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Thermomechanical analysis of laboratory ash, combustion ash and deposits from coal combustion

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Abstract

Mineral impurities in coal form ash and a part of the fly ash form deposits in pulverized coal-firing furnaces. Understanding of the transformation of mineral matter in coals to flyash and deposit formation has improved knowledge and helped industrial engineers better handle ash-related problems. In Australia, ash fusibility tested in accordance to the standardized procedure or measured by Thermo-Mechanical Analysis (TMA) has been widely used to compare and predict slagging potential of various coals. The current study aims at obtaining an understanding of the sensitivity of TMA analysis to the physical, chemical and morphological properties of coal combustion deposits. In the study combustion residues including ash prepared in a laboratory oven at a temperature of 815 °C, flyash collected in a pilot scale furnace and deposits collected from a utility furnace generated from one Australian coal are used for TMA analysis. Ash samples with various levels of iron content were obtained from different milling performance, ash samples with various silicon and alumina contents were prepared by mixing ash with quartz, kaolinite and bauxite. Results indicated that TMA measurements on coal ashes are very sensitive to iron content and can be used to indicate iron related slagging problems in pf-fired boilers. For ash deposits, both the physical properties such as their homogeneous/heterogeneous nature and ash chemistry affect TMA measurement.

Keywords: Thermomechanical analysis; Ash; Deposit

1. Introduction

Mineral impurities in coal form ash and a part of the fly ash form deposits in a pulverized coal-firing furnace. Ash deposition on furnace walls in pf fired boilers is termed slagging when it occurs in the high temperature areas of furnaces directly exposed to flame radiation, and fouling in other regions such as tubes in the convection section of the boiler. A number of engineering indices are being used to evaluate the potential of coal ash to form deposits in furnaces. These indices are derived from various techniques which include the ash fusibility temperature (AFT) test, ash composition analysis and ash viscosity measurements.

The AFT test has been the most accepted method by industry to evaluate fusibility of coal ashes prepared at 815 °C in laboratory. It provides four characteristic temperatures for laboratory ash as it is heated at approximately 5 °C to 10 °C/min from 1000 °C to 1600 °C. Initial deformation temperature (IDT) is the temperature at which the first rounding of the tip of the specimen occurs. Sphere temperature (ST) is the temperature at which the height of the specimen is equal to the width of the base. Hemisphere temperature (HT) corresponds to the temperature at which the height of the specimen is equal to half the width of the base, its shape being approximately hemispherical. The flow temperature is the temperature at which the height of the fused ash specimen is 1.5 mm [1].

Determination of AFT temperatures in standardized test in nature is continuous observations by a human operator on

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Table 1
Ash analysis of coal samples

	Coal A	Coal B	Coal C	Coal D	Coal E
Silicon as SiO_2	56.3	52	55.6	50.3	47.6
Aluminium as Al_2O_3	30.7	29.6	31	29.8	28.6
Iron as Fe_2O_3	6	13	6.2	13.4	16.0
Calcium as CaO	1.1	1.2	1.03	1.7	1.64
Magnesium as MgO	0.74	0.91	0.53	1.1	1.12
Sodium as NaO	0.08	0.12	0.21	0.08	0.37
Potassium as K_2O	0.34	0.29	0.24	0.22	0.11
Titanium as TiO_2	2	2	2.3	1.8	2.22
Manganese as Mn_3O_4	0.12	0.28	0.16	0.29	0.29
Phosphorus as P_2O_5	0.05	0.06	<0.01	0.07	0.09
Sulfur as SO_3	1	0.94	1.23	0.75	1.77

changes in shape of an ash specimen when it is heated under a specified heating rate. To eliminate the effect of operators and thus to improve repeatability and reproducibility of ash fusibility test, some alternative ash fusibility tests including thermomechanical analysis (TMA), improved ash fusion test (IAFT) have been developed in Australia to directly measure ash fusion behaviour by its mechanical characteristics, electrical conductance or by an computer controlled camera. [3,7,8,10] TMA developed in the CSIRO, Australia as an alternative fusibility test for laboratory coal ashes has been used to compare and predict slagging potential of various coals.[5,10,12]. TMA measurements provide two types of information: firstly it gives ram penetration into the sample expressed as a function of temperature; secondly it indicates characteristic temperatures expressed as “peaks” the temperatures of rapid penetration, with the height of the peak being proportional to the maximum change in penetration with change in temperature. The peaks are obtained from the first derivative of penetration trace.

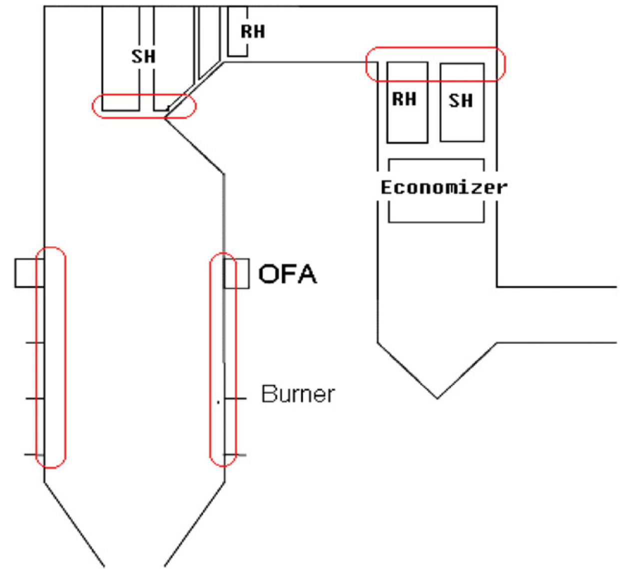

Fig. 2. Geometry and sampling location of boiler.

The TMA operating procedure has been standardised for ash configuration (sample mass and sample compression), heating rate, and TMA ram configuration (geometry and load of penetrating ram).[10]. The effects of ash chemistry on TMA measurements have been systematically studied at the University of Newcastle. Ash chemistry described by the amount of basic oxide, nature of basic oxide and the ratio of SiO_2/Al_2O_3 determines major peaks events in TMA measurements. The ash fusion behaviour can be correlated and interpreted with various eutectic temperatures from phase diagrams $SiO_2–Al_2O_3–X$, where X = FeO, CaO, MgO, K_2O, Na_2O. [4,6,12] Possible

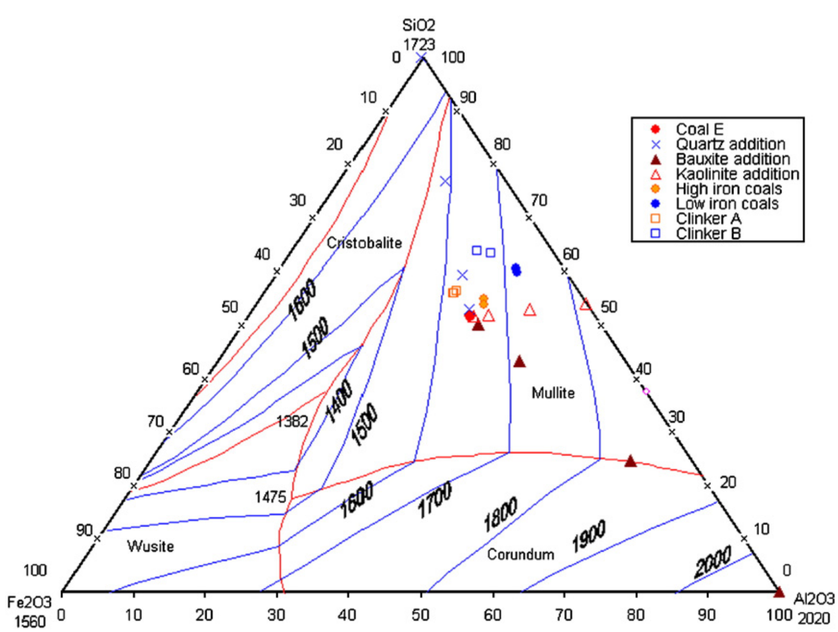

Fig. 1. Chemical compositions of coal ash and blends formed with various minerals.