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Emission Characteristics of Cowdung at Different Feeding Rates in a Fluidized Bed Combustor

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***Abstract*— Combustion of cowdung in a semi-pilot Fluidized bed combustor was carried with an aim of ascertaining the amount of emissions at different feeding rates. It was found that during combustion at excess air to fuel ratio of 30%, CO emitted was lower as compared to combustion at stoichiometric and 20% less air to fuel ratios. The amount was in a mean range of 0.000003% on the higher side and 0.000002% on the lower side as combustion progressed. A steady emission of Carbon dioxide gas attained a maximum value of 3.5% at 30% excess air to fuel ratio. It was therefore established that, the proportions of CO_2 and CO emitted during combustion of cowdung at different feeding rates vary in proportions and a stable emission behavior is observed at excess air to fuel ratios. The low emissions of CO_2 and CO gases shows that cowdung fuel can be used in a fluidized bed combustor to generate energy while mitigating the effects of global warming which can result if other fuels like coal are used.**

Keywords*— Cowdung; Fluidized Bed Combustor; Emissions; Feeding Rates

1. INTRODUCTION

The study on biomass report released by the International Institute for Environment and Development (IIED) [1] indicated that reliance on biomass is set to triple from 10 per cent to 30 per cent of global energy consumption by 2050.
The energy intervention policies in Kenya include acceleration on the implementation of green energy projects to target at least 15% of the total generation over the medium term [2]. In Kenya, Livestock sector cumulatively exceeds 94 million heads of cows, sheep, goats and poultry which cover about 75 percent of the total land surface [3]. This has great potential to produce a lot of energy if collected and burnt when dry. The typical characteristics of cowdung are shown in table 1.

Table 1: Cow dung's Ultimate and Proximate analysis [4]

Ultimate analysis (%)	O_2 37.8	Carbon 31.6	H_2 5.18	N_2 5.12	Ash 19.3
Proximate analysis (%)	VM 56.4	F.C 9.3	Ash 19.3	Density 1000kg/m^3	

Despite the huge energy potentials, emissions are unavoidable consequence of any biomass combustion. According to Saxena, [5], depending on the fuel composition ,the design of the combustion equipment, and the operation of the system ,the combustion of biomass can lead to emission of CO_2, HC, PAH, tar, soot, NO_X, N_2O, HCL, SO_2, salts and heavy metals.

The study seeks to establish the range of emissions of cowdung in a fluidized bed combustor at different feeding rates. Fluidized bed combustion was recommended in this study because the technique results in a vast improvement in combustion efficiency of high moisture content fuels, and has been adaptable to a variety of "waste type fuels" e.g. cow dung. It can also handle high-ash fuels and agricultural biomass residue [6].

2. MATERIALS AND METHODS

Cow dung was the main research material used as the fuel. It was collected locally, dried to a moisture content of approximately 16 % and crushed manually to particle size of less than 2mm for easier feeding. Dry Silica sand, which is locally available in nature, was used as bed material. Particle sieve analysis was done by the use of a vibrator and a set of two sieves of specification 350μm and 300μm respectively so as to obtain a mean particle size of 325μm. According to P. Basu and S. Fraser, [7] Fluidized bed systems works effectively with silica sand of specifications ranging from 300μm to 3mm in diameter.

Plate 1: Photo of FBC at the Dept. of Mechanical and Production Engineering- Moi University

Semi-pilot fluidized bed combustor test facility available in the Department of Mechanical and Production engineering Moi University was used in continuous combustion of cow dung fuel. The FBC has an internal diameter of 0.15m and a freeboard height of 2.5m as shown by plate 1. The combustor is heated electrically from outside with heaters, which can be

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adjusted to any given temperatures depending on the type of fuel being burnt. A compressor supplies preheated air to the combustor while the fuel is conveyed to combustor through an electrically operated screw feeder.
The combustor is also fitted with O_2, CO, CO_2 and SO_2 gas analyzers as shown in fig 1. Complete instrumentation of gas analyzer together with other combustion operations and controls is in-built to the facility and hence data is obtained and processed automatically from the acquisition system.

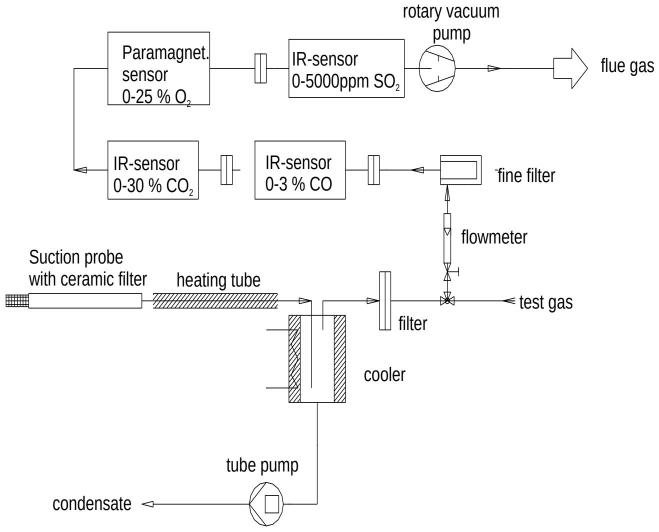

Figure 1: Flow diagram of the FBC gas analyzer

Prior to combustion process, the following tests were done on the combustor;

a) Determination of Air/fuel ratios of FBC

Stoichiometric Air/ fuel ratio was determined using data obtained from experiments on feed rate as well as that of minimum fluidizing velocity. It was established that 3.76 is the air/fuel ratio of cow dung calculated from its ultimate analysis. Thus maintaining the air flow rate constant and varying the level of feed, either a weak or rich mixture of combustion was obtained. A mixture which has excess air is termed weak mixture, while one which has a deficiency of air is termed rich mixture.

b) Calibration of Fluidized bed combustor

During the calibration of a FBC, temperature profiles, pressure drops across the bed and gaseous emissions were monitored to ascertain if the facility was working properly. The trend of CO_2 gas withdrawn from the centre line of combustor during the calibration process lasted for two hours. It was found that CO_2 gas registered was below 0.4 % and in most cases less than 0.1 % (fig.2). This corresponded to the level of CO_2 around that atmosphere. CO detected during the calibration process was found to be minimal, as shown by fig 3. At some instances there were no traces of CO, while a high of 0.000003 % was sometimes registered. The low CO emissions were probably due to no combustion process taking place. O_2 liberated during calibration process was found to be approximately 20%, (fig 4). Air from the atmosphere contains approximately 21.7 % oxygen. Therefore the registered level was not far from the actual value given that constant air flow rate was supplied and no fuel combustion was taking place.

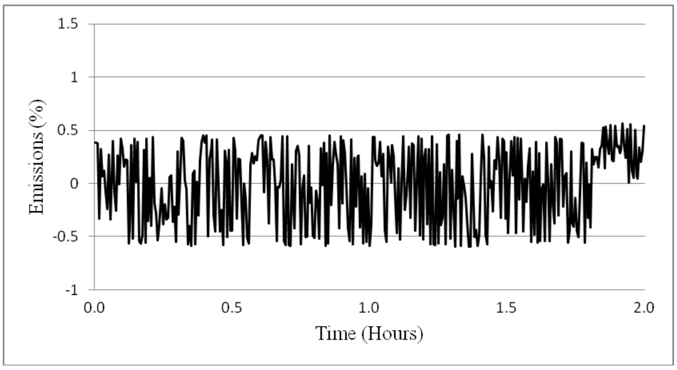

Figure 2: Graph of CO_2 emission profile during calibration. (No fuel feed)

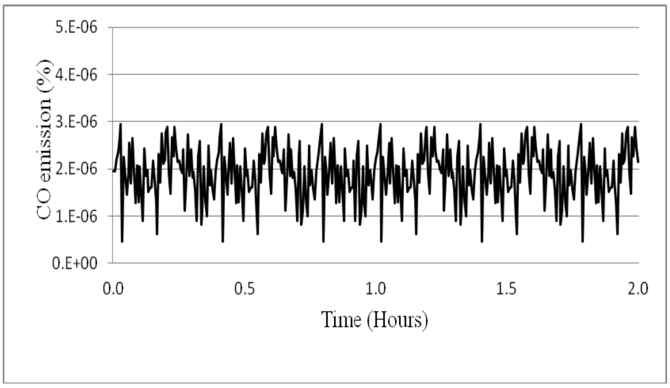

Figure 3: Graph of CO emission profile during calibration (no fuel feed)

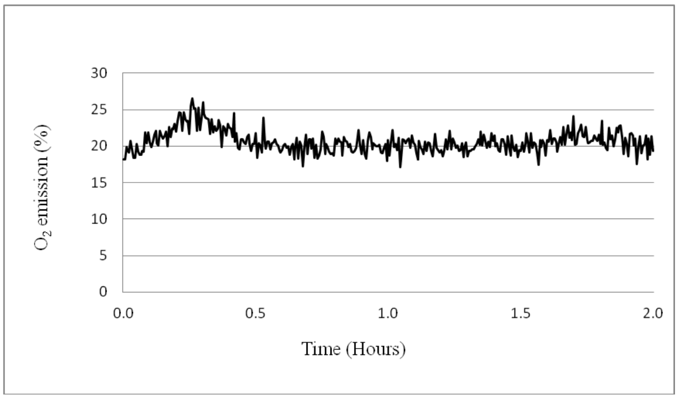

Figure 4: Graph of O_2 emission profile during calibration.

3. RESULTS AND DISCUSSION

When combustion of cowdung was done at calculated stoichiometric air/fuel ratio, 30 % excess air/fuel ratio and 20 % less air/fuel ratio, the emissions magnitudes for CO_2 and CO were recorded and analyzed.

3.1 Gaseous emissions at stoichiometric air/ fuel ratio

Results from emissions of CO_2 (fig 5) indicates that immediately on feeding cow dung, there was a steady increase of CO_2 to about 2.6 % and for the entire combustion period of three hours, emissions fluctuated between 2.6 % and 1.5 %. This showed that the level of CO_2 at a stoichiometric air/fuel ratio was substantial as compared to less than 0.4% obtained during calibration process.

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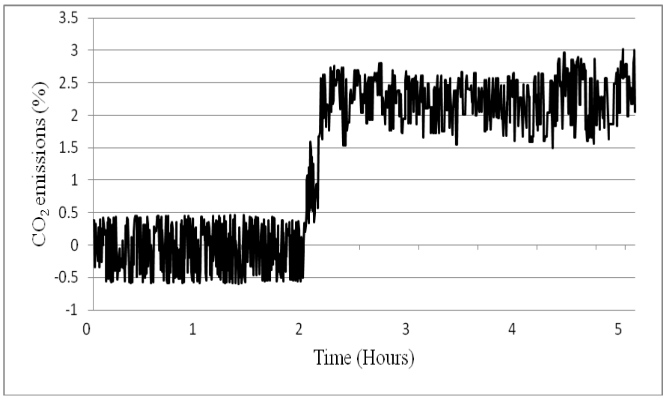

Figure 5: Graph of CO_2 profile at a stoichiometic air/ fuel ratio.

For the first two hours of heating the combustor, minimal emissions of CO equivalent to that of calibration process of below 0.000003 % was detected as shown by figure 6. Immediately on feeding cow dung fuel, there was an increase in the level of emissions to as high as 0.000004 % and thereafter minor fluctuations below 0.0000035 % were registered for the entire combustion duration.

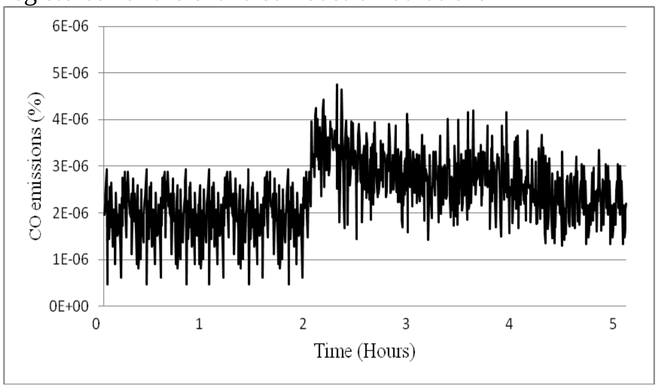

Figure 6: Graph of CO profile during combustion of cow dung at a stoichiometic air/ fuel ratio.

3.2 Gaseous emissions at 30% excess air/ fuel ratio

When the fuel was fed after two hours of combustor heating, a sharp rise in CO_2 emitted was observed as shown in fig 7.

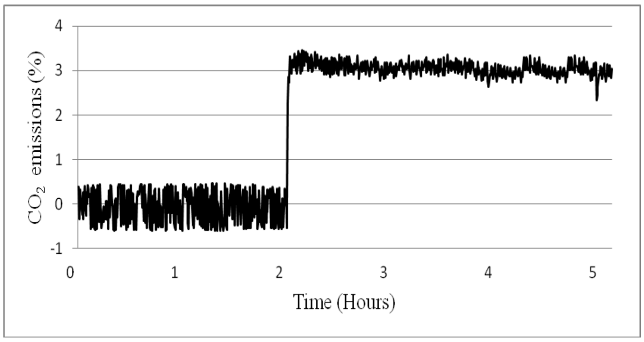

Figure 7: Graph of CO_2 profile at 30 % excess air/ fuel ratio.

A high value of 3.4 % and low value of approximately 2.7 % was registered throughout the combustion process. In comparison to combustion at stoichiometric air/fuel ratio, it was observed that the rate of emission of CO_2 at a 30 % excess air fuel ratio was high.

The trend of CO is as shown in fig 8. After two hours of heating the combustor to attain a stable combustion temperature of 700 °C, fuel feed was done. CO emissions rose to a high of 0.0000035 % with a fluctuation of up to 0.000002 % on the lower side. There was a general decline in CO emission as continuous combustion of cow dung was done. After two and half hours of feeding, an emission level of less than 0.000002 %, which is approximately same as for the calibrated, was attained. This shows that, eventually, there was complete combustion process after two and half hours of feeding at 30 % excess air/fuel ratio.

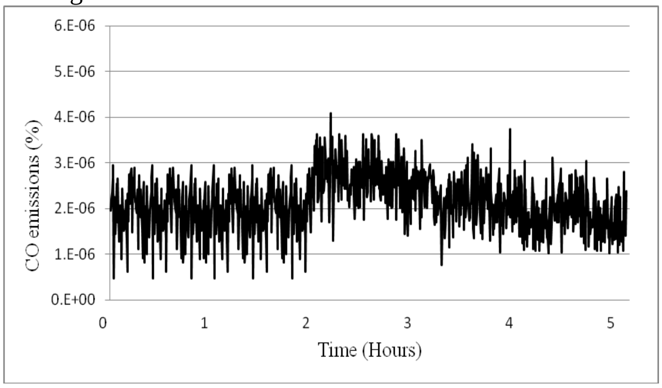

Figure 8: Graph of CO profile at 30 % excess air/fuel ratio

3.1 Gaseous emissions at 20% less air/ fuel ratio

The level of CO_2 detected during the first two hours of heating the combustor, was as low as 0.4 %. When the fuel was fed, a remarkable increase in CO_2 emission became eminent. After 13 minutes of feeding, 2.6 % emissions on the higher side was attained. It was also noted that lower emissions of up to 0.25 % was detected. An average emission of approximately 1.5 % was therefore registered throughout the combustion period as shown in fig. 9.

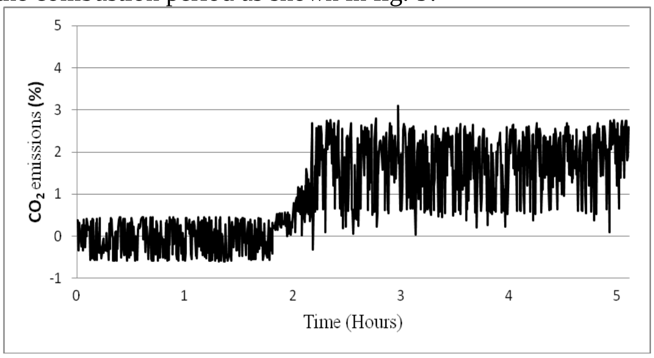

Figure 9: Graph of CO_2 profile at 20% less air/fuel ratio

During the first two hours of combustor heat up, CO emission registered an approximate mean value of 0.000002 %. Immediately on feeding the fuel, a sudden increase in emission was observed. There was a general fluctuation of as high as 0.000007 % but after two hours of feeding the level dropped to approximately 0.000003 % (Figure 10). This drop is likely due to presence of char in the combustor, which aids in the fast ignition and combustion of the new charge. There was a general high production of CO when cow dung was combusted at 20 % less air/fuel ratio as compared to at stoichiometric and 30 % excess air to fuel ratio.

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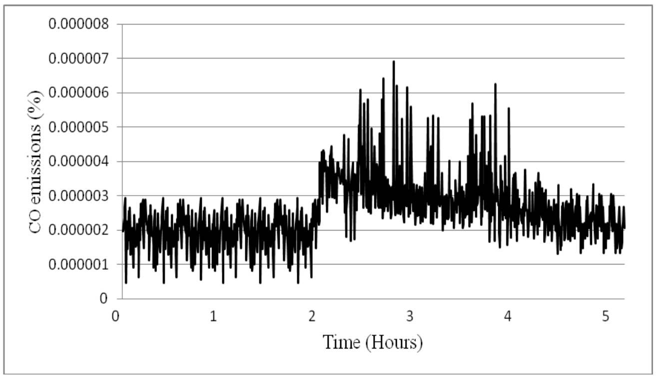

Figure 10: Graph of CO profile at 20% less air/ fuel ratio.

In general the proportions of CO_2 and CO emitted during combustion of cowdung at different feeding rates vary in proportions. It was established that during combustion at excess air to fuel ratios, CO emitted was lower as compared to combustion at less air to fuel ratios.

In stable combustion conditions, the amount of carbon monoxide in flue gas was in a mean range of 0.000003 % on the higher side and 0.000002 % on the lower side as combustion progressed. This was lower than emissions encountered during combustion at stoichiometric and 20 % less air/fuel ratios. According to Permchart W. and Tanatvanit S., [8] on rice husks, the combustor loading and excess air significantly affects CO concentration such that at reduced loads it becomes lower because of increase in the residence time of reactants.

Carbon dioxide in flue gas during cow dung combustion attained a maximum value of 3.5%. This was dependent on the combustion temperatures and fuel feed rates. This proportion was found to be less than what Brian *et al.*, [9] obtained while combusting coal using a fluidized bed combustor, whereby Carbon dioxide emitted ranged between 10 - 8.9 %. This indeed shows a reduction of Green House Gas (GHG) emission in using biomass (cow dung) to the use of fossil fuels (coal).

CONCLUSION

The study undertaken on combustion characteristics of cowdung in a fluidized bed combustor at varying feeding rates revealed that;

1. CO_2 and CO emitted vary in proportions depending on the feeding rates of cowdung to the combustor
2. Stable combustion process occurs at approximately 30% excess air to fuel. This is due to less emissions of CO as compared to stoichiometric or 20% less air to fuel ratios
3. CO_2 emitted in combustion of cowdung is significantly less compared to other fuels like coal which are in the range of 10-8.9%.

Therefore this study finds that combustion of cowdung in a fluidized bed combustor emits gaseous products including CO_2 and CO which are substantially less compared to other fuels like coal. Hence adoption of this technology will bring reduction of GreenHouse Gases (GHG)

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