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Melting Characteristics and Morphology of Bottom Ash and Filter Ash of the Circulating Fluidized Bed boiler

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ABSTRACT: The aim of this work was to investigate the melting characteristics and morphology of filter ash and bottom ash with and without 7% of peat addition to the fuel of the circulating fluidized bed boiler. The samples were characterized by simultaneous thermal analysis (STA) and scanning electron microscope (SEM). The STA results indicate that the filter ash melts at 1140°C with 10 wt% of the mass loss and Bottom ash partially melts at 1170°C with below 2 wt% of the mass loss. The low melting point of the filter ash is due to the high concentration of the alkali metals in the filter ash. Similar trends were observed in the case of fly ash and bottom ash with peat admixture to the fuel. Furthermore the elementary analysis via scanning electron microscopy, coupled with energy-dispersive X-ray analysis showed that 7% of peat addition to the fuel does not significantly effect on the ash composition.

Keywords: Filter ash; Bottom ash; Peat; STA; SEM; agglomerated slag.

1 Introduction

The need to develop a viable strategy for initial stabilization and future decrease of CO₂ emissions has led to an increased use of renewable and sustainable energy sources such as biomass fuels. Woody biomass fuel for generating heat and power is of interest because wood is a renewable, CO₂ neutral fuel, with low ash and sulphur content [1]. Despite the mentioned benefits, the use of woody biomass in boilers involves several technical difficulties, which are mainly related to the inorganic constituents in biomass. The relatively high alkali and chlorine content of woody biomass fuels has been reported as one of the main reasons for increased bed agglomeration, slagging, fouling and corrosion in boilers [2-4]. During combustion, the organic structure of plant material is decomposed and the inorganic material is released and transported either in the form of solid particles or as vapour species in the combustion gas. Particulate adventitious materials undergo phase transformations and reactions with other inorganic components. The large ash deposit formation is caused by the relatively large gas-phase concentration of alkali-containing species such as KCl, and the low melting temperature of many alkali-containing ash components. Gas-phase alkali components generate deposits by condensation on boiler heat-transfer surfaces and the partially melted deposits act as efficient glue for silicate-rich ash particles [4]. Some phases in ash have low melting points and act as an adhesive medium and attach bed particles to each other. The growth and increase of the agglomeration may lead to a complete defluidization of the bed and consequently to an unscheduled shutdown of the boiler. Therefore, improved knowledge of the melting characteristics and morphology of the ash and bed material from biomass combustion is of significant importance, to reduce ash related problem in circulating fluidized bed boiler. It has been reported that mixing of peat significantly can reduce the ash melting and bed agglomeration tendencies for biomass fuels and also reduce fouling and corrosion. The addition of peat to the fuel mixture increased the formation of alkali sulphate that prevents the formation of alkali

chlorides and hydroxides, which are responsible for bed agglomeration and deposit formation. Lundholm et al. [5] reported an increased bed agglomeration temperature when peat was combusted with bark or logging residue. The amount of peat added was 5- 30% of the total content of the ash content. Different bed agglomeration prevention mechanisms have been suggested for the various peat fuels used as additives, involving the effect of the elements Al, S, K, and Ca on the bed particle layers.

The objective of the present work was to examine the melting characteristics and morphology of the filter ash and bottom ash with and without 7% of peat addition to the fuel of the circulating fluidized bed boiler. Furthermore agglomerated slag and quartz sand used as a bed material were also investigated. Filter ash, bottom ash, agglomerated slag and quartz sand (bed material) were collected from of a circulating fluidized bed boiler (104 MWth) fired with forest residues as well as forest residues with admixture of 7% peat.

2. Experimental

2.1 Simultaneous thermal analysis (STA)

Simultaneous thermal analysis of the filter ash, bottom ash, agglomerated slag and quartz sand (bed material) were performed by, using a SETARAM Labsys TG-DTA 1600 instrument in order to determine the presence of exothermic or endothermic reactions. Samples were collected from of a circulating fluidized bed boiler (104 MWth) fired with forest residues as well as forest residues with admixture of 7% peat. Samples were heated up to 1350°C in flowing air in alumina cups, using a heating rate of 15°C/min. The precision in the measurement was estimated to be ± 5°C. Some of the samples were measured twice, in order to test the sample's homogenization and also the reproducibility of the instrument. Furthermore, after the end of each DTA run, the sample crucible was visually examined, to define

the final condition of the sample material and correlate it with the results derived from the generated DTA curves.

2. 2. SEM analysis

The morphology of the filter ash and bottom ash was examined by back-scattered electron images using a JSM 7000F scanning electron microscope. Elementary analysis were performed via scanning electron microscopy, coupled with energy-dispersive X-ray analysis, on each sample, with a Si detector and a LINK INCA program system.

3. Results and discussion

Results of the thermogravimetric analysis (TG) and differential thermal analysis (DTA) of the filter ash, bottom ash (with and without of 7% peat admixture), agglomerated slag and quartz, by the simultaneous thermal analysis (STA), are presented in Fig 1-3. As shown in Fig 1, The DTA results indicate that the filter ash melts at 1140°C with a total of 10 wt% of mass loss, with 4 wt% loss at below 700°C as shown in Fig 2. The initial mass loss observed at temperatures lower than 300 °C is due to the evaporation of water absorbed by the ash during the storing period. The peaks at 715 and 918 °C are due to the evaporation of alkali metals in the filter ash. Misra et al. [6] and Arvelakis et al. [4] pointed that the mass loss observed in the temperature range of 600 to 800 °C predominantly due to the decomposition of CaCO_3 and that beyond 850 °C is due to the decomposition of K_2CO_3 . No significant difference was observed in the melting behaviour of filter ash when using 7% peat admixture, as shown in Fig 1 and 2. Bottom ash sinter at 1170 °C and below 2 wt% of the mass loss is due to the evaporation or decomposition. The observed peak at 560 °C can be correlated to the loss of KCl present at the bottom ash. Similar trend was observed in the case of bottom ash with peat admixture to the fuel as shown in Fig 1 and 2.

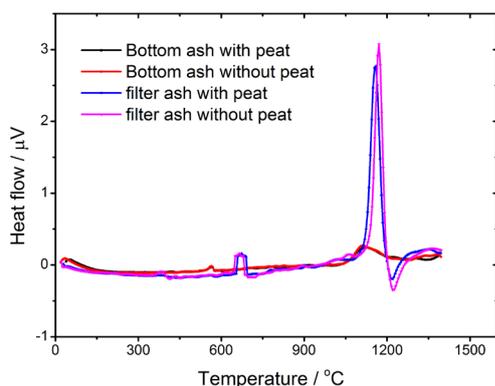


Figure 1: DTA analysis of bottom ash and filter ash (with and without 7% admixture of peat to the fuel).

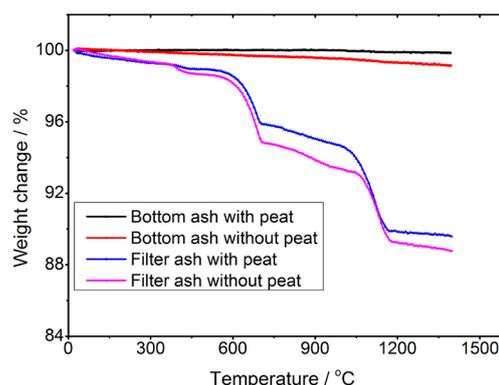


Figure 2: TG analysis of bottom ash and filter ash (with and without 7% admixture of peat to the fuel).

The agglomerated slag melted at 1180 °C indicating that the bed material react with the inorganic metals present in the woody biomass fuels. A mass loss of 2 wt% occurs between 1080 and 1170 °C as shown in Fig 3.

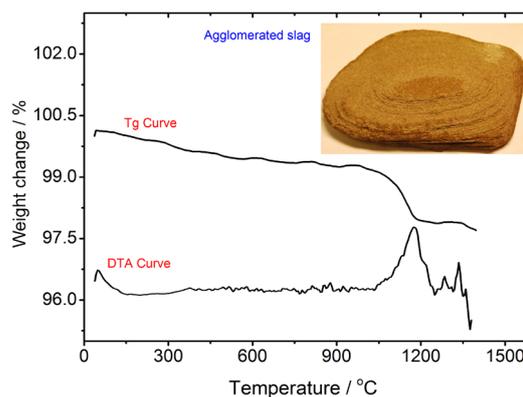


Figure 3: STA analysis of agglomerated slag.

The mass loss is due to the evaporation of KCl and/or decomposition of K_2CO_3 . Arvelakis et al [4] suggested that in the low- temperature melting ashes, potassium is more likely present as K_2SO_4 than as KCl and the residual potassium appears as K_2CO_3 . Quartz sand (used as a bed material) having melting temperature of c.a. 1700 °C does not melt at 1400 °C and no significant gas-phase release or other distinct phase change was observed. Furthermore, after the end of each DTA test, the sample was visually inspected, to define the final condition of the sample. The filter ash and agglomerated stone turn to be glassy material after the heat treatments while the bottom ash sinter but did not melt see Fig. 4.

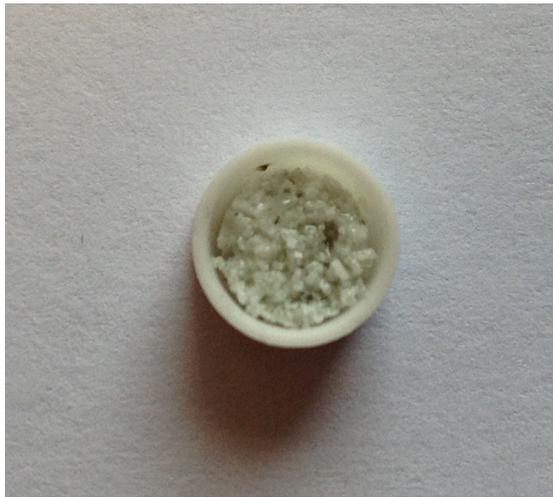


Figure 4: Image of the bottom ash after STA run at 1400 °C.

Preliminary elementary analysis via scanning electron microscopy, coupled with energy-dispersive X-ray analysis showed that the filter ash mainly consist of Ca (ca. 10 at%), K (ca. 6 at%), Na (ca. 4 at%), Si (ca. 12 at%), Al (ca. 6 at%), O (ca. 60 at%) and some small amount of Mg, S, P and Cl, as shown in fig 5. It was observed that the filter ash have very heterogeneous nature, exhibiting a wide variation in composition and morphology. No substantial difference in the chemical composition and morphology was observed in case of fly ash with 7% peat admixture.

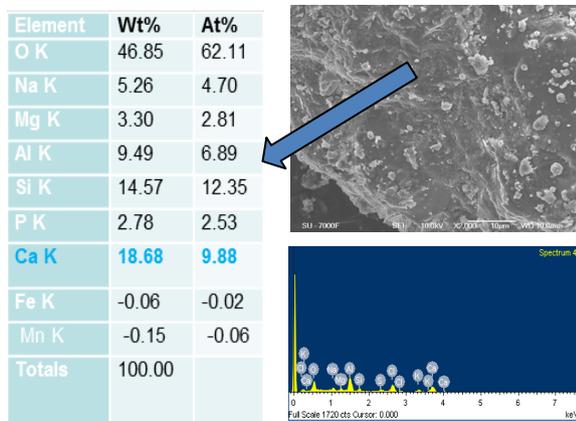


Figure 5: SEM Image with corresponding EDX analysis of the Filter ash without peat.

The bottom ash mostly consist of Si (ca. 13 at%), Al (ca. 5 at%), Ca (ca. 13 at%), K (ca. 3 at%), Mg (ca. 3 at%), O (ca. 63 at%) and some small amount of Na, S, P, Fe, Mn and Cl . No significant difference was observed with the addition of 7% peat. In general the bottom ash contain high amount of Ca and Mg and Low amount of Na and K compared with the filter ash. Furthermore, in our on-going work we are analysing the effects of increasing the peat addition to the bed material.

4. Conclusions.

No significant difference was observed in the melting behavior of the ash when using 7% peat admixture. The low melting point (c.a. 1140 °C) of the filter ash is due to the high concentration of the alkali elements.

Filter ash and agglomerated slag turn to be amorphous material after the STA run. Bottom ash containing mostly Si did not melt at 1400 °C. Wide variations in composition and morphology were observed for both filter ash and bottom ash. The EDX analysis showed that the filter ash contain high amount of alkali earth elements e.g. K compare to bottom ash.

5. Acknowledgements.

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6 REFERENCES

- [1] C. Yin, L.A. Rosendahl, S.K. Kaer Grate-firing of biomass for heat and power production, Prog Energy Combust, 34 (2008),pag.725.
- [2] B.M. Steenari, O. Lindqvist, High-temperature reactions of straw ash and the anti-sintering additives kaolin and dolomite, Biomass Bioenerg, 14 (1998), pag. 67.
- [3] B.M. Steenari, O. Lindqvist, V. Langer, Ash sintering and deposit formation in PFBC, Fuel, 77 (1998),pag .407.
- [4] S. Arvelakis, P.A. Jensen, M. Dam-Johansen, Simultaneous thermal analysis (STA) on ash from high-alkali biomass, Energ Fuel, 18 (2004),pag. 1066.
- [5] K. Lundholm, A. Nordin, M. Ohman, D. Bostrom, Reduced bed agglomeration by co-combustion biomass with peat fuels in a fluidized bed, Energ Fuel, 19 (2005),pag. 2273.
- [6] M.K. Misra, K.W. Ragland, A.J. Baker, Wood Ash Composition as a Function of Furnace Temperature, Biomass Bioenerg, 4 (1993), pag.103.