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EVALUATION OF CSC CHARCOAL FOR PRODUCTION OF DRY COMBUSTION PLASMA

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Abstract

Evaluation of CSC charcoal by standard thermoanalytical techniques shows that the dry material contains ≤99% carbon having calorific value of about 16.32 mJ/kg; its hydrogen and ash contents are insignificant. On admixture with small amount of K_2CO_3 (seed for generation of combustion plasma) its combustion characteristics remain more or less unaltered though the combustion rates are greatly enhanced.

Keywords: calorific value, combustion plasma, CSC charcoal

Introduction

Combustion plasma produced from coal and natural or petroleum gases, hitherto employed in magnetohydrodynamic (MHD) experimental ensemblies, contains large amount of H_2O. The molar proportions of CO_2/H_2O in the combustion products of coal is generally $\lesssim 2$ while with the gases it is invariably <1. The water vapour is only a diluent of the plasma which is quite detrimental as regards its electrical conductivity since the OH radical, generated therefrom at high temperature, is a strong electron scavenger which substantially reduces the electron density and hence the conductivity of the plasma. These problems can be easily overcome, as proposed by George [1], by employing dry combustion plasma (DCP).

The prime criterion in the selection of fuel for production of DCP is that its hydrogen and water contents will be very low so that on burning, H_2O formed in the combustion products will be $\ll$10%, remaining as an impurity, and not form a major component of the combustion products.

A typical variety of charcoal, designated as CSC, obtained from agricultural wastes, is found to fairly meet the above criterion. Detailed analyses of CSC and its mixtures with potassium carbonate, employing TG, DTG, DSC, EGA and X-ray powder diffraction techniques are discussed here.

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Experimental

The lumpy charcoal after drying in an air oven was ground and sieved to 200 mesh. While preparing mixtures of the CSC with potassium carbonate required amounts of the freshly dried components were weighed, ground together and sieved to 200 mesh.

Thermogravimetric (TG) and differential thermogravimetric (DTG) analyses of the samples were carried out in air on a Mettler TGA-50 thermobalance while enthalpy measurements were done on the Mettler DSC-30 differential scanning calorimeter, also in air. The calorimeter was calibrated against heat of fusion of indium 6.80 cal g^{-1} and melting point of 429.6 K.

Hydrogen and water in the charcoal were determined using the quadrapole mass spectrometer effusion gas analyser (EGA) coupled to the Netzsch Thermal Analyser STA409 under flowing argon. X-ray powder diffraction was recorded between 20 span of 15° and 60° on a Philips wide angle goniometer using Ni-filtered CuK_{α} radiation.

Results and discussion

Typical results of TG and DTG analyses of CSC carried out upto 900 K are shown in Fig. 1. After loss of moisture combustion of CSC begins at about 575 K which is complete at around 835 K; the total mass loss observed being >99%. The normalised DTG plots of the CSC and its mixtures containing 2(CSC2) and 5(CSC5) wt% of K_2CO_3 are given in Fig. 2. The details of the observed weight losses of the samples are given in Table 1. From the data it is seen that the ash content of dry CSC is ≲1 wt%. The increase in the water content of CSC2, particularly due to moisture absorption by the hygroscopic potassium carbonate is only nominal while that of CSC5 is quite substantial. However the water is only loosely bound and more than 90% of which is lost below 373 K. As seen in the figure no major change in the mechanism of combustion of CSC is brought about by potassium carbonate, though the onset of burning and its rates are somewhat enhanced and combustion of both mixtures is complete at about 765 K. From the

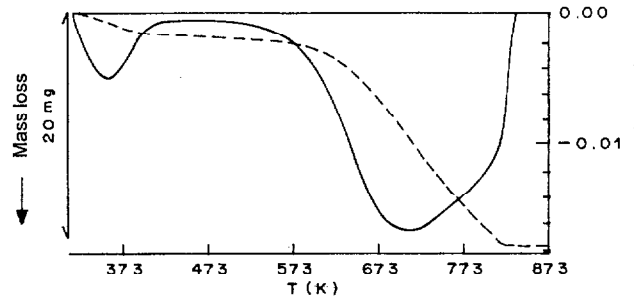

Fig. 1 Typical TG and DTG plots of CSC in air, heating rate 10 K min^{-1}

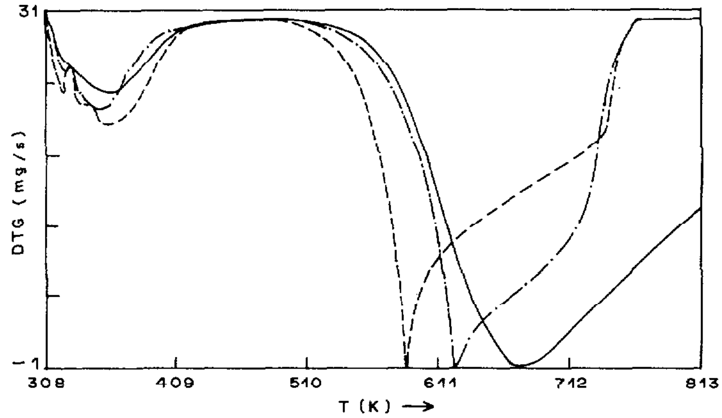

Fig. 2 Normalised DTG plots of CSC and its mixtures with potassium carbonate in air: —— CSC, –·–·– CSC2, and – – – – CSC5 (heating rate 10 K min^{-1})

Table 1 Data of mass losses of CSC and its mixtures with potassium carbonate

Sample	Moisture loss/	Combustion loss/	Total loss/
		wt.%	
CSC	10.11	88.99	99.10
CSC2	10.64	87.20	97.84
CSC5	12.43	83.16	95.59

mass losses of CSC2 and CSC5 it appears that their residue after the burning contains most of the K_2O along with the ash.

The normalised DSC plots of CSC, CSC2 and CSC5 are shown in Fig. 3. Upto about 550 K the heat capacities of both the mixtures are nearly same and are substantially higher than that of CSC (and hence seen to be more endothermic in the figure). This could be due to the potassium carbonate in the samples which has a higher heat capacity [2]. The calorific value of CSC was calculated from the area of its DSC plot relative to the heat of fusion of indium; the value of 16.32 mJ/kg is only about half the value reported for standard coal [3]. This is understandable since the hydrogen content of CSC is negligible compared to that of coal, as seen from the EGA results given below.

The EGA of CSC carried out from room temperature to 1300 K showed a single sharp peak at 393 K due to loss of water while in the case of hydrogen a broad weak band appeared between 750 and 1200 K. This temperature interval of hydrogen release was found to correspond to partial burning of CSC in the oxygen impurity in the argon, as ascertained by monitoring the CO_2 released from the sample. The maximum current observed for hydrogen in the mass spectrometer analyser was

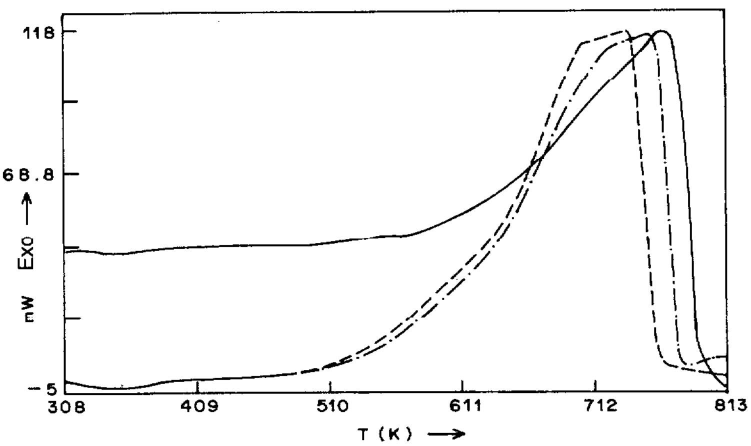

Fig. 3 Normalised DSC plots of CSC and its mixtures with potassium carbonate in air: ——— CSC, –·–·–·– CSC2, and – – – – CSC5

more than fifty times less than that for moisture i.e. $I(H_2^+) \ll I(H_2O^+)$. Since the amount of moisture in the sample is known from the thermogravimetric data its hydrogen content was estimated to be ~0.20 wt%.

A broad peak spread between 2Θ of 20° and 35° was observed in X-ray diffraction of CSC showing thereby that it is highly amorphous.

Conclusions

The investigations on CSC show that its hydrogen and ash contents are extremely low and it will be a convenient fuel for production of DCP; dry fuel will be preferred to insure the superior quality of the plasma. Its ash content being very low, it is an added advantage and high homogeneity of the plasma can be obtained.

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