Abstract:

One efficient, cost effective and increasing popular option for decarbonisation of existing coal fired power plant is the introduction of carbon neutral biomass fuels to the combustion process either in co-firing with coal or 100% conversion of coal fired boiler to biomass firing. In an effort to ensure efficient, economic, safe and environmentally sustainable utilisation of a wider range of biomass fuels in large scale combustion applications the reported experimental programme aims to gain a fuller understanding of their devolatilisation and char combustion properties within pulverised fuel (PF) firing systems. As such this investigation has concentrated on the derivation of an easily implementable classification system for lignocellulosic biomass able to predict their combustion performance given basic understanding of their physiochemical composition.

A range of commercially available biomass fuels (pine chips, miscanthus pellets, eucalyptus pellets, corn stover, wheat straw pellets, thermally treated mixed wood pellets, DDGS and 3 pine samples having undergone differing degrees of torrefaction) have been analysed alongside chemically delignified and demineralised analogues. Samples were first characterised as to their standard physical/chemical compositions - assessing chemical makeup (ultimate and inorganic mineral composition), structural composition (aromatic/aliphatic carbon content by Solid State $^{13}$C CP-MAS NMR) and physical properties (proximate composition). The combustion performance of the fuels was then assessed using both standard slow heating techniques (thermogravimetric analysis (TGA)) and under simulated PF firing conditions using an entrained flow Drop Tube Furnace (DTF). DTF devolatilisation was conducted under an inert (N$_2$) atmosphere with temperatures from 900 to 1300$^\circ$C and residence times of up to 600 ms. A synthetic ash (silica) tracer method being utilised to account for mineral vapourisation and provide accurate volatile matter yields. The inherent reactivity (activation energy, pre-exponential function, rate constants and 90% burnout times) of chars thus produced were determined under isothermal combustion conditions using TGA.

Both aromatic carbon and alkali/alkaline earth mineral contents were observed to have a dramatic influence on DTF volatile matter yields and char combustion parameters for all fuels. The volatile content of de-mineralised samples showed strong linear correlation ($R^2=0.98$) with aromatic carbon content, alkali/alkaline earth metal species acting to strongly catalyse char production and subsequent oxidation reactions. A global correlation able to predict volatile content and char burnout properties given appreciation of fuel aromatic/aliphatic carbon and inorganic mineral composition has been proposed. Such a system will provide utilities with an intuitive tool able to predict combustion performance of biomass fuels given their simple chemical characterisation.

Keywords: biomass characterisation, devolatilisation, char combustion, drop tube furnace

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