CARBON REDUCTION IN FLYASH USING MICROWAVES

Chris Dodds*[1], Ed Lester[1], Sam Kingman[1], Steven Bradshaw[2]

[1] - School of Chemical Environmental and Mining Engineering, University of Nottingham, Nottingham, NG7 2RD.
[2]- Unit for High Temperature Materials Processing, Department of Process Engineering, University of Stellenbosch, Private Bag X1, Matieland, 7602, Stellenbosch, South Africa.

The ratio of furnace bottom ash (FBA) to flyash produced in a coal-fired boiler was historically around 25:75 with utility boilers operating with an unstaged combustion regime. With the advent of low NOx burner systems this ratio has changed and is now 15:85 or even lower. This is unfortunate since the demand for FBA is high, with 100% of is sold to the construction industry, whereas only 50% of flyash is used. Currently 6 million tonnes of flyash is produced annually in the UK alone. *There is currently 250 million tonnes of flyash stockpiled with no foreseeable use*. Carbon content in flyash can dictate its potential saleability with the potential market for flyash with a carbon content greater than 5% being relatively poor. Needless to say, the carbon is present in flyash as a result of incomplete burnout in the boiler and the low NOx burners (that produce more flyash relative to FBA) operate at lower temperatures than other systems, which inevitably leads to higher carbon levels in ash. Burnout efficiency also relates to many factors such as grind size, residence time in the boiler, coal type and boiler conditions. Regardless of the causes of carbon in ash, its removal will increase the value of the flyash as an ash product.

The use of microwaves to remove carbon from flyash is ideal, in that the carbon responds rapidly to microwave heating whilst the ash remains relatively transparent at lower temperatures. This has been shown by measuring the dielectric properties of concentrated carbon and pure ash samples. The ash in flyash has a loss factor (e'') of around 0.05, which is particularly low when compared with the pure carbon from the flyash at around 5. The carbon is therefore an excellent candidate for rapid heating in microwaves. Under conventional heating the flyash is a bulk powder with low thermal conductivity thus heating costs are high. Microwave heating is a far more efficient way of raising the temperature as only the carbon needs heating and only the carbon particles are responsive to microwaves. The reason for carbon being such a responsive material relates to its chemical structure. Preliminary tests carried at Nottingham have shown that the 'ordering' of the carbon, in terms of aromatic to aliphatic structuring, increases its response to microwaves. The carbon in flyash has been 'graphitised' during combustion in the boiler (at temperatures in excess of 1500^{o}C), and therefore has a more ordered structure than that of its parent coal. This ordering leads to a high response to microwaves and a rapid heating rate. A notable increase in loss factor was seen when comparing the coal with the intermediate char and the final flyash char.

The project has focussed on two main areas. Firstly, characterisation of a range of different flyash samples produced from different world coals. Secondly, microwave processing of each flyash to reduce carbon content.

The chars were characterised using several different techniques to determine the variability in the size distribution of the carbon particles and also the physical and chemical characteristics of the carbon.

Scanning electron microscopy provided a non destructive means of qualitative analysis of the flyash. The association of carbon and ash in each flyash was found to be extremely variable. Coals with a high level of inherent ash, such as South African coals, tend to produce char particles with a higher level of ash. The effect of varying degrees of inherent ash was linked to heating rates in batch experiments.

Oil immersion microscopy was used for quantitative and qualitative analysis of section char material to verify char thickness and morphology. Since certain coals produce cenospheres (round hollow carbonaceous shell) rather than thicker walled networks or unfused dense char particles, it has been important to show the relationship between char morphology and heating characteristics, especially since the system is designed to remove carbon from any flyash regardless of origin. Char type is important from a microwave heating point of view as it dictates the minimum residence time for combustion to occur.

Combustion kinetics were determined across a range of temperatures for each flyash using a thermogravimetric analyser. Two sets of experiments were carried out to look at how various size fractions within the flyash. Non-isothermal tests were used to determine char reactivity (ignition and final burnout temperature). Isothermal tests were used to determine burnout times at a range of temperatures between 400^{o}C and 1000^{o}C. These thinner walled, high porous chars were found to have a much smaller burnout time especially at higher temperatures. The data from these experiments helped in the final cavity design for larger scale experiments.

Dielectric properties of flyash material at various frequencies and with increasing temperature were determined using the cavity perturbation technique. The data was used as an input to the numerical simulation and design of a microwave heated fluidised bed system which is presented within this paper. The paper discusses the use of such a system for carbon removal from flyash materials.

As would be expected there is a clear relationship between fluid bed residence time and the type of carbon removed with more resistant, thicker walled carbons being more likely to exist in the final product. With sufficient residence time and oxygen supply almost all carbon was removed from the feed material.

It was also found that microwave power could be significantly reduced after a certain heating time. This was obviously due to the exothermic nature of carbon oxidation. Control strategies are suggested to meet this requirement industrially.

The paper concludes with a preliminary techno economic analysis of carbon removal from flyash using microwave energy compared to other techniques such as froth flotation, tribo-electric separation and traditional electrostatic precipitation.