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Mineralogical and elemental composition of fly ash from pilot scale fluidised bed combustion of lignite, bituminous coal, wood chips and their blends

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Abstract

The chemical and mineralogical composition of fly ash samples collected from different parts of a laboratory and a pilot scale CFB facility has been investigated. The fabric filter and the second cyclone of the two facilities were chosen as sampling points. The fuels used were Greek lignite (from the Florina basin), Polish coal and wood chips. Characterization of the fly ash samples was conducted by means of X-ray fluorescence (XRF), inductive coupled plasma-optical emission spectrometry (ICP-OES), thermogravimetric analysis (TGA), particle size distribution (PSD) and X-ray diffraction (XRD). According to the chemical analyses the produced fly ashes are rich in CaO. Moreover, SiO_2 is the dominant oxide in fly ash with Al_2O_3 and Fe_2O_3 found in considerable quantities. Results obtained by XRD showed that the major mineral phase of fly ash is quartz, while other mineral phases that are occurred are maghemite, hematite, periclase, rutile, gehlenite and anhydrite. The ICP-OES analysis showed rather low levels of trace elements, especially for As and Cr, in many of the ashes included in this study compared to coal ash from fluidised bed combustion in general.

Keywords: CFB fly ash; Bituminous coal; Wood chips; Lignite

1. Introduction

Despite the fact that combustion of solid fuels using conventional combustion technologies is and will probably continue to be an important part of the heat and power generation systems, combustion of solid fuels applying more environmental friendly technologies, such as the circulated fluidised bed (CFB) technology, continuously gains ground. Moreover, this technology has another important advantage in comparison with the conventional technologies; it is able to burn low quality fuels, such as lignite, alternative fuels such as biomass (wood chips) as well as blends of these fuels.

Fly ash can be either an industrial waste material and ecological nuisance, or a valuable raw material. For the latter purpose, its properties need to be defined precisely and controlled so that a uniform and reproducible material can be supplied. This paper describes a comprehensive study of some fly ash samples, with the intention of elucidating their chemical, physical, mineralogical and technical properties as an incentive to their utilization.

A result of the continuous development of the CFB technologies is that the amounts of combustion by-products such as fly ash are steadily increasing [1]. This material has found limited applications in the cement and concrete industry and in land reclamation and restoration.

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The characteristics of fly ash such as type of particles, size distribution and chemical composition are of paramount importance with a view to their potential applications. Fly ash particles may differ, depending on the mineral matter content of the coal and on the way the combustion process is conducted [2].

2. Materials and analytical methods

2.1. Sampling

The fly ash samples examined were produced from the combustion of different solid fuels in laboratory and pilot scale CFB boilers. Investigation has been accomplished through XRF, PSD, XRD and ICP.

The combustion experiments were carried out at the 50 kW lab scale boiler of VTT Technical Research Centre of Finland, and the 12 MW pilot scale boiler of the Chalmers University of Technology (CUT) in Sweden. The experimental facilities are following the flow chart as presented in Fig. 1.

2.2. Analytical methods

The experiment was carried out using Greek lignite, a Polish bituminous coal and wood chips from Swedish conifers, and various blends of these three feeds.

Combustion was accomplished at a temperature of 900 °C in both facilities without the use of limestone.

The proximate and ultimate analyses of the used fuels, as well as their heating values are presented in Table 1.

Table 1
Average characteristics and energy contents of the feed fuels

Parameter	Polish bituminous coal	Greek lignite	Wood chips
Proximate analysis (wt% dry basis)			
Moisture	1.9	36.5	4.6
Volatiles	29.33	41.67	80.10
Ash	12.96	38.36	1.14
Fixed carbon	57.71	19.97	18.76
Ultimate analysis (wt% dry basis)			
Carbon	68.42	32.29	48.77
Hydrogen	3.91	3.42	5.85
Nitrogen	1.32	1.33	0.45
Oxygen	12.69	17.96	43.79
Sulphur	0.7	1.64	0
Gross heating value d.b. (kJ/kg)	29,171	17,887	25,154
Net heating value d.b. (kJ/kg)	28,330	17,150	23,899

During the above mentioned experiments, fly ash samples from the same part of each facility (the fabric filter and the second cyclone) were collected. These samples, the feed fuels combusted and the sampling point are stated in Table 2.

2.2.1. Bulk chemical analysis

The major elements of the solid residues were determined with a Spectro X-Lab 2000 Energy Dispersive X-ray fluorescence (XRF) spectrometer applying the samples in a pressed powder form.

Loss-on-ignition (LOI) tests were performed as follows: moisture, volatile matter, ash and fixed carbon measure-

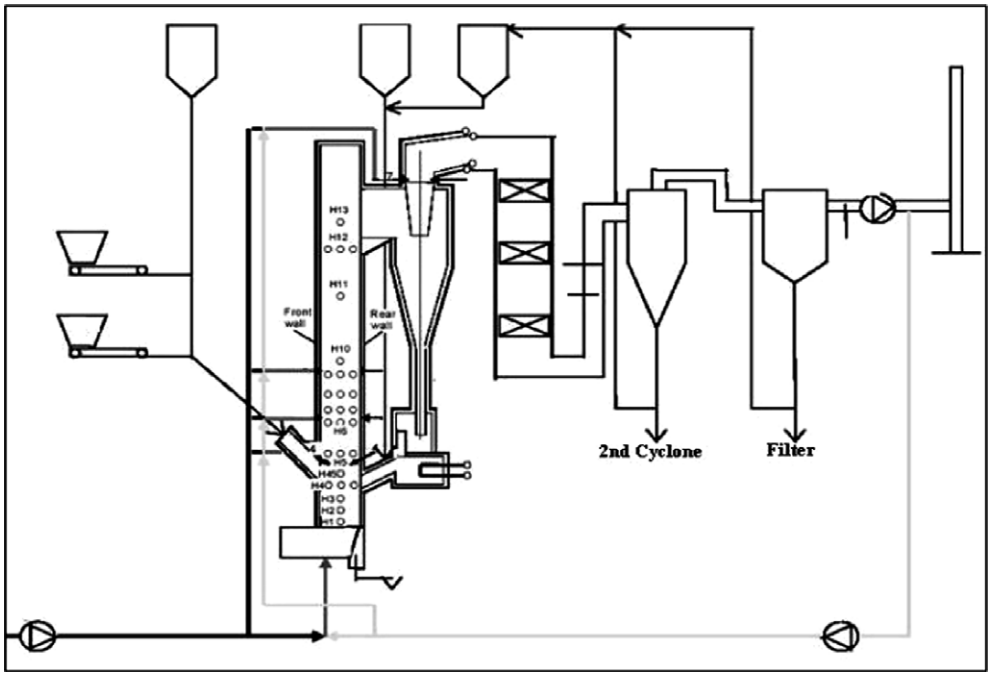

Fig. 1. Schematic diagram of the fluidised bed set-up.