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Combustion Characteristics of Sawdust in a Bubbling Fluidized Bed

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Abstract. Fluidised bed combustion has proven to be an efficient way of converting biomass fuel into clean energy. This experimental work investigated major gaseous emissions from a fluidized bed combustor with a rectangular shaped bed firing sawdust with high, over 99%, combustion efficiency. Experiments were carried out to study the effect of fuel feed rates (20 & 25 kg/hr) for different values of excess air (EA) and for different fuel particle sizes. When all other parameters are held constant, the optimum excess air found to 50% for achieving maximum combustion efficiency with in acceptable CO emissions.This results in ash with consistently low carbon content.

Keywords: Experimental study, saw dust, Carbon monoxide, Combustion efficiency.

1. Introduction

Among the different sources of renewable energy, biomass is the only renewable source of carbon and host of other chemicals. Biomass can be converted into desired gaseous, liquid and solid secondary fuels through thermo chemical conversion process like pyrolysis, gasification and combustion. Fluidized bed combustion technology is proven to be the most effective technology for energy conversion from biomass. The significant advantages of fluidized bed combustors over conventional combustors include their compact furnaces, simple designs, effective combustion of a wide variety of fuels, relatively uniform temperatures, and ability to reduce emissions of nitrogen oxide and sulfur dioxide gases (saxena and joshi,[1]) . Peel and Santos[2] and Peel[3] have investigated the combustion of sawdust, bagasse, rice husks, wood chips and corn cobs in a 200 mm diameter fluidized bed combustion test rig. It has been suggested that satisfactory combustion of the bagasse, sawdust and the rice husks could be achieved with under-bed feeding only. Hellwig[4] analyzed the heat distribution during the combustion of wood chips and straw and showed that over 67% of their calorific values were released through the combustion of the volatiles. Bhattacharya and weigzhhang[5] have reported that the loss of unburnt carbon in the form of carbon monoxide(CO) is in the order of 3to 10%. The higher CO emissions have been observed at higher fluidization velocities and this could be because of shorter residence time. Salour..et al [6] have found that the combustion efficiency is dependent on the fuel particle size, excess air level and bed temperature and gas velocity in bubbling beds. It is recommended tha the height of freeboard must be increased to increase the combustion efficiencies. Kouprinov and permchart[7] have studied the effects of operating conditions(load and excess air), as well as the fuel quality and the bed height, on the major gaseous emissions(CO_2,CO and NO_x) in a conical fluidsed bed combustor while burning a mixed sawdust generated from different woods in thailand. It has been found that the bed height had a minor influence on the emission profiles. The CO_2 emission profiles along the combustor height were found to be almost independent of the combustor load and fuel quality. Kouprinov and permchart[8] have conducted experimental studies in a conical fluidized bed combustor with different biomass fuels: rice husk, sawdust and bagasse. It has been revealed that for the maximum combustor load and excess air of 50-100%, a combustion efficiency of over 99% could be achieved when firing sawdust and

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bagasse. From the literature it could be concluded that due to sudden devolatalisation of biomass fuels the combustion operations should be conducted in highly excess-air environment.

This research was performed with the objective of determining the combustion efficiency of the newly designed rectangular fluidized bed at lower excess air and to reduce the emissions. Furthermore this research aims to demonstrate the technical feasibility of a fluidized bed as a clean technology for burning biomass fuels

2. Experimental

2.1. Fuel characterization

In this study, sawdust collected from local saw mills was employed as a fuel. The proximate and ultimate analysis performed on sawdust is summarized in Table 1. Table 2 shows the main characteristics of sawdust fuel and inert bed material (sand).

2.2. Experimental apparatus and operating procedures

Fig. 1 shows a schematic diagram of the atmospheric fluidized bed combustor used in this investigation. The entire experimental setup consists of three sections, rectangular furnace (at bottom), fluidization bed reactor (middle) and free board section (top). Fluidizing air was introduced at the base of the bed through a nozzle type distributor and provided air for both fluidization and combustion. Fluidization chamber is a cylindrical vessel made of seamless stainless steel material with an inner diameter of 200 mm, thickness of 6 mm, height 1500 mm and bottom rectangular furnace is of 450× 440 × 480 mm. A cast able 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 sealed and air leakage is not a problem, draft can be used to control the amount of air entering the distributor. The fuel is fed to the combustor with the help of a screw feeder arrangement. Bed and free board temperatures were measured at fifteen different heights above the distributor plate by means of sheathed type K Ni/Cr-Ni thermocouples. Two thermocouples are located in cyclone to measure the temperature of residual ash and flue gas. A heating coil of stainless steel 316 (of dia. 25 mm X 6 m length) pipe is provided inside main vessel in the form of helical shape through which water is circulated. To measure the water line temperature three thermocouples are provided at water outlet line and one thermocouple at water inlet line. Fuel was fed pneumatically into the bed surface from a sealed hopper through an inclined feeding pipe, the flow rate through which was controlled by a screw feeder. A cyclone was fitted to the combustor exit, and the carryover from the bed was collected for analysis. Flue gases were measured using Quintox KM9106 continuous emission analyser. A fly ash sample was collected from the catch pot after finishing the combustion run. The sample was analysed to determine the total amount of unburned carbon in the test fuel.

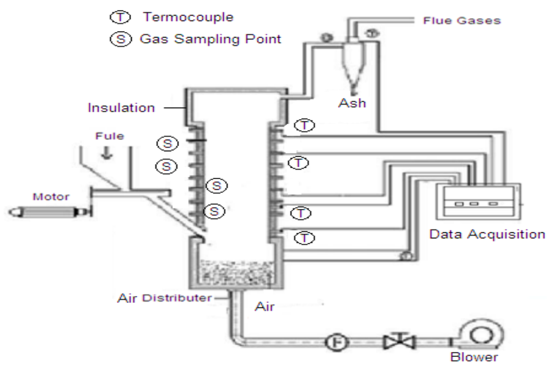

Fig 1. A schematic diagram of the Fluidized bed Combustor

Table 1: Saw dust Properties

Proximate analysis		Ultimate analysis	
Property	Wt%	**Property**	Wt%
Moisture (%)	6.4	Carbon %	48.98
Ash (%)	3.3	Hydrogen %	4.89
Volatile matter(%)	74.3	Oxygen %	36.01
Fixed carbon (%)	16.0	Nitrogen %	0.32
Calorific value, Kcal / kg	4380	Sulpher %	0.18

2.3. Experimental Procedure

The characteristics of bed material are presented in table 2. From the cold flow studies it is found that sand particle of size 0.463 mm is most suitable for sawdust to achieve low minimum fluidization point and good mixing with fuel particles without segregation characteristics. Before sawdust is burnt in the fluidized bed it is necessary to heat the inert bed solids to about 500^0C using auxiliary heating system. For heating the inert bed up to 500^0C, 1-2 kgs of coal along with small amount of sawdust burnt with gasoline at the surface of the bed. The present experimentation is aimed to investigate the control of CO emissions from the fluidized bed along with highest possible combustion efficiency.

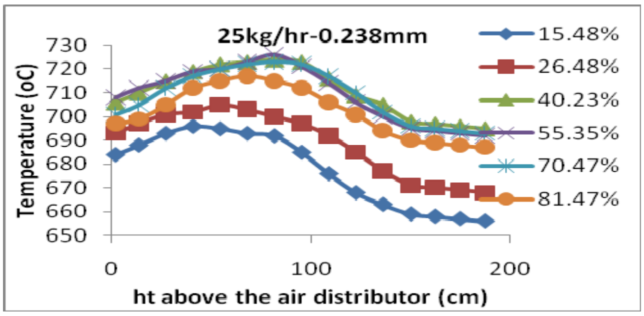

Fig 2. Axial temperature profile

Table 2. Hydrodynamic properties of sawdust and inert bed material

Material/Property	Saw dust		Sand
Mean Particle size (mm)	0.238	0.126	0.463
Bulk Density (kg/m^3)	144.8	159.1	2519
Particle Density (kg/m^3)	680.3	655.9	1600
Static voidage (ε_o)	0.787	0.757	0.36

3. Results and discussion

This section describes the combustion of sawdust in a fluidsed bed combustor. The influence of properties (such as particle size, particle density and volatility) and the influences of operating parameters (e.g., the amount of excess air, the effect of fluidizing velocity on axial temperature profile, the combustion efficiencies and the CO emissions) are discussed.

3.1. Temperature profiles

Fig 2 shows a plot of axial temperature distributions along the FBC height for fuel studied at various excess air factors . The highest temperature was observed at a height of 90cm for all excess air factors. As can be seen from figure 3, combustion of smaller particle size creates a slightly higher bed temperature in comparison to larger fuel particle size . Beyond 90 cm above the distributor plate, all of the temperatures begin to fall, indicating that most of the combustion was completed. This significant combustion behaviour can be explained by the devolatilisation process of fuel (sami et al[9]). With high volatility (more than 50%)

and low ignition temperature, biomass will start to devolatilise at 90 cm above the FBC height and will be mostly burned before it reaches the free bed region.

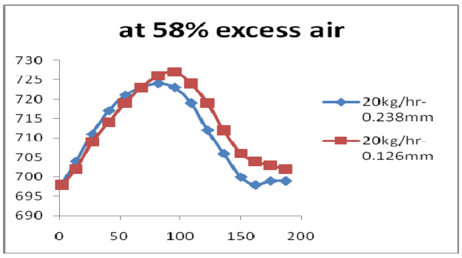

Fig 3. Axial Temperature Profile

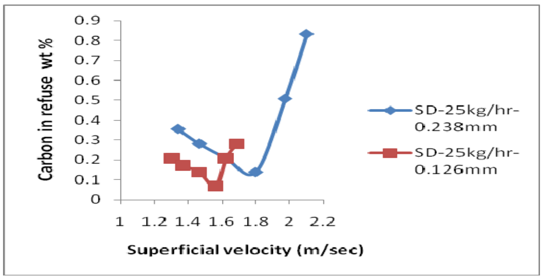

Fig 4. Effect of superficial velocity on carbon loss at cyclone exit

3.2. Analysis of Carbon carry over loss

The analysis from all tests demonstrates that using sawdust as the fuel results in the least amount of unburned carbon detected in the recovered ash. The amount of unburned carbon was quite low, corresponding to approximately less than 5% of the total carbon input. Such observations seem to suggest that particle size of the fuel affect combustion performance. The volatile matter burns rapidly, and the higher volatile content of the sawdust can also result in a highly porous char, thus also accelerating the char combustion (leckner et al., [10]). In all cases, the amount of unburned carbon in the ash initially decreases and then increases as the fluidising velocity increases. Even though the combustion of volatiles was completed , the char particles did not have a residence time long enough for complete combustion. The unburned carbon percentage in total carbon feed, however contribute only a small percentage (about a 3% difference) to the overall combustion efficiency calculation. Fig 4 clearly illustrates the elutriated carbon loss. Silicate content in sawdust ash could pose problems, such as bed agglomeration or ash deposition during fluidised bed combustion (Baxter et al., [11]). However , none of these phenomena occurred during all of the combustion runs. This is primarily due to fact that the bed and free board temperatures were lower than the ash fusion temperature. Further more, almost no bed ashes havebeen found during the experiments. It suggests that the all the carryover was elutriated to the cyclone and that the char combustion was completed during the runs.

3.3. Analysis of Carbon monoxide emissions

To enable the comparison of CO data, all the tests were converted to moles of CO emitted per kg of fuel burnt. From the fig 5 it is evident that there are significant fluctuations in CO emissions for the same feed rate varying the excess air and the fuel particle size.The trends observed were similar to those observed by abelbha et al [12], Kuprisnov et al [7]. The difference in the trend is caused by slight variations in feed particle size, and this effect is reflected in the temperature profiles. It is noted that increase in excess air has significant influence on CO emissions during combustion test runs, and the optimum values for CO were found to be at 50% excess air, where emissions tend to be lower than the expected in reference to the higherfuel particle size.

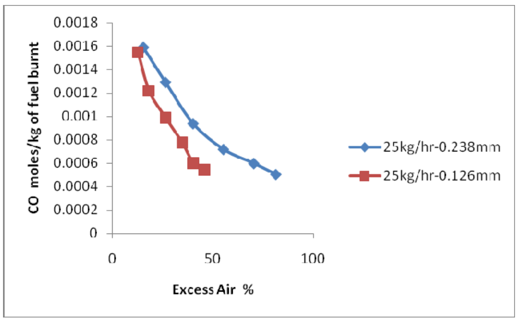

Fig 5:Effect of exces air on Corbonmonoxide

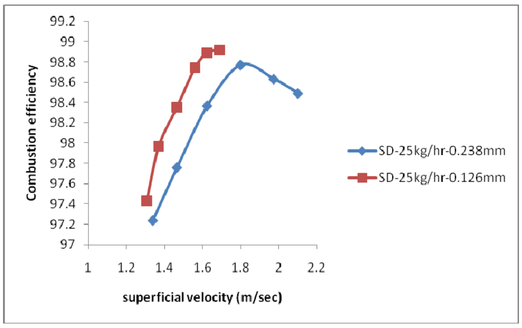

Fig 6: effect of superficial velocity on combustion efficiency

This phenomenon is due to the diffusion of oxygen which depends on the fuel particle size. The combustion of char involves the diffusion of oxygen into the char , which enhances the char reactivity and lowers the CO emissions. The fine char has much lower concentration since it has much larger surface area. The decrease in CO levels at low percentages of excess air, not below 50% , can be attributed to rapid enhancement and ignition of volatiles from sawdust due to both the low excess air and relatively high bed temperature.

3.4. Combustion Efficency

The combustion of biomass was evaluated in terms of combustion efficiency. The combustion tests were performed using two different particle sizes of sawdust varying excess air factors and fuel feed rates. Fig 6 shows the effect of air fluidising velocity on combustion efficiency for two different fuel particle sizes. The combustion efficiencies range between 95 % and 99.2%. The improved combustion efficiency of sawdust can be attributed to an increase in bed temperature, which is caused due to the high rate of reaction of smaller fuel particle size. Thus, there is more chances for fuel conversion of carbon to carbon dioxide as the particle size decreases.

The increase of fluidising velocity creates more turbulence in the bed, which leads to improved solid mixing and gas –solid contacting and further improves the rate of combustion. Subsequently, a higher carbon burnout yields higher combustion efficiency. When the combustion process is stabilised the increase in fluidisation velocity contributes to particulate elutriationwhich is greater than the carbon to conversion rate and leads to increase in unburned carbon . This phenomena can be seen in fig 6 which shows that the combustion efficiency decreases when the fluidising velocity increases beyond optimum value.The rise in fluidising velocity improves solid mixing and also influences the fuel particle settling time during the combustion process. The settling time for biomass will be greater, and a portion of the combustion will be completed before the particles return to the bed and this also a function of particle size and density. As the fluidising velocity increases more elutriation of solids were observed , this is caused either by fine particles in the feed or by a size reduction by attrition in the bed.

4. Conclusisons

The combustion of biomass in an existing rectangular FBC was evaluated in terms of combustion efficiency. The axial temperature profiles in fluidised bed combustion chamber are fairly uniform at all operating conditions. Generally, the factors that influence combustion efficiency are the loss of carbon in the refuse collected at the cyclone outlet, and the loss of carbon as CO in flue gases as a result of incomplete combustion The operating parameters such as percentage excess air, fluidising velocity and bed temperatures played an important role in the combustion process. From this study the existing rectangular fluidised bed was found to be capable of burning sawdust with as high as 99.2 % at 50% excess air factor for particle size of .125mm with an acceptable CO emission limit.

5. Acknowledgements

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6. References

[1] Saxena, S.C., josji, C.k., Fluidized bed incineration of waste materials. Progress in energy and Combustion Science 1994, 20. 281

[2] Peel, R.B., Santos, F.J. " Fluidised bed combustion of vegetable fuels". In Proc Fluidised bed combustionSysytems and Applications, Insitute of Energy Sympsium Series4, London, UK, IIB2, 1980.

[3] Peel, R.B ., "Fluidised bed combustion and gasification of biomass". Proceedings of the 5th E.C.Conference on biomass for enery and industry, II, London : Elsevier Applied Science 1989, 541-55,

[4] Helwig,G. " basic of the combustion of wood and straw ". In 3d E.C. Conference on Energy from biomass, Londn,1985, 793-798.

[5] Bhattacharya, S.C., and Wu, Weizhang " Fluidised Bed combustion of rice husk for disposal and energy recovery " . Energy from biomass and wastes XIV ., Institiute of gas Technology, Chicago,1990, 591-60.

[6] Salour, D., Jnkins, B.M., Vafaei, M., and Kayhanian, M " Control of in bed agglomeration of fuel blending in a pilot scale straw and fueld AFBC " Biomass and Bioenergy, 1993, 4(2) 117-133.

[7] Kouprianov,V.I., and Permchart, W , (2003) " Emissions from a conical FBC fired with a bomass fuel" Applied Energy 2004, 74, 383-392.

[8] Permchart,W., and Kouprianov,V.I. " Emission performance and combustion efficiency of a conical fluidized-bed combustor firing various biomass fuels " Bioresource technology 2004,92,83-91.

[9] Sami.M., Annamalai, K., Woodridge, M., "CoCombustion of coal and biomass fuel blends". Progress Energy Combustion Science 2001, 27, 171-214

[10] Leckner. B., Amand, L.E., Lucke, K., Wether, J., "Gaseous emissions from co-combustion of sewage sludge and coal/wood in a fluidized bed " . Fuel 83, 47-486.

[11] Baxter et al., " The behavior of inorganic material in biomass-fired power plants boilers : field and laboratory experiences" . Fuel processing Technology 1998, 54, 47-58