_3	1.87	medium	1.86	slight	1.86	slight
Rz	2.30	medium	1.65	medium	1.40	slight
Sc	0.60	medium	0.36	slight	0.28	slight

It can be seen from table 3 and table 5 that the slagging characteristics will be improved after mixing sludge except for the ash melting temperature. Therefore, the slagging characteristics of this kind of coal can be improved by blending sludge or additives rich in silicon and aluminum compounds.

4 Conclusion

When the alkali metal rich coal is blended with sludge, the ash melting point of the mixture will be lower than that of the original coal ash, and with the increase of sludge mixing proportion, the temperature difference of DT, st and ft of coal ash will also increase. When SiO_2 and Al_2O_3 are used as single additives, the ash melting point of coal will decrease first and then rise. With the increase of sludge mixing ratio, the slagging characteristics of coal ash show a trend of gradual alleviation. The slagging characteristics of coal rich in alkali metals can be improved by mixing sludge or additives rich in silicon and aluminum compounds, especially Al_2O_3.

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