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Combustion and Emission Characteristics of Rice husk in a Rectangular Fluidized Bed Combustor

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***Abstract*--The experimental results on combustion of Rice husk in a lab scale fluidized bed combustor (FBC), using river sand as the bed material are presented in this paper. The Fluidized bed was operated at 15–25 kg/h of rice husk feed for various excess air factors (20-100%) and for the different fuel particle sizes. The effect of fuel feed rate , excess air factor and fuel particle size on the concentration profiles of the major gaseous emissions (CO and CO2), combustion efficiency , as well as the temperature profiles along the combustor height, were investigated. The concentration of the CO was found to have a maximum value at active combustion zone. Based on CO emission and unburned carbon content in fly ash, the combustion efficiency of the Fluidized bed combustor was calculated for the rice husk fired under different operating conditions. The maximum combustion efficiency of the rice husk is found to be 95%**

Keywords-FBC; Ricehusk; Combustion Efficiency; operating conditions; Particle size, CO.

I. INTRODUCTION

Biomass is the third largest primary energy resource in the world, after coal and oil. Biomass is a major source of energy in developing countries, where it provides 35% of all the energy requirements. The use of biomass to provide partial substitution of fossil fuels, has an additional importance as concerns global warming since biomass combustion has the potential to be CO2 neutral [1]. Biomass materials with high energy potential include agricultural residues such as straw, bagasse, groundnut shell, coffee husks and rice husks as well as residues from forest-related activities such as wood chips, sawdust and bark. Residues from forest-related activities account for 65% of the biomass energy potential whereas 33% comes from residues of agricultural crops [2].

Among the proven combustion technologies (grate-fired, suspension-fired and fluidized bed systems), the fluidized bed technology is reported to be the most efficient and suitable for converting agricultural and wood residues into energy[1,3]. Extensive experimental investigation has been carried out to date on the feasibility and performance of the fluidized bed combustion of different alternative fuels. CO and NOx (generally, as NO) are also the major harmful pollutants emitted from biomass combustion in fluidized bed systems [4]. For a selected fuel, CO emission (strongly affecting the combustion efficiency) is a function of operating variables, such as excess of combustion air as well as combustor load, and can be effectively controlled by the air supply[5].

This paper deals with the experimental study of combustion of selected agro fuel i.e. rice husk, in a lab scale fluidized bed combustor (FBC) using river sand as inert material. The main objectives of this work were to study formation of the major gaseous pollutants (CO and CO_2) in the FBC when firing agro fuel rice husk, and to determine the combustion efficiency of the FBC at different operating conditions.

II. EXPERIMENTAL SETUP FOR COMBUSTION STUDY

The entire experimental setup consists of three sections, rectangular furnace (at bottom), fluidization bed reactor (middle) and free board section (top). The bottom of the chamber consists of a nozzle type distributor plate. Free board section is connected to a cyclone separator by a pipeline. The required amount of air for combustion is supplied by a centrifugal blower. The fuel is fed to the combustor with the help of a screw feeder arrangement. K-Type thermocouples (15 No's) are provided at equal spacing along the height of the reactor for continuous measurement of temperatures within the bed. Two thermocouples are located to measure the temperature of residual ash and flue gas. To measure the water line temperature three thermocouples are provided at water outlet line and one thermocouple at water inlet line. For finding out the Pressure drop across the bed, there are 10 differential pressure transmitters (MODEL: CP100) are provided along the reactor. A heating coil of stainless steel 316 (of dia. 25 mm X 8 m length) pipe of one inch diameter is provided inside main vessel in the form of helical shape through which water is circulated. A flue gas analyzer was used to measure the flue gas analysis (MODEL: KM 9106)

Fluidization chamber is a cylindrical vessel made of seamless stainless steel material with an inner diameter of 200 mm, thickness of 10 mm, height 1500 mm and bottom rectangular furnace is of 450× 440 × 480 mm. A castable refractory lining of 25 mm thickness is provided to minimize the heat loss during the combustion process. The vessel is insulted with ceramic wool of thickness 120mm. Induced draft fan was used to maintain a sufficient vacuum in the furnace. In setting draft the objective is to avoid a very high draft that would cause excessive air leakage into the furnace and to avoid a very low draft that would cause positive pressure underneath the convection tubes and cause hot flue gas to leak out of the furnace. However, when the furnace is well scaled and air leakage is not a problem, draft can be used to control the amount of air entering the distributor.

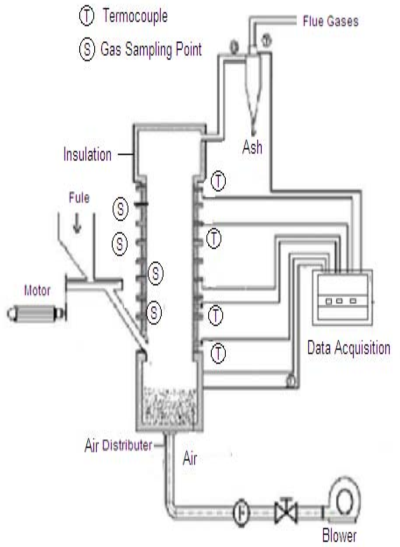

Figure 1. Schematic diagram of the FBC

TABLE .1: PROPERTIES OF RICE HUSK

Hydrodynamic Properties			
Particle Size, mm	1.043	0.594	0.345
Bulk density	100.2	121.6	140.2
Particle density	605.1	596.8	592.4
Static voidage	0.835	0.791	0.744

Proximate analysis		***Ultimate analysis***	
Property	**Wt%**	**Property**	**Wt%**
Moisture (%)	6.1	Carbon, %	36.4
Ash (%)	20.6	Hydrogen, %	4.84
Volatile matter (%)	58.40	Oxygen, %	25.11
Fixed carbon (%)	14.9	Nitrogen, %	0.44
Calorific value, Kcal / kg	3420	Sulpher, %	0.17

A. Experimental procedure

The concentrations of major gaseous pollutants (CO, CO2) in flue gas were measured in the experimental tests along the combustor height above the air distributor when firing the selected biomass fuel. In addition, temperatures were detected along the combustor height and in the flue gas at the cyclone outlet. For each test run, the value of excess air in the flue gas was determined using the O2 and CO concentrations at the cyclone outlet. Three parameters were chosen in this work as independent variables: fuel feed rate (FR), particle size and percent excess air (EA). The FBC was tested at two different fuel feed rates, and the required feed rate was provided by the corresponding rotational speed of the feeder screw. The biomass fuel (rice husk) used in this study was derived from local mills. Table 1 shows ultimate and proximate analyses as well as the gross calorific value and hydrodynamic properties of biomass fuel used in this work. The FBC was tested at two different fuel feed rates (20 and 25Kg/hr) for different fuel particle sizes (1.043, 0.594, 0.345mm), At each fuel feed rate combustor was operated at different excess air factor (20, 40, 50 and 60%).

III. RESULTS AND DISCUSSION

The axial profiles along the height of the combustion chamber were plotted for rice husk fuel fired in the FBC under different operating conditions. The concentration profiles of CO, CO_2 and temperature profiles for rice husk are compared for some operating conditions. Figure 2 shows the axial temperature profiles for the feed rate of 25 Kg/hr, at 50% excess air. These profiles seem to be rather uniform and characterized by small temperature gradient along the height above the air distributor. The highest temperatures in the combustor were observed in splashing zone with proximately 30^0 C rise in temperature. This is due to the combustion of fine char produced by attrition of coarse char in the splashing zone. The finer char has much lower concentration since it has much larger burning rate owing to the very much larger surface area. As seen in figure 2 at fixed excess air, the temperature of the combustor for the large particle size 1.043mm is less than small particle size 0.345mm and the bed temperature is dropped by some 10^0C.

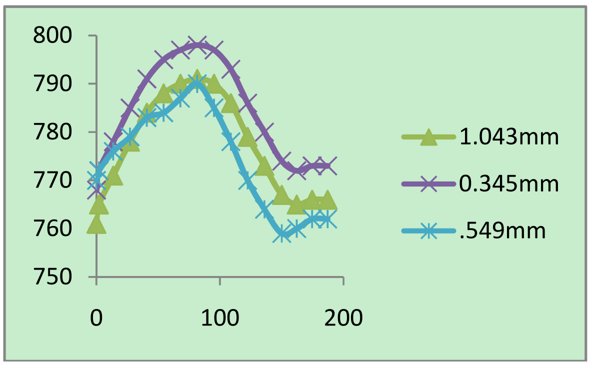

Figure 2. Axial Temperature Profile

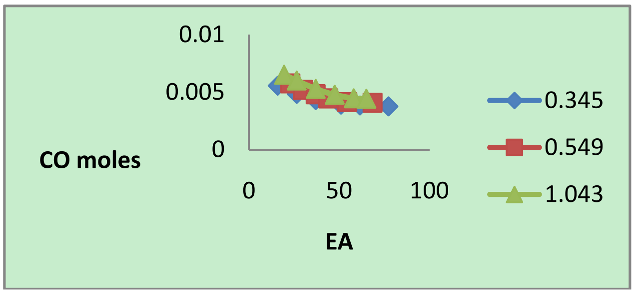

Figure 3. Effect of excess air on CO leaving with flue gases at The cyclone separator

Figure 3 shows the CO concentration leaving with flue gas for the same operating conditions. As seen in the figure 3 the concentration of CO is very high at first, further it reached a minimum value. The formation of CO in the Bed section will raise the concentration of CO in this section and oxidation of CO to CO_2 reduces the CO concentration in the splashing and freeboard region. From figure 3 we can observe that the heterogeneous reactions of the char play a significant role in the formation of CO which is depend on particle size. The combustion of char involves the diffusion of oxygen into the char and reaction of that diffused oxygen with carbon in the char. The diffusion of oxygen depends on the fuel particle size. The available oxygen for inner part of the coarse char is less which results in partial combustion (high concentration of CO). Besides this the rate of CO formation is high for the low temperature of the combustion chamber. This released CO is further oxidized in the splashing and freeboard region.

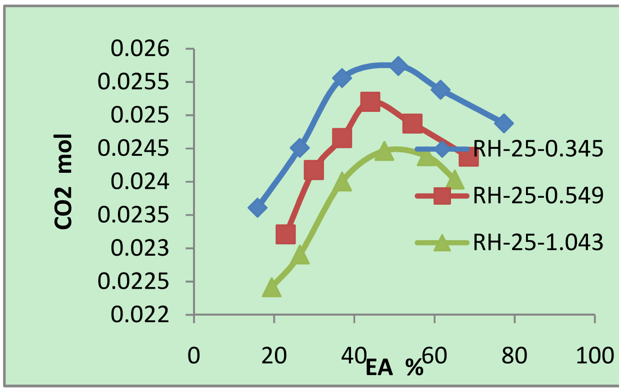

Figure 4. Effect of excess air on CO_2 leaving with flue gases at The cyclone separator

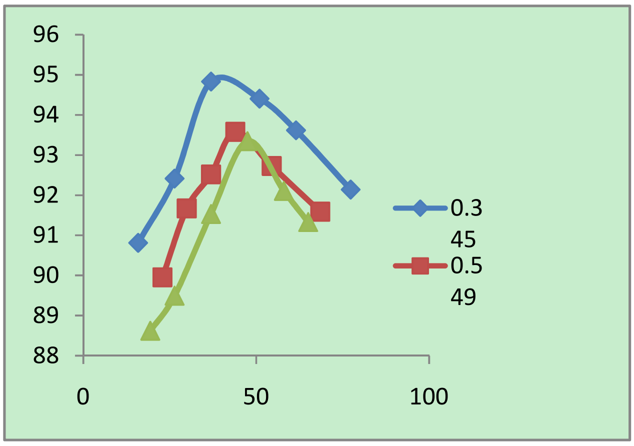

Figure 5. Combustion efficiency of FBC at Different Excess air Factor

Figure 4 shows the concentration of CO_2 leaving with flue gases for different excess air factor at fixed feed rate. As shown as in figure the maximum concentration of the CO2 is observed at 48% excess air factor with particle size of 0.345 mm and 59% excess air factor with particle size of 1.043 mm. The velocity of air increases with excess air supplied to the combustion chamber which results in decrease in concentration of CO2 because of less residence time of the particle in the combustion chamber. Decrease in residence time of particle leads to increase of unburnt carbon in the ash and decrease in combustion efficiency.

IV. COMBUSTION EFFICIENCY

Combustion efficiency will determine the performance of combustion process. For estimation of combustion efficiency, the heat losses owing to incomplete combustion and unburnt carbon in the ash are determined. The combustion efficiencies of selected biomass fuel rice husk are shown in Figure 6 at different excess air factor. Combustion efficiency is mainly affected by Biomass fuel particle size and velocity of air in the combustion chamber. The complete combustion of the carbon in the fuel gives the highest combustion efficiency. The incomplete combustion of the carbon to carbon monoxide and unburnt carbon in the ash will affect the combustion efficiency of the Fluidized bed combustor. The maximum combustion efficiency is observed at the same excess air which has highest CO2 concentration in the flue gases. The combustion efficiency is low for large particle size 1.043 at same excess air factor. This is due to the in complete combustion of rice husk. Further increase in excess air results in decreasing of residence time of particle which leads to the increase in unburnt carbon in ash. The maximum combustion efficiency is 95% at 50% excess air for particle size of 0.345.

V. CONCLUSION

The current rectangular cyclonic fluidized-bed combustor was developed to integrate the distinct features of cyclonic and fluidized-bed combustion. The success of the FBC was clearly observed through the high combustion efficiency of 95%. Temperature profiles within the combustion chamber indicated the existence of nearly isothermal bed conditions, operating at temperatures of around 700–800 °C, a result of thoroughly mixing in the bed. The changes in the amount of excess air of 25–70% seemed to have significant effect on combustion efficiency, except for high fluidizing velocity (excess air >80%), which resulted in an increased elutriation rate. The maximum combustion efficiency was observed (at optimum condition) 95% at 50% excess air factor for particle size of 0.345, and the combustion efficiency of 93.5% is observed for particle sizes of 0549 and 1.06 at 56 %, 60% excess air respectively. With further increase in excess air the combustion efficiency is further reduced due to unburnt carbon and incomplete combustion.

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