AN EXPERIMENTAL STUDY OF MECHANISM OF COMBUSTION OF CARBON IN SHALLOW FLUIDIZED BEDS

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ABSTRACT

The mechanism of combustion of carbon in fluidized beds has been studied further by measuring (i) burning rates and temperatures of electrode carbon particles and (ii) burn-out times of batch charges of char particles in an electrically heated fluidized bed combustor at 1073-1173 K. Experimental results showed the inadequacy of the existing models based on diffusion-controlled combustion mechanism. Chemical kinetics and mass transfer of oxygen by forced convection were important controlling influences. Bed design and operating parameters were varied and shown to effect burning rates of carbon in fluidized beds considerably.

INTRODUCTION

Avedesian and Davidson (1973) first presented a model of combustion of carbon in fluidized beds assuming that the combustion is controlled entirely by molecular diffusion and that the only reaction that occurs at the carbon surface is the endothermic reaction, \( C + O_2 \rightarrow 2CO \). Their combustion experiments supported this model. The burning rate of a single carbon particle was given as:

\[
\dot{m} = 24 \pi \text{Sh} \mathcal{D} d c_E \quad \ldots \ldots \quad (1)
\]

Later experiments by Basu et al (1975), suggested that oxygen reaches the carbon surface, producing both CO and CO\(_2\) there. A heat balance calculation around a burning carbon particle also indicated that insufficient heat was available to support the above
endothemic reaction. Basu et al (1975) also presented an expression for burning rate of a single carbon particle, namely:

$$\dot{m} = 48 \pi D \frac{\varepsilon}{m} \frac{d}{c_E} (1 + 12 \frac{c_E}{\rho_g})$$

Beer (1977) also reported that Song and Sarofim (1975) drew attention to the fact that Avedesian and Davidson's (1973) experimental data showed faster burning rates than was possible through the \(\text{C} + \text{O}_2 \rightarrow 2\text{CO}\) reaction alone and indicated the presence of oxygen at the surface. Ross (1979) reported that more recent work indicated that for large carbon particles (> 3 mm) the conversion of carbon to carbon dioxide may be assumed to take place essentially at the surface. Thus it appears that for large carbon particles, the mechanism of combustion needs further investigation. The object of the present work was (i) to study the mechanism of combustion of coal in fluidized beds over a wider range of variables than reported to date; (ii) to test the existing models of combustion of coal in fluidized beds over these ranges and (iii) to suggest improvements to these models to cover such conditions.

EXPERIMENTAL EQUIPMENT

The experimental fluidized bed combustor consisted of a 71.5 mm inside diameter quartz glass tube wound with Kanthal heating elements for heating the bed. Silica sand particles were used as the inert material. A porous ceramic plate was used as the distributor.

Two types of carbon particles were used, namely (i) electrode carbon spheres, 2-12 mm in diameter and (ii) char particles, 1.84-4.375 mm in size, prepared from a blend of high volatile coals having a proximate analysis as follows: Ash 4.37%; Moisture 1.05%; Volatile matter 27.09% and Fixed carbon 67.49%.

EXPERIMENTAL PROCEDURES

Burning Rates and Temperatures of Electrode Carbon Spheres

The bed temperature was controlled by electrical heating at desired values (1073-1173 K). Burning rates of spheres were determined from measurement of mass loss when burning in the bed for a specified time (100 s). Attrition of the spheres was shown to be negligible in separate tests.

The temperature of some of the carbon spheres was measured using a thermocouple embedded at the centre under the same experimental conditions as for burning rate tests.