Monitoring of Alkali Chlorides Concentration in Biomass Combustion through Flame Spectral Analysis- A Feasibility Study

(1st Feb - 31st March 2013)
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Following the award of the Faculty Science, the investigation into the feasibility of measuring alkali chlorides concentration in biomass combustion through flame spectral analysis has been carried out. The objectives of the project were (1) to investigate the spectral characteristics of metal radicals Na and K in flames and their relationships to the properties of biomass fuels being used, and (2) to investigate suitable computing algorithms for determining the concentrations of alkali chlorides (KCl and NaCl) in the flue gas using the spectral characteristics of Na and K (intensity, etc) of the flame.

Under the current fund, a part-time Research Assistant (Mr Md M Hossain) was appointed from 1st Feb to 31st March 2013. The project started with a literature survey followed by experiments on a gas-fired combustion rig in the EDA Instrumentation Lab. A Bunsen-type burner with an outlet diameter of 11 mm was used to generate a flame in a cylindrical chamber (150 mm inner diameter and 300 mm high) (Figure 1). Propane was used as the primary fuel, and flour was used as biomass fuel. Biomass (flour) was pneumatically conveyed to the burner using a turntable feeder. Two test conditions (i.e., a small biomass addition and large biomass addition) were created by varying the rotational speed of the feeder [1]. A total of 25 data of the four flame radicals were captured simultaneously using a high resolution UV-Visible spectrometer (USB2000+UV-Vis, Ocean Optics).

Figure 2 shows the spectroscopic profiles of propane-flour flames. Two dominant peaks of the propane-flour flame radiation are observed consistently in the spectroscopic profiles [i.e., figure 2(b) and 2(c)] in comparison to that of the diffusion flame [figure 2(c)]. It has been identified that these discontinuous spectra are attributed to free radicals Sodium (Na, 590.8nm) and Potassium (K, 766.6nm). When the fuel reacts with oxygen at high temperature, these free radicals are produced in excited electronic states, showing as strong emissions spectral bands [2]. It is also evident that the magnitude of the peaks increases with the biomass addition, i.e., a smaller addition results in a smaller magnitude whilst a larger addition results in a greater magnitude of the peak. It is also clear that Potassium gives a stronger peak than of Sodium. This is because flour has more Potassium and less Sodium as shown in table 1. With a suitable calibration, it is possible to quantify the relationship between the magnitude of the peak and the concentration of the corresponding metal species (Na and K) in the flame. The concentrations of alkali chlorides (KCl and NaCl) in the flue gas can then be predicated using the spectral characteristics of Na and K of the flame. These are very encouraging results which has proven the possibility of predicting concentrations of alkali chlorides in combustion flue gas using flame radical data.
The preliminary results obtained from this investigation have led to further research included in the EPSRC Fellowship Grant Application ‘Measurement, Characterisation and Modelling of Biomass Particle Flow and Biomass Fired Flames’ which is supported by Drax Power Station, and RWE npower and has been submitted to the EPSRC in March 2013 [3]. The research fund has also allowed Dr G Lu to attend and give a presentation (Measurement of Particulate Emissions through Electrostatic Sensing and Digital Imaging) at the Coal Research Forum 24th Annual Meeting and Meeting of the Environment Division on the 10th of April 2013 in Cranfield University [4].

In a review of the outcomes of the research, it is evident that the most measurable outputs set in the proposal have been met. Future work will focus on establishing the relationship between the magnitude of the peak and the concentration of the corresponding metal species (Na and K) in the flame, and thus the concentrations of alkali chlorides (KCl and NaCl) in the flue gas.

References

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