Characterisation of Pulverised Coal and Biomass Co-firing on a 3MW$_{th}$ Combustion Test Facility Using Flame Imaging and Gas/Ash Sampling Techniques

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Experimental investigation into the co-firing of pulverised coal with biomass on a 3MW$_{th}$ Combustion Test Facility has been conducted. A variety of combustion parameters including flame temperature, gas species within the flame and fly ash in flue gas, were measured using flame imaging and gas/ash sampling techniques under a range of co-firing conditions. The results suggest that, due to the varying physical and chemical properties of the biomass, the biomass additions have impact on the combustion characteristics such as increased temperature, improved flame stability and higher level of char burnout.

Introduction

Co-firing of biomass with coal at existing coal-fired power plant has been widely adopted as one of the main technologies for reducing CO_2 emissions. However, biomass has very different physical and chemical properties from coal. The uncertainty of the fuel properties and co-firing conditions has resulted in a range of combustion problems including flame stability, low thermal efficiency, high levels of unburned carbon and other pollutant emissions, fouling and corrosion of the furnace [1-3]. To achieve efficient operation of co-firing power plant it is vitally important to develop the knowledge and in-depth understanding of the characteristics of co-firing biomass and coal under a wide range of combustion conditions.

As part of European Interreg IIIa project-Combustion Optimisation through Advanced Modelling and Measurements, research work on the characterisation of the co-firing biomass and coal has been carried out on a 3MW$_{th}$ Combustion Test Facility (CTF). The characteristic parameters of the combustion are measured using flame imaging and gas/ash sampling techniques. The correlations between the measured parameters and corresponding combustion conditions are investigated.

Methodology

The temperature of solid particles within the flame (such as coal particles, char, soot etc.) was measured using the flame imaging system developed by the University of Kent [4, 5]. The system, working on the two-colour pyrometry, is capable of providing the two-dimensional temperature distribution of the flame, along with other characteristic parameters including the oscillation frequency, brightness, size and shape of the flame. In this study, the optical probe/camera of the system was installed at a view spot of the furnace sidewall close to the burner (Fig. 1) so whole root of the flame is visualised.

The gas phase temperature of the flame zone was also measured using a suction thermocouple probe. There are total of 18 measurement points along the two lines across the flame zone, as shown in Fig. 1.

In addition, online analysis of gaseous products was carried out throughout the tests. Concentrations of O_2, CO, CO_2, NO and SO_2 were measured within in the flame and in the flue gas based on the diamagnetism (for O_2) and the IR absorption method (for CO, CO_2, NO and SO_2).

Experimental

Extensive tests were carried out on the 3MW$_{th}$ CTF. The CTF is a pilot pulverized fuel fired furnace, having a cylindrical water-cooled combustion chamber fitted horizontally with a low-NO$_x$ burner. Fig. 1 also shows the scheme structure of the burner. The secondary and tertiary air is preheated up to 400°C to ensure a stable combustion.

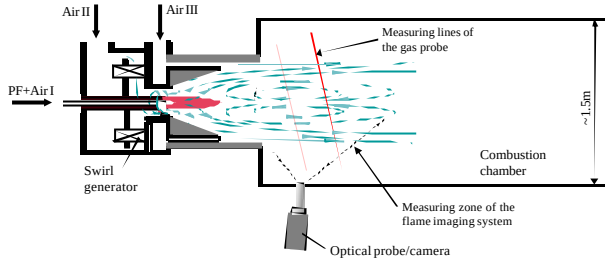

Fig. 1. Structure of the burner and the locations of the flame imaging sensor and temperature probe

A South African coal (Middelburg) was used as primary fuel. It contains 25% of VM and 14.6% of ash. The biomass tested was pelletized sawdust which was a mixture of 80% oak wood and 20% pinewood and contains 89% of VM, 4.5% of ash and 3.8% of moisture The biomass was blended with the coarse coal lump before fed into the pulverising mill for four different portions, i.e., 5%, 10%, 15% and 20% of the biomass (by weight, equivalent to 3.6%, 7.6%, 12% and 17% of biomass by heating value basis).

Results

Fig. 2 shows the typical example of flame temperature profiles for the 20% biomass co-firing test. It has been found that the flame for all co-firing tests was more stretched in the comparison to the neat coal flame but this may also be attributed by an increased swirl number of the burner.

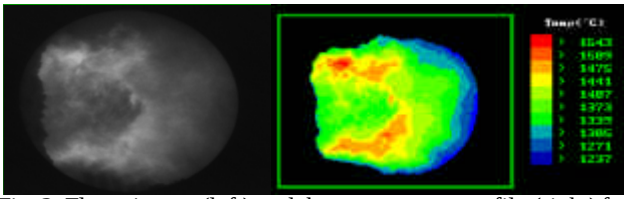

Fig. 2. Flame image (left) and the temperature profile (right) for co-firing coal with 20% biomass

Table 1 summarises the concentrations of the inert matter in the fly ash which were obtained from the fly ash collected from the flue section of the furnace. The results have revealed that the co-firing biomass and coal results in less unburned carbon in the ash. In addition, sulphur content in the ash and emissions is significantly reduced in all co-firing cases.

Severe slagging and fouling were also observed during the co-firing tests as a thick layer of white ash deposited on the probe shield surface, probably due to high calcium content of the biomass.

Table 1 Char burnout

PF Sample	Inert matter in the fly ash (%)
Neat coal	65.7
5% biomass	70.8
10% biomass	71.6
15% biomass	83.2
20% biomass	87.2

Conclusions

Experimental investigations into the co-firing of pulverised coal with different biomass additions have been conducted on a 3MW$_{th}$ CTF. The results have suggested that the biomass addition (up to 20%) to the coal tested does not affect significantly flame temperature. It has also been found that, in general, a certain amount of woody biomass addition to coal would improve the combustion efficiency as the results of lower CO concentrations and higher char burnout level demonstrate. However, severe ash slagging and fouling were observed during the co-firing tests. Their impact on the corrosion and thermal efficiency of the furnace was not yet estimated due to the short duration of the tests.

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