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Relationship Between Ash Fusion Temperatures and Coal Mineral Matter in Some Turkish Coal Ashes

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This paper describes the slagging problems resulted from the coal chemistry in various coal-fired electrical power generation plants in Turkey. The fusion temperature test has been used to evaluate the melting and slagging behaviour of coal ash for years. However, the coal ash fusion temperatures alone are not sufficient to be able to separate the good *versus* poor performance of coals. Further investigations about the subject revealed that the iron levels in the coal ash and several indexes such as base to acid ratio, slagging factor *etc.* are also providing good bases for separating the coals that caused problems. The studies using different approaches showed that the chemical and mineral compositions of coal ash determine its melting characteristics and fusion temperature. The correlative equations based on this assumption are still the most widely used techniques for assessing the deposition characteristics and fusion temperature. It also involves the investigation of chemical and mineralogical composition of coal ash samples from Kemerköy-Yeniköy-Yatagan-Soma coal-fired electrical power plants. The effects of slag indexes causing slagging were calculated after the determination of the ash fusion temperatures. The calculated values were compared with chemical compositions. The results showed that Soma-Yatagan-Yeniköy coal fly ash holds a tendency of high capacity slagging. Kemerköy coal ash samples have less slagging tendency compared to the others. This is most probably due to their high acidic alkali content.

Key Words: Coal combustion, Power plant, Slagging, Ash fusion.

INTRODUCTION

Coal consists organic and inorganic matters. The inorganic matters of coal are transformed into products that may transfer to furnace walls and form deposits during combustion. It is hard to determine the tendency to slag conditions in power station boilers. It is important to be able to predict the potential combustion products and especially for coals with high ash content, the extent to which a coal will slag or foul upon combustion.

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The studies using different approaches have shown that the chemical and mineral compositions of coal ash determine its melting characteristics and fusion temperature (AFTs). The correlative equations based on this assumption are most widely used techniques for assessing the deposition characteristics and fusion temperature[1].

EXPERIMENTAL

Coal fly ash samples were collected from electrostatic precipitators of Soma, Yatagan, Yeniköy and Kemerköy thermal power plants. Samples were used in the experiments without any preparation. The samples were analyzed and subjected to the experimental work after homogenization. The elementary composition of the material has been determined by atomic absorption spectroscopy.

The fusion temperature or cone melt test has been used to evaluate the melting and slagging behaviour of coal ash for years. These tests[2] have been applied for present studies.

The conventional method of ash fusibility characterization involves heating of a pyramid of ash at *ca.* 5-10 °C/min from 1000 to 1600 °C. The time taken for the test is about 1-2 h. The results of an AFT analysis consist of four temperatures; these are the initial deformation temperature (DT), softening temperature (ST), hemispherical temperature (HT) and flow temperatures (FT). (i) Deformation temperature, when ash just begins to flow as shown by the first sing of deformation of pyramid. (ii) Softening temperature is recorded when the height of the ash becomes equal to the width of the base. (iii) Hemispherical temperature is noted when the height of the fused ash becomes equal to half of its width. (iv) Flow temperatures is noted when the height becomes a 16th of the width[3].

Seggiani[4] has reported the fusibility as a function of the content of the 8 principal oxides frequently found in coal ash, *i.e.*, SiO_2, Al_2O_3, TiO_2, Fe_2O_3, CaO, MgO, Na_2O and K_2O. The acid/base ratio is often used as a parameter for correlating ash fusibility with its composition. Slegeir *et al.*[5] highlighted the fact that coal ash fusibility characteristics are difficult to determine precisely, because coal ash contains many components and does not have a sharp melting point like a pure compound. Correlations between AFT data and ash composition indicate that, in many cases they are no more accurate than the approaches based on acid-base formalism. Correlation are thus not obtained with single elements, but as an interaction between different ash elements[6].

RESULTS AND DISCUSSION

The mineral components of ashes are presented in Table-1. The ash test specimens were produced in laboratory according to the ASTM D1857 standard. Australian Standard AS 1038.15-1995 specifies AFT measurement. Results are given in Table-2.

Initial deformation temperatures of Yeniköy and Kemerköy coal ashes were lower than the others (Fig. 1).

TABLE-1
MINERAL COMPONENTS OF COAL ASH

Component	Kemerköy (K)	Soma (S)	Yeniköy (Y)	Yatagan (Ya)
CaO (%)	29.46	25.48	15.56	13.98
SiO_2 (%)	23.62	36.78	43.41	54.65
Al_2O_3 (%)	24.49	23.32	17.89	14.28
Fe_2O_3 (%)	5.84	5.71	5.23	5.07
MgO (%)	0.85	0.66	1.01	0.76
SO_3 (%)	10.52	3.97	9.82	6.63
Na_2O (%)	0.72	0.99	0.33	0.19
K_2O (%)	2.23	1.93	1.28	1.63
LOI	1.76	0.71	4.04	2.56

TABLE-2
ASH FUSION CHARACTERISTICS OF COAL ASHES

Ash fusibility (ºC)	Kemerköy (K)	Soma (S)	Yeniköy (Y)	Yatagan (Ya)
(IT)	1150	1190	1150	1225
(ST)	1210	1225	1200	1250
(HT)	1220	1290	1225	1290
(FT)	1250	1330	1250	1340

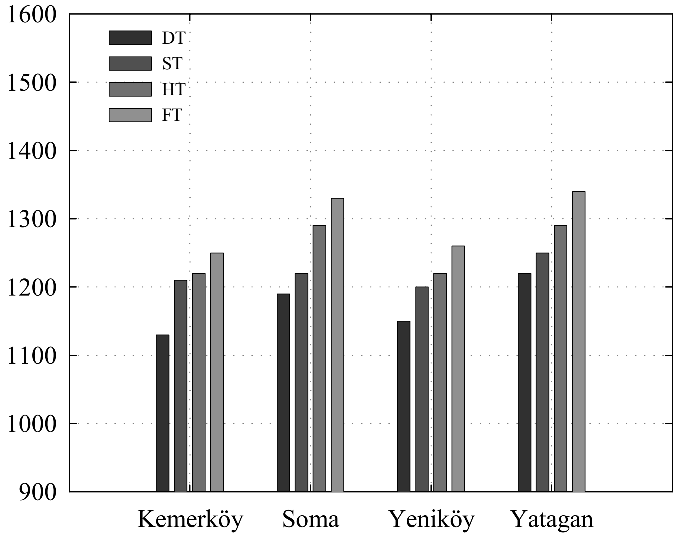

Fig. 1. AFT measurement values of coal ash

The correlation between the coal ash and the fusion temperatures (FT) can be determined by required calculations. The ash composition is expressed as mass percentages:

$$\text{Silica }\% = \frac{SiO_2}{SiO_2 + Fe_2O_3 + CaO + MgO} \times 100$$

Coals can be classified as the coals having good and poor slugging behaviours according to their silica content[7]. This value is required to be above 86 % for a coal having good slugging behaviour.

$$B/A = \frac{Fe_2O_3 + CaO + MgO + K_2O + Na_2O}{SiO_2 + Al_2O_3 + TiO_2}$$

The ratio of basic to acidic oxides as expressed by B/A has been described by Winegartner[8]. This ratio is expected to be below 0.11, higher ratios indicate a higher tendency to form slag.

$$\text{Slagging index (Rs)} = \text{dry S\%} \times B/A$$

This ratio should not exceed than 0.6.

Gray and Moore[9] proposed an index value based on the initial deformation temperature (DT) and hemispherical temperature (HT) of the ashes.

$$Fs = (DT + HT)/5$$

Fe_2O_3 and CaO contents of the ash are the important parameters determining the slagging behaviour of coal. CaO content of the ash should be between 5-40 % and Fe_2O_3 is expected to be below 6 %.

Basic oxides/acidic oxides ratio, slagging index and silica modulus of the coal ashes have been calculated from the results of chemical analyses and are given in Table-3.

TABLE-3
SLAGGING INDEXES OF COAL ASHES

	Kemerköy (K)	Soma (S)	Yeniköy (Y)	Yatagan (Ya)
Silica (%)	39.52	53.59	66.57	73.40
B/A	0.80	0.57	0.38	0.31
Rs	3.37	0.91	1.48	0.82
Fs	1164	1210	1165	1238

Fs = (DT + HT)/5.

Gray and Moore[9] classified the coal ash according to the Fs as following;

Fs (ºC)	
1231, 85-1341	Medium
1051-1231	High
< 1051	Hard

Sulfur contents of the coal is another important factor affecting slagging behaviour of the ash. High sulfur content increases the tendency to form slag. For this reason, all the important parameters given above should be taken into account while determining the slagging potential of a coal.

The studies show that coal ash samples from Yatagan thermal power plant has higher deformation temperature than the others. Initial deformation temperatures of Yeniköy and Kemerköy coal ashes were lower. Ash samples taken from Soma thermal power plant have high index values. However, low sulfur contents of these samples determines the slagging behaviour.

It was observed from the calculated index values and measured deformation temperatures that all the coal samples used in the study have a tendency to form slag. Acidic oxides content in the coal body should be more than the basic oxide content to interfere the slag formation.

Conclusion

As discussed and observed from the results, the findings can be summarized as follows: (i) It was reconfirmed that AFTs were decreased by an increase in the basic oxide content[1]. (ii) It was observed that the tendency of the ash samples to form slag is found to be related with the chemical composition of the coal. The ash samples having high acidic oxides content were observed as having high initial deformation and deformation temperatures. The ash samples taken from Yatagan thermal power plant has a lower tendency to slagging. The ash samples from Soma, Yeniköy and Kemerköy thermal power plants have increasing tendencies to slagging, respectively. (iii) It can be noted that the ash samples from Yeniköy termal power plant have better index values for slag formation than the ash samples from Soma thermal power plant. Nevertheless, the sulfur contents of the ash samples from Yeniköy was higher and high sulfur contents lowers the deformation temperature. This finding indicates that sulfur contents of the coal strongly affect the slagging behaviour. (iv) In last years, coals having a high tendency to slagging are being mixed with coals holding a poor slagging behaviour before burning in the thermal power plants. Thus, the deformation temperature of the coal ash is being increased and slag formation in the burning chamber is decreased.

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