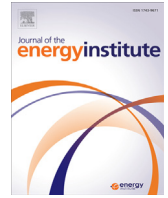




Contents lists available at ScienceDirect

Journal of the Energy Institute

journal homepage: <http://www.journals.elsevier.com/journal-of-the-energy-institute>

Ash deposition behavior under coal and wood co-firing conditions in a 300 kW downfired furnace

Q5 Hao Zhou^{*}, Weichen Ma, Jiakai Zhang, Yong Xu, Menghao Zhao

State Key Laboratory of Clean Energy Utilization, Institute for Thermal Power Engineering, Zhejiang University, Hangzhou 310027, People's Republic of China

ARTICLE INFO

Article history:

Received 18 January 2017

Received in revised form

16 May 2017

Accepted 22 May 2017

Available online xxx

Keywords:

Wood co-firing

Ash deposition

Fly ash

Online measurement

ABSTRACT

Growth of ash deposits when wood was co-fired with coal was visually investigated in a 300 kW pilot-scale furnace. For comparison, combustion of pure coal was also conducted. A total of 10% and 20% wood were mixed with coal. The thickness and heat flux were obtained. The collected ash deposits and fly ash were characterized by a series of analysis methods to determine the physical and mineral properties. Their relationships were also revealed. Results showed that co-firing of coal with wood dramatically increased the ash deposition propensity. During the coal combustion, shedding of ash deposit occurred and the maximum deposit thickness was 15.33 mm. A deposit thickness of up to 27.02 mm was achieved for 10% wood, and the thickness increased to 34.20 mm for 20% wood. The variation in heat flux with deposit thickness substantially changed when wood was co-fired. A significant change was also observed in the mineral composition of ash deposit with the increase in wood ratio. The proportion of anorthite increased because that of lime in fly ash increased with wood ratio. In addition, the mean diameter of fly ash particles increased as wood ratio increased.

© 2017 Energy Institute. Published by Elsevier Ltd. All rights reserved.

1. Introduction

As a promising solution to reducing CO₂ emissions, co-firing of coal and biomass in existing coal-fired boilers has been a hot topic in recent years [1–4]. However, problems regarding slagging, fouling, and corrosion increase owing to the high content of alkali metals and chlorine [5,6]. These problems can lead to reduced efficiencies of the combustion in boilers and limit the wide application of co-firing biomass. To mitigate the deposition problems, investigations on ash deposition mechanism of biomass co-firing have been conducted.

Wood is a typical biomass fuel used in utility boiler, and firing woody biomass generally produces less ash; however, the contents of alkaline and alkali earth metals, such as potassium and calcium, are high and lead to severe ash deposition [7]. Alkali transformation during the combustion of wood was studied and the role of potassium in deposit formation was determined previously. For wood, potassium is released mainly during char combustion [8]. Alkali/earth alkali-silicates with low melting point are formed and produce compact deposits [9]. CaSO₄ is formed by sulfation of Ca-containing particles and results in deposits to be sintered to a large extent [10]. Chlorine contained in wood promotes serious fouling deposits and corrosion [11]. Some investigations reported that combustion of wood can reduce the ash deposition propensity in comparison with other biomass fuels [12,13]. In these investigations, ash deposits were collected and analyzed after the combustion, and detailed growth process of ash deposits were not presented by experimental methods.

In the current study, an online measurement of ash deposits from co-firing using wood was proposed to present a complete process of ash deposit growth, thereby providing better understanding of ash deposition. In addition, the heat flux with time along the flow and side directions was obtained. The main objective was to evaluate the effects of wood blend ratio on ash deposition and reveal the relationships between the ash deposit and the fly ash. For this purpose, the physical and chemical characteristics of ash deposit and fly ash were analyzed by laser granularity analysis, scanning electron microscopy (SEM), X-ray fluorescence (XRF) spectrometry, and X-ray diffraction (XRD) spectrometry. Similar studies (online measurement of ash deposits during wood co-firing) have not been done at such a pilot-scale furnace.

^{*} Corresponding author. Fax: +86 571 8795161.

E-mail address: zhouhao@zju.edu.cn (H. Zhou).

2. Experimental

2.1. Test runs

Woody biomass was co-fired with coal in a 300 kW downfired furnace. The properties of the fuel including proximate analysis, ultimate analysis, and ash fusion temperature are listed in Table 1. To obtain the ash compositions, the coal and wood ashes were prepared according to Standards Australia 2000 [14] and then analyzed by XRF spectrometry. The results are also shown in Table 1. The coal ash had high aluminum and silicon contents of 31.484% and 42.746%, respectively. The calcium content in wood ash was as high as 62.924%. In addition, the content of potassium in wood ash (4.839%) was much higher than that in coal ash (0.451%). The wood and coal were pulverized and mixed prior to the experiment. The test rig in the experiment shown in Fig. 1 consisted of five systems: a fuel-feeding system, a pilot-scale furnace with a swirl burner, a charge-coupled device (CCD) monitoring system, an ash deposition probe, and a flue gas emission system. We previously conducted much research on ash deposition of coal on the same rig [15–17]. The fuel-feeding rate was regulated by adjusting the speed of the screw feeder. The furnace had a combustion chamber of 3950 mm height and 350 mm inner diameter. The furnace comprised four zones, namely, the first, second, third, and fourth stages, from the top to bottom.

The experimental conditions are listed in Table 2. The wood fractions in the blends were set to 0, 0.1, and 0.2 (by weight). The co-firing of coal with low ratios of wood fuels has been reported. However, the conclusions about the effects of wood on the behavior of ash deposition were inconsistent. Some studies reported a modest effect [18,19] whereas others presented opposite results [20,21] even at the same biomass ratio. The difference can be attributed to the striking difference in fuel properties of various woods. The current study aimed to investigate the influence of co-firing calcium-rich wood at a low range on the ash deposition. The deposition probe was inserted into the third-stage furnace when its temperature was stable at around 1350 °C. To simulate the water wall tube in actual condition, the probe was equipped with an oil-cooling system. The cooling oil circulated in the probe with an inlet temperature of 230 °C. A CCD camera was placed directly in front of the probe, and water was induced into the protective container to cool the monitoring system. Compressed air was also applied to protect the lens from the ash.

2.2. Measurement principle of deposit thickness and heat flux

The schematic of the deposition probe is shown in Fig. 1b. The diameter of the probe head was 40 mm, and the thickness was obtained on the basis of the relative scale. As shown in Fig. 2, the original image was first converted to a binary image. Then, the edges of the probe and ash deposit were extracted and the center of the head face of the probe was located. The pixels corresponding to the probe radius and the distance between the center and the surface of ash deposit were numbered (denoted as P_r and P_h). Finally, the thickness of ash deposit was calculated using the following equation:

$$T = \left(\frac{P_h}{P_r} - 1 \right) \times r, \quad (1)$$

where T is the thickness of ash deposit (mm); r is the radius of the probe with a value of 20 mm.

Table 1
Fuel properties.

Fuel	Coal	Wood
Moisture, (wt%, ar)	8.30	14.75
Proximate analysis, (wt%, db)		
Volatile matter	26.92	65.41
Fixed carbon	45.82	18.22
Ash	27.25	1.62
Ultimate analysis, (wt%, daf)		
Carbon	80.38	56.91
Hydrogen	5.46	5.23
Nitrogen	1.24	1.34
Sulfur	0.95	0.12
Oxygen	11.96	36.52
HHV (MJ/kg)	20.6	17.6
Ash fusion temperature, (°C)		
IT	1450	1483
ST	>1500	>1500
HT	>1500	>1500
FT	>1500	>1500
Ash analysis (wt% ash)		
Al ₂ O ₃	31.484	1.827
CaO	2.997	62.924
Fe ₂ O ₃	4.041	1.19
K ₂ O	0.451	4.839
MgO	0.34	4.198
MnO ₂	0.026	0.181
TiO ₂	0.985	0.223
Na ₂ O	0.231	0.384
P ₂ O ₅	0.273	1.076
SiO ₂	42.746	4.038
SO ₃	0.756	1.704

Download English Version:

<https://daneshyari.com/en/article/8955762>

Download Persian Version:

<https://daneshyari.com/article/8955762>

[Daneshyari.com](https://daneshyari.com)