ISSN 0511-5728
The West Indian Journal of Engineering
Vol.41, No.2, January 2019, pp.22-30

Modular and 3D-Design of a Fluidised Bed Boiler with Agricultural Residue for Steam Energy Production

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(Received 18 February 2018; Revised 23 April 2018; Accepted 13 September 2018)

Abstract: *In this study, a miniature fluidised bed boiler for steam generation was designed and constructed. The boiler is made up of a steam drum, combustion chamber, downcomer and riser tubes as a heat exchanger, a non-return valve and superheater tube. Experimental investigation on the fuel distribution was carried in two-dimensional chamber with cross-section of 500 mm x 1000 mm and bed height of 77 mm, 47 mm and 27 mm. The results obtained from the performance evaluation of the fluidised bed boiler operated with corncob at constant feed rate of 6kg/h for various bed heights of 77 mm, 47 mm and 27 mm recorded stability in the saturation temperature of 121 ^oC at 50 minutes, 144 ^oC at 45 minutes and 153 ^oC at 30 minutes, respectively. In additional, saturation pressures of 2.0 bar from 50 to 55 minutes for bed height of 77 mm, 2.1 bar from 45 to 50 minutes for bed height of 47 mm and 3.6 to 3.7 bar from 45 to 55 minutes for bed height 27 mm were obtained. The effect of fuel particle size on emissions and over all combustion efficiency of corncobs has proven to be efficient in a fluidised bed boiler as the emission analysis of the flue gas has shown to be low in various percentages of 0.0003% of NO_x, 0.001% HC, 0.02% of CO and 0.93% of Nitrogenm, respectively.*

Keywords: *Solid fuels, Bed height, Heat transfer, Steam, Saturated temperature, Saturated pressure, Flue gas*

1. Introduction

Fluidised bed combustion (FBC) is a combustion technology that offers many unique advantages such as large interfacial surface areas between the fluid (gas or liquid) and particles, high fluid-particles contact efficiency, excellent heat transfer, uniform bed temperature and the ability to handle wide range of solid fuels (Thenmozhi and Sivakumar, 2013; Zhou et al., 2008). In its most basic form, fuel particles are suspended in a hot, bubbling fluidity bed of ash and other particulate materials (sand, limestone, etc.) through which jets of air are blown to provide the oxygen required for combustion. The resultant fast and intimate mixing of gas and solids promotes rapid heat transfer and chemical reactions within the bed. FBC plants are capable of burning a variety of low-grade solid fuels, including most types of coal and woody biomass, (Thenmozhi and Sivakumar, 2013) at high efficiency and without the necessity for expensive fuel preparation (e.g., pulverising).

According to American Society of Mechanical Engineers (ASME), a steam generating unit is defined as a combination of apparatus for producing, furnishing or recovering heat together with the apparatus for transferring the heat so made available to the fluid being heated and vaporised (Rajput, 2010). Boilers are pressure vessels designed to heat water or produce steam, by combustion of fuel which can then be used to provide space heating and/or service water heating to a building (Odigure et al., 2005). Steam is preferred over hot water in some applications, including absorption cooling, kitchens, laundries, sterilisers, and steam driven equipment. Steam is therefore important in engineering and energy studies. Boilers are classified into different types based on their working pressure and temperature, fuel type, draft method, size and capacity, and whether they condense the water vapour in the combustion gases.

Boilers are also sometimes described by their key components, such as heat exchanger materials or tube design. Two primary classifications of boilers are Fire tube and Water tube boilers. In a Fire tube boiler, hot gases of combustion flow through a series of tubes surrounded by water. On the other hand, in a water tube boiler, water flows in the inside of the tubes and the hot gases from combustion flow around the outside of the tubes. Steam generator is a complex integration of furnace, superheater, reheater, boiler or evaporator, economiser and air preheater, along with various auxiliaries such as pulverises, burners, fans, stokers, dust collectors and precipitators, ash-handling equipment, and chimney or stack. The boiler (or evaporator) is that part of the steam generator where phase change (or boiling) occurs from liquid (water) to vapour (steam), essentially at constant pressure and temperature (Nag, 2008).

Biomass is an intriguing alternative fuel as it is readily available in various forms throughout the world, is renewable and can be harnessed by agricultural means. Though biomass is a renewable source, the growth of some materials, such as wood, is a very long process and cannot be rapidly grown, while other crops are perennial, such as corn, straw and switch grass (Saidur et al., 2011). Growth rate as well as availability must be considered while selecting a viable crop. It is also necessary to replace nutrients that are absorbed from the ground by plant growth or biomass production will be depleted over time (Christensen, 2011).

A wide variety of techniquesis available to utilise biomass resources, but the most efficient have been to burn them directly for heat in a controlled environment. The crop residues that are commonly used as sources of energy includes rice husks, sugar cane fiber, groundnut shells, maize cobs, coconut husks, and palm oil fibre. (Kyauta et al., 2015). The use of biomass as alternative sources of energy is attractive because it addresses both problems of waste disposal and fuel wood shortages (Armesto et al., 2002; Varol et al., 2014). The extraction of useful energy from biomass could contribute to sustainable development and bring very significant social and economic benefits to both rural and urban areas (Khan et al., 2009). Folayan et al. (2015) investigated the environmentally friendly methods of extracting biomass energy for rural use, one such means is energy recovery using fluidised bed combustors. This system uses agricultural waste as fuel source to produce heat energy as an alternative to power rural community for light load applications. Test results recorded high flue gas and bed temperatures of over 300°C and 850°C respectively, suitable for rural application including grain drying and water boiling.

Martínez et al. (2011) presented the conceptual design of a three fluidised beds combustion system capturing CO_2 with CaO. In their work, three fluidised bed reactors are interconnected in such a way that it is possible to perform the $CaCO_3$ calcination at a temperature of 950 ^oC with the energy transported by a hot solid stream produced in the circulating fluidised bed combustor operating at 1030 ^oC. They presented that the stream rich in CaO produced in the calciner was splited into three parts. The reported result shows that due to high temperatures involved in all the system, it was possible to recover most of the energy in the fuel and to produce power in a supercritical steam cycle. A case study was studied and it was demonstrated that under these operating conditions, 90% CO_2 capture efficiency can be achieved with no energy penalty further than the one originated in the CO_2 compression system.

Ohijeagbon et al. (2013) reported on the design of laboratory fire tube boiler for eventual construction and use as teaching aid and for research purposes, the design enables the availability of portable and affordable steam boiler for steam generation in school laboratory and to enhance research and students' learning process in area of thermodynamics, heat transfer and energy studies.

The objective of this work seeks the utilisation of locally sourced materials to design, develop and test the fluidised bed boiler for steam generation by carrying out technical feasibility of using corncob as fuel and varying the bed height while keeping the superficial velocity of fluidising gas constant. More so, the characteristic of the steam generated was used in the selection of an applicable steam turbine.

2.0 Material and Methods

2.1 Description of the Fluidised Bed Boiler

The physical geometry of the fluidised bed water tube boiler was developed and a 3-D model diagram is shown in Figure 1. The boiler consists fundamentally of the fluidised bed combustion chamber and steam drum, other parts such as; steam tubes, steam trap, steam tap, downcomer, exhaust pipe, air blower and insulations were designed in the geometry of the miniature water-tube steam boiler.

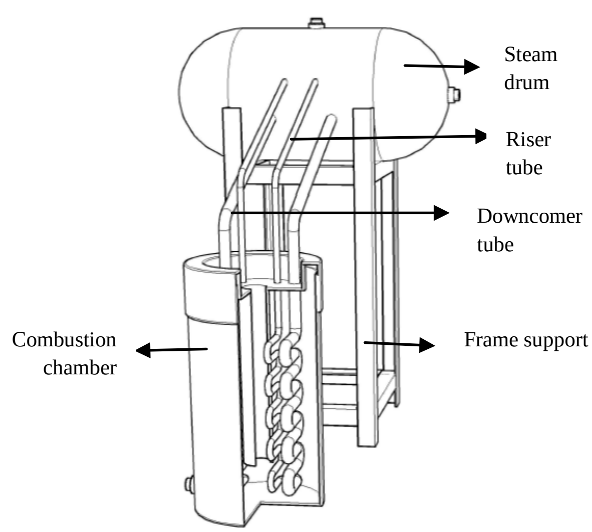

Figure 1. 3-D Model of the Developed Boiler

2.2 Design Considerations

The systematic approached to the design, fabrication, experimental procedure and testing of the (Boiler and Code, 1989) developed bubbling fluidised bed boiler for energy generation are as follows:

i. Steam pressure of 2 bar to 5 bar
ii. Steam temperature of 120 ^oC to 180 ^oC
iii. Steam capacity of 2 kg/h to 10 kg/h

iv. Stoichiometric air-fuel ratio
v. Calorific value of corncob as fuel

2.3 Material Selection

The suitable materials selected for the fabrication of the fluidised bed boiler were selected based on the physical and mechanical properties, and their availability. The materials include the following:

i. Galvanised plate was used for the steam drum because it can withstand high temperature applications and resistivity to corrosion.
ii. Galvanised pipes were used for steam tubes due to its hollow shape.
iii. Mild steel plate was used for fluidised bed combustion chamber because of its high melting temperature resistance.
iv. Mild steel used as the grate and distributor plate because of the reaction that is expected to occur during combustion.
v. Safety valve and Non-return valve were made of brass
vi. Granular Material (Sand)
vii. Pipes and Fittings were made of galvanised materials

2.4 Design Theories and Calculations

The boiler is a vessel that operates under pressure; hence, the design theories are the basic principles considered to evaluate the various parameters, dimensions and the performance of the boiler under internal pressure.

2.4.1 Internal Designed Pressure of a Boiler

The design pressure higher than operating pressure with 10% or more will satisfy the requirement. The maximum allowable working pressure is the maximum permissible pressure at the top of the boiler in its normal operating position at specific temperature. This pressure is based on the nominal thickness. The internal design pressure is given by (Ohijeagbon et al., 2013).

$$P_d = \frac{\sigma_u \times t}{R_i \times f_s} \quad (1)$$

where, P_d = Internal design pressure on inside of drum or shell (N/m^2)
σ_u = Ultimate strength of plate (N/m^2)
t = Thickness of plate (m)
R_i = Internal radius of drum (m)
f_s = Factor of safety (ultimate strength divided by allowable working stress)

Tensile stress, σ_{ut} = 385 MN/m^2
Compressive stress, σ_{uc} = 665 MN/m^2
Shear stress, τ = 308 MN/m

2.4.2 Stresses in Tubes and Drums

Stresses are induced in different parts of an operating boiler by the temperatures and pressures of hot flue gases, feed water and steam respectively. The magnitudes of these stresses must be known so that the boiler will be operated under safe conditions. Thus, the wall of the boiler subjected to internal pressure has to withstand two types of tensile stress, namely, 1) Circumferential or hoop stress and 2) Longitudinal stress (Khurmi and Gupta, 2005)

$$\sigma_{t1} = \frac{P_d \times D_i}{2t} \quad (2)$$

where, P_d = Internal design pressure of the drum or shell (N/m^2)
σ_{t1} = Circumferential or hoops stress (N/m^2)
t = Thickness of plate (m)
D_i = Internal diameter of drum (m)

$$\sigma_{t2} = \frac{P_d \times D_i}{4t} \quad (3)$$

where, σ_{t2} = Longitudinal stress (N/m^2)

2.4.3 Design of the Steam Drum

The design of this component must be strong enough to contain steam or hot water that was generated and to mechanically hold the boiler tubes as they expand and contract with changes in temperature. Hence, its volume is of importance and is written as (Balogun et al., 2016).

$$V_{dru} = A_{dru} \times L_{dru} \quad (4)$$

where, A_{dru} = Cross sectional area of the drum (m^2)
L_{dru} = Length of the drum (m)

2.4.4 Design of the Steam Tube

Materials which can withstand high temperature and resistance to corrosion such as galvanised steel material was selected to form tubes.

$$V_{st} = A_{st} \times L_{st} \quad (5)$$

where, A_{st} = Cross sectional area of the tube (m^2)
L_{st} = Length of the drum (m)

2.4.5 Design Height of the Combustion Chamber

This is given by the ratio of volume to combustion chamber area of the boiler (Balogun et al., 2016).

$$H_{com} = V_{com} / A_{com} \quad (6)$$

where, H_{com} = Height of the combustion chamber (m)
V_{com} = Volume of the combustion chamber (m^3)
A_{com} = Cross sectional area of the combustion chamber (m^2)

2.4.6 Minimum Wall Thickness of Tubes and Drum

The minimum required wall thickness of a boiler is a value beyond which the boiler wall cannot be easily damage by the operation pressure in a boiler. The formula is given as (Ohijeagbon et al., 2013).

$$t_w = \frac{P_d \times R_i}{\sigma \times \eta_E - 0.6P_d} \quad (7)$$

where, σ = Allowable working stress of the material (N/m^2)
t_w = Minimum wall thickness (m)
η_E = Ligament efficiency of the welded joint

Therefore, the minimum wall thickness of the tubes is given as:

$$t_{w\,tubes} = \frac{P_d \times r_i}{2 \times \sigma \times \eta_E + 0.8P_d} + C \tag{8}$$

where, C = Corrosion allowance

2.4.7 Velocity of Fluid inside Tubes, Pipes and Drum

To control the boiler operation, it is necessary to determine the velocity of fluid. It is given as (Ganapathy, 2003)

$$V = 0.05 \times M_w \times \frac{v}{D_i^2} \tag{9}$$

where, V = Velocity (m/s)
v = Specific volume of liquid (m^3/kg)
M_w = Mass of water in the steam drum (kg/hr)
D_i^2 = Square of inner diameter of the drum (mm)

For steam, v can be obtained from steam table.

2.4.8 Quantity Flow Rate of Fluid inside Tubes

The quantity of fluid to be delivered depends upon the inside diameter of the tube, and is given as:

$$Q_d = \frac{\pi}{4} d_i^2 \times V \tag{10}$$

where, Q_d = Quantity flow rate (m^3/h)

Therefore, in boiler design the operating pressure of a boiler must be determined in order to make other important calculations required for effective functioning of the boiler. Table 1 shows the summary of the design calculation.

2.5 Construction Procedures

The techniques followed in order to achieve the modular construction of the developed fluidised bed water-tube boiler and evaluation of the materials that were used are as follows:

2.5.1 Combustion Chamber

The combustion chamber was fabricated from mild steel of thickness 3 mm, which was rolled into shape to form a diameter of 0.5 m and 1 m long (see Figure 2), was adopted for the fluidised bed combustion chamber. A perforated distributor grate that was made from mild steel was also adopted for the combustion of fuel and the whole combustion chamber was enhanced by air blower rated as 0.28 kW which provides the air for combustion.

2.5.2 Steam Drum

The steam drum was fabricated from a galvanised steel of 3 mm thick and welded together by gas welding to form the drum of 1m long and 0.6 m in diameter (see Figure 2), in which water was feed in at top through a valve, and steam tubes and downcomers was also be welded to it. The downcomer which convey water from the drum into combustion chamber where it was heated to form steam due to density differences of water in both steam tubes and downcomers results into natural circulation. Lastly, it was designed to hold up to 40 liters of water, steam pressure of 5 bars was also anticipated and steam capacity of 10 kg/h was also being desired.

Figure 2. Combustion Chamber at Early Stage of Fabrication with Coiling of Tubes

Figure 3. Steam Drum at Early Stage of Fabrication (Gas Welding)

2.5.3 Steam tubes

Materials which can withstand high temperature and resistance to corrosion such as galvanised steel materials were selected to form tubes. The steam tubes of 0.0127 m diameter were achieved after machining processes. Both downcomer and riser tubes were fabricated from a ¾" and ½" galvanised pipe of 3 m long that was cut and then bent it into 3” curvature (see Figure 3), which was 76.2 mm. Two (2) downcomer and riser tubes were achieved in line with these design specifications, welded to front of the steam drum, and went through the top of the combustion chamber. The curvature of tubes at the bottom bend was allowed to suspend at a height of 0.3 m just above the distributor plate.

Table 1. Summary of the Design Calculation

Initial Data	Calculations	Results and Remarks
Type of boiler	Bubbling fluidised bed boiler	
Internal designed pressure of the boiler		
σ_{ut} = 385 MN/m^2 t = 0.003 m R_i = 0.3 m f_s = 5	$P_d = \frac{\sigma_u \times t}{R_i \times f_s} = \frac{385 \times 0.003}{0.3 \times 5}$ $P_d = 0.77\ MN/m^2 \cong 770{,}000\ N/m^2$ Hence, $P_d = 7.7\ bar$	The design pressure was calculated as: $P_d = 7.7\ bar$
Stresses in the tubes and drum		
For the Drum P_d = 7.7 bar t = 0.003 m D_i = 0.6 m	$\sigma_{t1} = \frac{P_d \times D_i}{2t} = \frac{0.77 \times 0.6}{2 \times 0.003}$ $\sigma_{t1} = 77\ MN/m^2$ $\sigma_{t2} = \frac{P_d \times D_i}{4t} = \frac{0.77 \times 0.6}{4 \times 0.003}$ $\sigma_{t2} = 38.5\ MN/m^2$	σ_{t1} = Circumferential or hoops stress (N/m^2). Calculated as $\sigma_{t1} = 77 \times 10^6\ N/m^2$ σ_{t2} = Longitudinal stress (N/m^2). Calculated as $\sigma_{t2} = 38.5 \times 10^6\ N/m^2$
Design of steam drum		
$D_i = 0.6\ m$ L_{dru} = 1 m	Volume of steam drum or boiler shell $\frac{\pi}{4} \times 0.6^2 \times 1 = 0.283\ m^3$	For this design specification, the volume of steam drum was calculated as V_{dru} = 0.283 m^3
Design of steam tubes		
$d_i = 0.0127\ m$ L_{st} = 3 m	Volume of tube $\frac{\pi}{4} \times 0.0127^2 \times 3 = 0.038\ m^3$	Babcock and Wilcox, stated that the minimum and maximum allowable tube diameter are 0.01 m and 0.0635 m. Therefore, the volume of the steam tube was calculated as $V_{st} = 0.038\ m^3$
Design of combustion chamber		
$D_i = 0.5\ m$ H_{com}= 1 m	Volume of combustion chamber $V_{com} = \frac{\pi}{4} \times 0.5^2 \times 1 = 0.196\ m^3$	For this design specification, the volume of combustion chamber was calculated as V_{com} = 0.196 m^3
Types of feed Bed material	Agricultural waste (chipped corncob and charcoal) Sand	The corncob was from Shika community, Zaria. Sand material of 250 µm and particle density of 2.659 g/cm^3 was used with bed height of 0.027 m, 0.047 m and 0.77 m were adopted.
Design of minimum wall thickness		
For the Drum $P_d = 0.77 MN/m^2$ D_i = 0.6 m η_E = 1 $\sigma_{t1} = 77\ MN/m^2$ Also, for the tube $d_i = 0.0127\ m$ $C = 3$	$t_w = \frac{P_d \times R_i}{\sigma \times \eta_E - 0.6P_d} = \frac{0.77 \times 0.3}{77 \times 1 - 0.6 \times 0.77}$ $t_w = 3.0181 \times 10^{-3}\ m$ $t_w = 3.018\ mm$ $t_{w\ tubes} = \frac{P_d \times r_i}{2 \times \sigma \times \eta_E + 0.8P_d} + C$ $t_{w\ tubes} = \frac{0.77 \times 0.00635}{2 \times 77 \times 1 + 0.8 \times 0.77} + 3$ $t_{w\ tubes} = 3.0312\ mm$	$t_w = 3.018\ mm$ Take $t_w = 3.0\ mm$ $t_{w\ tubes} = 3.0312\ mm$ Take $t_{w\ tubes} = 3.0\ mm$
Velocity of fluids in tubes, pipes and drum		
From steam table; v = 0.3427 m^3/kg of water @ 155 ºC M_w = 48 kg/hr	$V = 0.05 \times M_w \times \frac{v}{D_i^2} = 0.05 \times 48 \times \frac{0.3427}{0.6^2}$ $V = 2.284\ m/s$	For this design specification, the velocity of fluids in the steam drum is calculated to be $V = 2.284\ m/s$
Quantity flow rate of fluid inside tubes		
$V = 2.284\ m/s$ d_i = 0.0127	$Q_d = \frac{\pi}{4} d_i^2 \times V = \frac{\pi}{4} \times 0.0127^2 \times 2.284$ $Q_d = 2.8933 \times 10^{-4}\ m^3/h$	Q_d= 0.000289 m^3/h $Q_d = 4.817 \times 10^{-6} m^3/min$
Design of frame support		
L = 0.6 m B = 0.3 m H = 1.5 m	Area of frame support $A_{fs} = 0.6 \times 0.3 \times 1.5 = 0.270\ m$	$A_{fs} = 0.270\ m$

2.6 Experimental Procedure

Fine sand of 250 µm was fed evenly onto the distributor plate through the manhole opening up to a desired static bed height of 77 mm, 47 mm and 27 mm respectively. An air blower with capacity of 0.7 MPa rated 0.28 kW, 60 Hz was used to provide the buoyant forces for fluidisation and in addition provides the oxygen for combustion. Some charcoal in small pieces was fed onto the bed for pre-heating of the system. Additionally, 1 kg of the corncob waste samples from Shika community, Zaria as the raw biomass fuel was cut into pieces with 3 ± 0.5 mm in diameter and 10 ± 0.5 mm in length to equalise their sizes and was feed in at 10 minutes’ interval through the hopper.

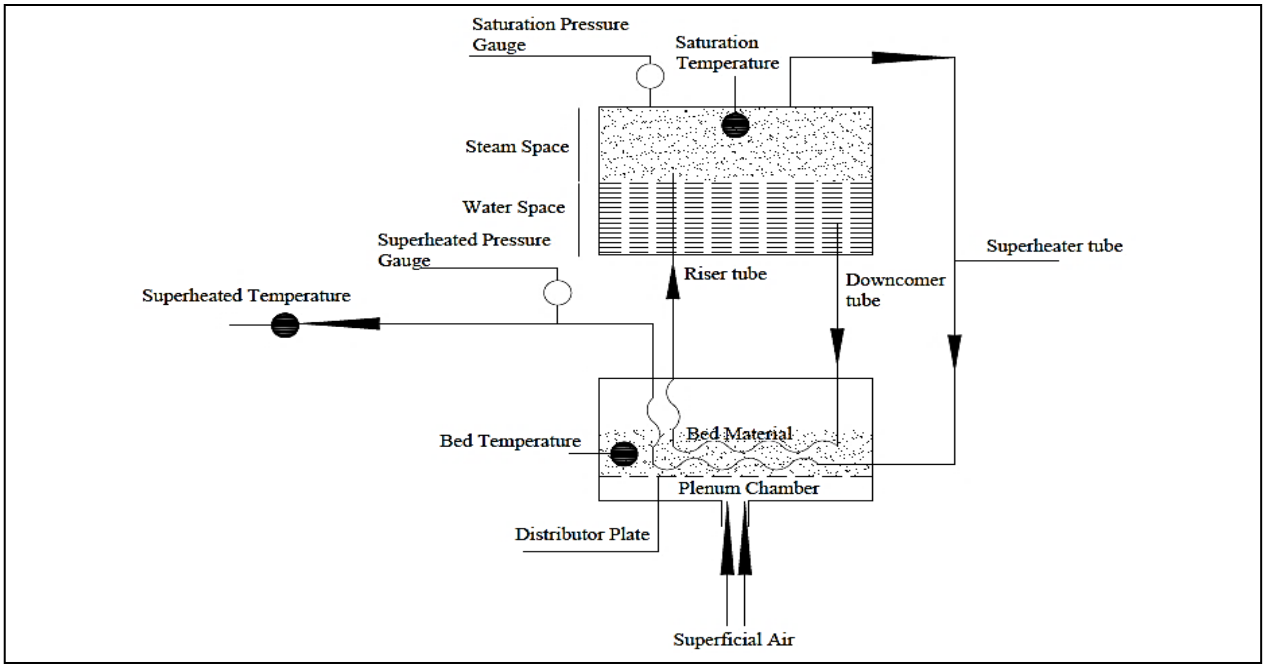

Figure 4. Schematic Flow Diagram of the Developed Boiler

Figure 4 shows three temperature-measuring devices that were used to determine temperatures at various points; mercury in glass thermometer ranging from 0 °C-360 °C was used to determine the ambient temperature as well as the initial temperature of the water. Two digital thermometers (Kane-May and MASTERTECH multipurpose clamp meter) with thermocouple wire props having one connected to the outlet of the super-heater tube, one buried in the bed to determine the bed temperature, one inserted in the steam drum to determine the saturated temperature and the last one connected to the exhaust pipe to determine the temperature of the flue gases at every 5-minutes interval.

3. Results and Discussion

The combustion of agricultural residue (corncobs) in the developed fluidised bed boiler are described in this section. The influences of operating parameters such as; the effect of pressure, effect of temperature as a function of time, steam generated with respect to bed heights, and emission characteristics are discussed.

3.1 Saturation Temperature of Steam

The temperatures of the steam at the steam drum with respect to time were taken at 5 minutes' interval. According to literature, a denser material and larger volume of bed height required more bed pressure to equalise the gravity force for fluidisation (Hilal et al., 2001). It was deduced from Figure 5 that the saturation temperature of water in the steam drum increases with increase in time; subsequently, from the bed heights of 77 mm, 47 mm and 27 mm. There was a noticeable change at 10 minutes in the temperature. This can be said to be attributed to heat gain by the water.

In addition, there was a rapid change in temperature at 25 minutes this is attributed to phase change of water from liquid to vapour. Temperature stability was attained in the bed height of 27 mm at 30 minutes from temperature ramp of 153 °C to 155 °C compare to bed height of 47 mm and 77 mm which were at 40 minutes and 45 minutes which were in temperature ramp of 142 °C to 144 °C and 117 °C to 121 °C, respectively. This behavior is attributed to complete bubble fluidisation of the crystalline material and the specification of the blower being able to provide enough buoyant force of fluidization (see Figure 5).

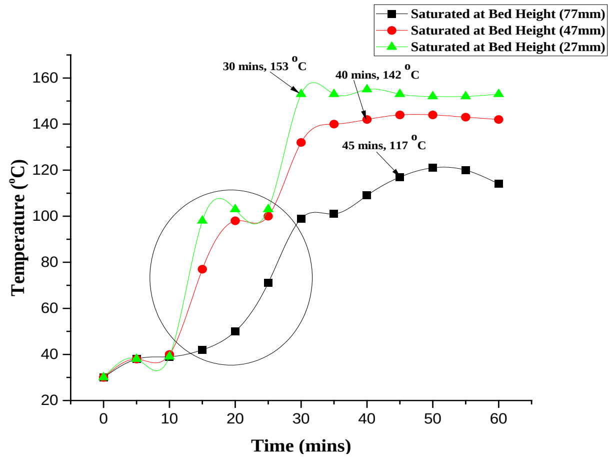

Figure 5 Saturation Temperature of Steam/Bed Height as a Function of Time

3.2 Saturation Pressure of Steam

Pressure developed is a major parameter in any designed boiler (Zhong et al., 2006), Figure 6 presents the saturated pressure obtained which revolve round the designed pressure. Saturation pressures of the steam from steam drum at 5 minutes' interval were taken. It shows that the maximum saturation pressure obtained from the three experiments carried out was 3.7 bar.

The pressures obtained are 2.0 bar from 50 to 55 minutes for bed height of 77 mm, 2.1 bar from 45 to 50 minutes for bed height of 47 mm and lastly, 3.6 to 3.7 bar was obtained from 45 to 55 minutes for bed height 27 mm.

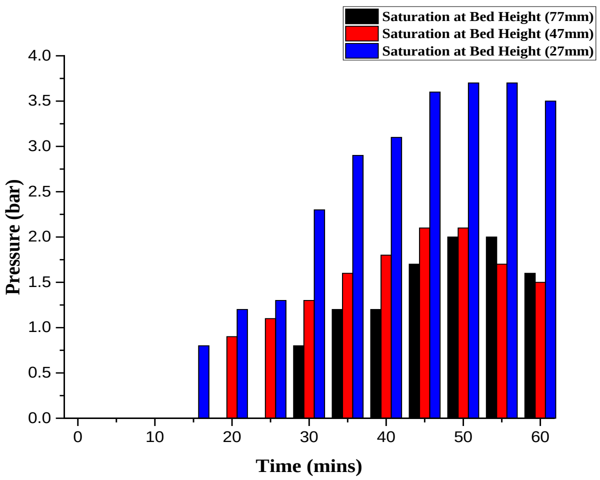

Figure 6. Saturation Pressure of Steam/Bed Height as a Function of Time

3.3 Amount of Steam Generated

Figure 7 shows the plot of the amount of steam generated in kg/h in the steam drum of the developed fluidised bed boiler. The figure revealed that 5.6 kg/h of steam was achieved from bed height of 77 mm, 6 kg/h was achieved from 47 mm and 6.6 kg/h as maximum capacity of steam achievable from the bed height of 27 mm and this is capable to run a small steam turbine, sterilisation of medical equipment, laundry and soil steaming for pest control.

3.4 Flue Gas Temperature at Exhaust Pipe

Figure 8 shows the flue gas temperature of the developed fluidised bed. The initially measured temperature of the bed at the onset of fluidisation was 51 ^{o}C for bed height of 77 mm, 86 ^{o}C for bed height of 47 mm and 89 ^{o}C for bed height of 27 mm respectively. Conversely, it increases with increase in time (Folayan et al., 2015) up to 45 minutes, at 50 minutes a drop in temperature begins to set in and this is because of fuel stoppage.

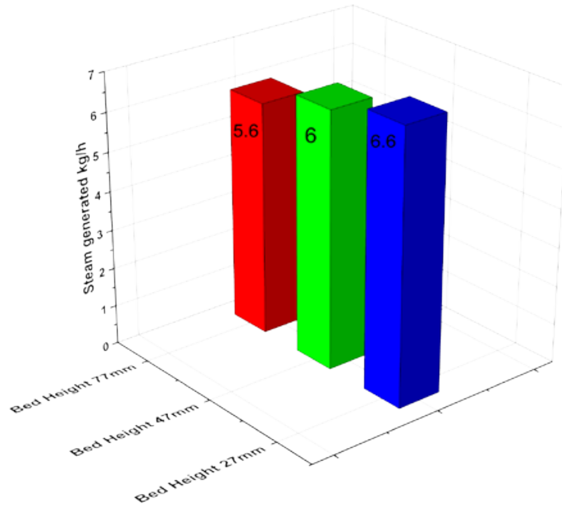

Figure 7. Steam Generated as a Function of Bed Height

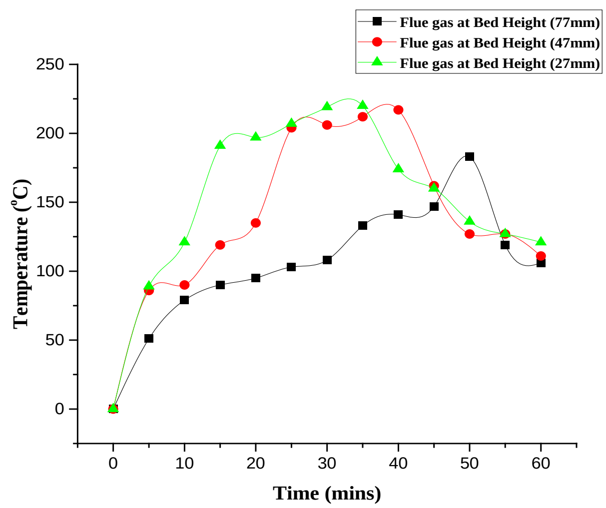

Figure 8. Flue Gas Temperature as a Function of Time

3.5 Analysis of Flue Gas Emission

The exhaust flue gas of the developed boiler is presented below after being analysed with a flue gas analyser. Figure 9 presents the exhaust emission in their percentages to be 0.001% of hydrocarbon, 0.0003% for oxides of nitrogen, 0.02% of carbon monoxide, 0.04% of carbon dioxide.

The harmful emissions were very low and this is attributed to granular material which is crystalline in nature that absorbs the harmful gas within it (Thenmozhi and Sivakumar, 2013). The excess nitrogen that was present for the combustion was found to be 0.93%. In conclusion, the oxides of Sulphur were found to be zero and this can be said to be attributed to low contents of Sulphur in biomass fuel.

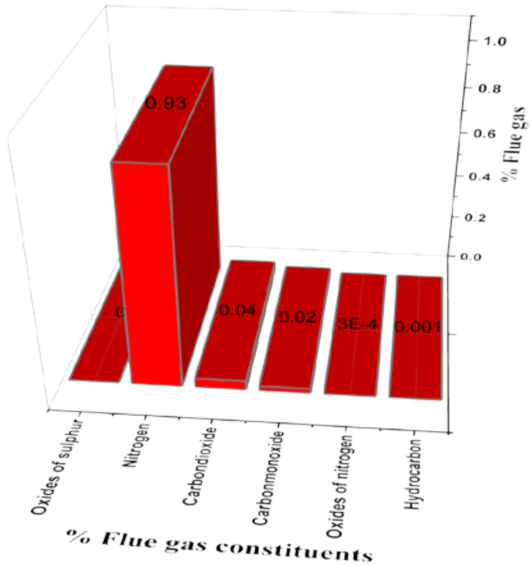

Figure 9. Percentage Composition of the Flue Gas Constituent

4. Conclusions

Fluidised bed technologies are proving to be the most practical option for biomass conversion. The fabrication of the boiler was successfully accomplished based on the design specifications of length of steam drum to be 1 m, diameter of 0.6 m, the length of the steam tubes of 3 m and diameter of 0.0127 m, respectively. Local mild steel and galvanised steel were sourced for the fabrication owing to the fact they have heat resistance and corrosion resistance.

The result of the performance evaluation showed that the bed height of 27 mm gives a better fluidisation result. Stability in the saturation temperature of steam was observed at 30 minutes up to 60 minutes with corresponding temperature ramp of 153 °C to 155 °C. The efficiency of the boiler was found to be 53.69% for bed height of 77 mm, 57.42% for bed height of 47mm and 61.72% for bed height of 27 mm. This shows that the developed fluidised bed boiler has its application in medium capacity steam turbine.

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