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Research on the slagging characteristics of easy to slagging coal in a pilot scale furnace

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HIGHLIGHTS

- Digital image technique was used to monitor the morphology of the ash deposits growth on-line.
- The change in thickness of ash deposit with time was obtained through digital image technique.
- Layer structure of deposit, the stage of ash deposit growth, and heat flux versus deposit thickness were analyzed.
- Mineralogy, chemical compositions, and microstructure of layer structure of deposit were analyzed.

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ABSTRACT

Digital image technique was applied to monitor the slagging characteristics of easy to slagging (ES) coal in a pilot scale furnace. Mineral of the ash deposit was analyzed by X-ray diffraction (XRD), chemical composition and microstructure of the ash deposit were analyzed by scanning electron microscopy (SEM) equipped with energy dispersive X-ray spectrometry (EDX), respectively. The ash deposition growth rates detected by the digital image technique in the 4 stages were 0.036, 0.169, 0.039, and 0 mm/min, respectively. The stable thickness of the deposit is 8.2–8.3 mm. The ratio of heat flux reduction to thickness increment were 441.38, 39.45, 23.44, and 0 kw/(m^2 mm) for stages 1, 2, 3, and 4, respectively, which indicated that the initial layer of the deposit had the lowest thermal conductivity.

The analysis results of XRD showed that the initial layer (stage 1) was abundant in anorthite and quartz and scarce in mullite and soda-melilite. The components of the layer in stage 2 were similar to those of stage 1 except that no soda-melilite was included in stage 2. Nevertheless, the slag layer corresponding to stage 3 contained only quartz and sodium anorthite. Moreover, the content of mineral phases in the deposit decreased along the deposit growth direction.

1. Introduction

Coal fired power plants remains the major electrical power sources in the next decades in China due to abundant reserves of coal. Coal characteristic influenced the overall performance of the utility including requirements of waste treatment, capacity of electricity production, breakdown of equipment, and in general it affected the environment [1]. Ash depositing on heat-transfer surfaces is one of the most serious influence of coal. It not only leads to the reduction of thermal conductivity of heat-exchanger, but also causes the corrosion of boiler tubes, resulting in reduced electricity production capacity, unscheduled outages and subsequent decreases in the availability of system and increases in the cost of the generated electricity [2–6].

Ash deposition phenomena can be influenced by many physical and chemical processes, such as, chemical composition of ash, distribution of mineral matter in ash, ash fusion temperature, temperature of furnace, temperature of ash particle, surface temperature of heat-exchanger tubes, materials of tube, the flow field in the furnace, and ash transport mechanisms [7].

Inorganic constituents of coal can be transported into fly ash during combustion. According to Zbogar et al. [8], ash species deposit on boiler tubes from the flue gas mainly through three transport mechanisms, for instance, inertial impaction, diffusion, thermophoresis. Rushdi et al. [9] indicated that inertial impaction and turbulent diffusion are the main transport mechanisms for large particles to deposit on heat-transfer surfaces, while for fine particles, they are controlled by Brownian motion and thermophoretic foreces.

In recent years, many researches had carried out investigations of the characteristics of ash deposits in both theoretical and experimental fields. For theoretical research, they either proposed 2D modeling of deposit formation, or incorporated a deposition model into a comprehensive combustion code [2,10–14]. Nevertheless, it was difficult to accurately simulate the ash deposit growth process

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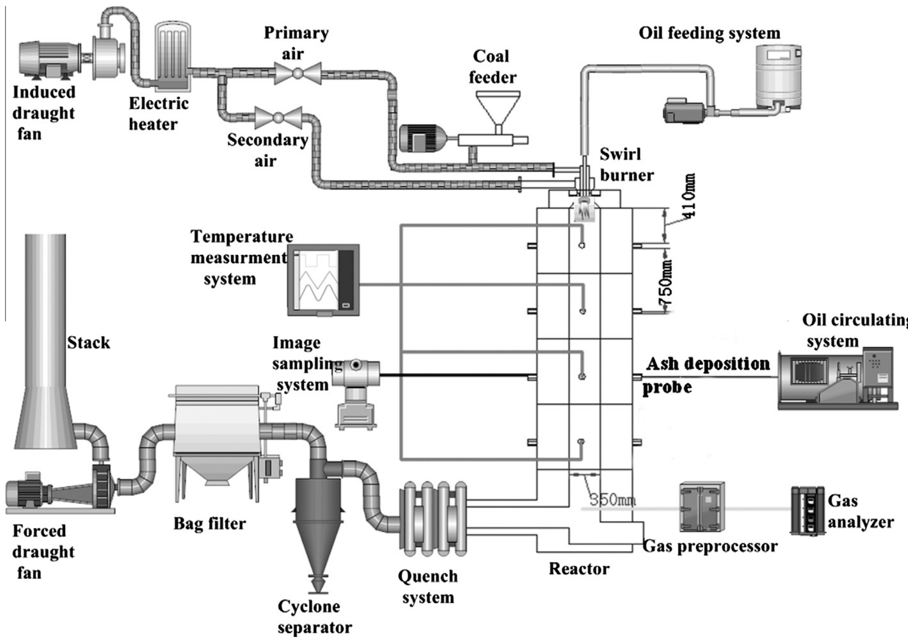

Fig. 1. Schematic diagram of the pulverized coal combustion furnace.

Table 1
Experimental conditions.

Coal sample	ES
Thermal load (kW)	350
Excess air ratio	1.2
Gas velocity (m/s)	~2.8
Average furnace temperature around ash deposition probe (°C)	~1250
Maximum temperature in furnace (°C)	~1310
Oxygen concentration at the furnace outlet (%)	4.0–5.0
Exposure time for ash deposition (min)	180

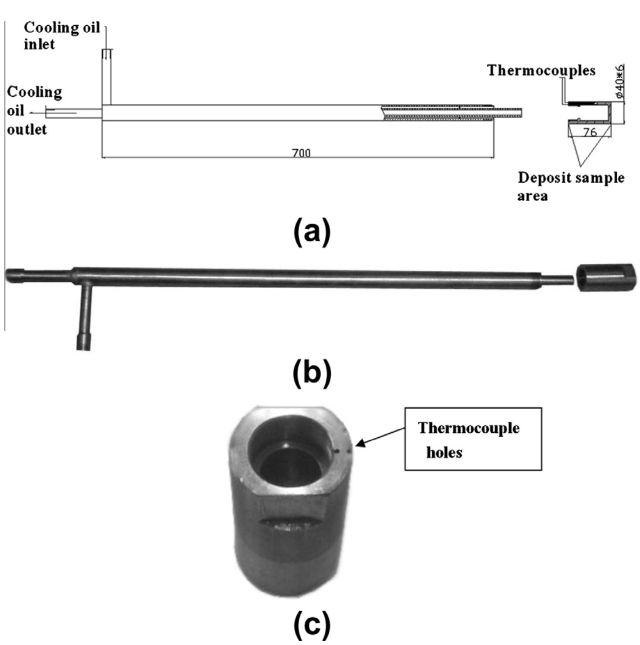

Fig. 2. (a) Schematic diagram of deposition probe. (b) Deposition probe detail. (c) Deposition sampling part detail.

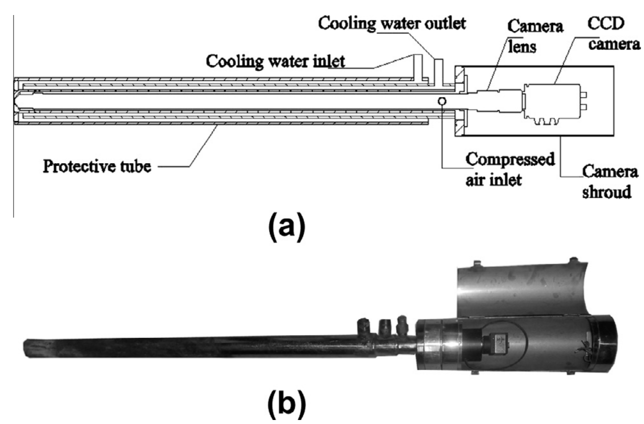

Fig. 3. (a) CCD monitoring system. (b) CCD monitoring system detail.

due to numerous physical and chemical processes involved. For experimental studies, most of them used air/water-cooled probe to investigate the slagging characteristic [15–20]. In addition, the growth of ash deposit was measured by online weighing technique [21]. Even so, as to studies on online observation of the morphology of the ash deposit growth and quantifying the deposits with the development of digital image technique, such as Charge Coupled Device (CCD) are scare.

The aim of present work is to investigate the slagging characteristic of the ES coal in pilot scale furnace through digital image technique. Moreover, XRD and SEM–EDX were applied to analyze mineralogy, chemical composition, and microstructure of ash deposits, which would provide valuable information for explaining the mechanism of the deposit formation.

2. Experimental

2.1. Combustion facility

The pilot scale slagging test was performed on the pulverized coal combustion furnace, as shown in Fig. 1. It was principally composed of the vertical furnace, coal feeder, swirl burner, temperature