Fabrication Process of A Water Steam Boiler Using Palm Kernel Shell As Fuel

Lawal A. S[1]., Kareem B.[2], Adetula S. A.[3]
[1] Department of Mechanical Engineering, Ekiti State University Ado Ekiti, Nigeria,
[2]Department of Industrial and Production Engineering, Federal University of Technology, Akure, Nigeria,
[3]Department of Mechanical Engineering, Federal University of Technology, Akure, Nigeria,

ABSTRACT : *A boiler is a device used to create steam by applying heat energy to water. The aim of this study is to develop a 5KV palm kernel shell steam boiler. Design drawing were produced and used to fabricate palm kernel shell steam boiler combusting unit. Durability, local availability, and functionality were considered in the design of components. Boiler's maximum combustion efficiency, steam temperature and pressure were estimated. The boiler's maximum steam temperature and mass flow rate recorded for 5kW power rating were 220^{o}C and 0.035kg/s respectively and were adequate as alternative source of energy.*

KEYWORDS - *Boiler, Furnace, Palm Kernel Shell, Flow Rate, Alternative Energy Source*

I. INTRODUCTION

A steam generator or boiler is a closed vessel made of high-quality steel in which steam is generated from water by the application of heat. Function of boiler is to convert chemical energy of the fuel to heat energy and to transfer this heat energy to water for evaporation as well as to steam for super heating [1]. Boilers are pressure vessels designed to heat water or produce steam which can then be used to provide space heating and/ or service water heating to a building. In most commercial heating applications, the heating source in the boiler is a natural gas fired burner. Steam is preferred over hot water in some applications, including absorption cooling, kitchen, laundries, sterilizers and steam driven equipment [1].When water is boiled into steam, it's volume increases about 1,600 times, producing a force that is almost as explosive as gun powder. This causes the boiler to be extremely dangerous equipment and should be treated carefully. Any part of the boiler metal that actually contributes to making steam is known as heat surface. Heating surface is any part of the boiler; hot gases for combustion are on one side and water on the other side. The burner is meant for the combustion generated, while the boiler is meant for building steam [2]. The Ineffective utilization of biomass from the steam boiler, constitutes environmental hazard and pollution, it also leads to emission of strong irritating smell due to microbial breakdown activities at dump sites. Despite providing useful heat to generate power, there are unwanted byproducts generating from the process, which are the stack gases. This calls for an efficient utilization of this biomass as fuel for the industry. These waste products can be in form of Empty fruit bunches, palm fiber and palm kernel shell**.** Palm kernel shells are remnants of the palm oil refining process and have long been abandoned. Palm kernel shell (PKS) is characterized by high calorific value and as a result, it has been a choice to fuel boilers. Application of PKS in most combustor have been adversely challenged by quantity and quality of ash generated. PKS shows tendency of bed agglomeration in fluidized bed combustor due to its high alkali content. Increased ash deposition resulting from PKS combustion has been linked to decrease in the combustor utilization efficiency, increased damages and maintenance challenges. This development has attracted research effort towards improvement on PKS calorific value for effective operation of combustion system [3]. PKS can be suitably mixed with additives to raise melting temperature of ash higher than those encountered in steam power plant. This will reduce ash deposition and eventually increase its potential for use in heat and power production. Addition of kaolin has improved ash characteristics of palm empty fruit bunch (EFB), which adsorb volatile potassium (25% content) at maximum temperature, 900 °C. The use of alumina sand or dolomite as the bed material in the conical fluidized bed combustor confirmed safe utilization of PKS at elevated potassium content. Aluminum silicate, phosphorus and calcium in sewage sludge played critical role in capturing potassium from wheat straw upon combustion for heat and power generation [4, 5]. Several technologies such as grate (1 kW–50 MW), fluidized (5 MW–100 MW) and dust technology (10 MW–500 MW) have been used to enable oil palm mill to generate enough energy for its consumption and sometimes export excess. Efficiencies of these technologies are dependent on fuel properties and the mixing quality between flue gas and combustion air. Grate-fired boilers are characterized with low sensitivity to fuel bed agglomeration and this is of advantage when applied to biomass combustion, since biomass fuels often have low ash melting temperatures. Deposit formation and high temperature corrosion on biomass grate furnaces can be mitigated using additives [6]. Additives are groups of minerals or chemicals that can change the ash chemistry, decrease concentration of thought-provoking species and increase ash melting temperature in biomass combustion process. The materials that have been found to raise the melting temperature of ash higher than one normally encountered in grate furnace includes aluminum oxide (Al_2O_3), magnesium oxide (MgO), calcium oxide (CaO), limestone ($CaCO_3$) and kaolin [7]. Additives such as A $l_2O_3$and SiO_2 reduced the slagging potential of coal and biomass combustion in utility boiler, but the drop in slagging propensity is weightier by adding Al_2O_3 in contrast with SiO_2 as established by chemical equilibrium calculations [8]**.** Addition of CaO, MgO and bauxite with high alkali biomass produced high alkali compound relative to alkali chloride. On this basis, Al_2O_3, MgO and CaO would be promising when use as ash reduction agents palm kernel shell combustion in a grate furnace. Ash deposition on the surface of furnace components can inhibit heat/power generation. Many industrial and small scale furnaces and steam boilers fueled with PKS have been developed. PKS was found to be attractive renewable energy source with high heat content. The effect of ash deposition on the heating value was rarely considered in the past studies. Many of the past studies focused on how best the tides of gaseous emissions (pollutants) can be reduced to the barest minimum. Though they have recorded a degree of success in emission reduction, no tangible success has been recorded in the area(s) of minimizing ash deposition and/or maximization of heating value [6, 10]. Today, many countries began to try to put palm shell mixed coal fuel together to provide energy to alleviate the rising costs of fuel and reduce carbon dioxide emissions [2]. Large-scale palm oil plant uses the recovered fiber and nutshells to fire the steam boilers for power generation and steam supplying in the palm oil mill. The palm kernel shell is used as a source of fuel for the boilers and can be disposed of as gravel for plantation roads maintenance. Blacksmiths also buy the shells to use as fuel material in their casting and forging operations [9, 10].

II. MATERIALS AND METHOD

The main components of this furnace are steam drum, down comer, riser tubes which represents the complete fluid flow loop. Water flows to the steam drum through down comer riser loop. The riser tubes were situated inside furnace where heat of flue gases vaporizes the water into steam and back to the steam drum through steam header collection (Fig. 1). Due to the fact that steam water mixture inside riser tubes is less dense than the saturated water at inlet tube, fluid flows upwards in the riser tubes and back to the drum. The density difference between water at the inlet tube and steam-water mixture produces enough force to overcome friction and gravitational resistance to flow, therefore maintain a steam flow system. The steam drum is partitioned into two zones. The lower section allows water intake to the drum while the upper section produces steam which flows from the top of the drum into the superheated tube. The superheated steam is expected to turn turbine to generate electricity.

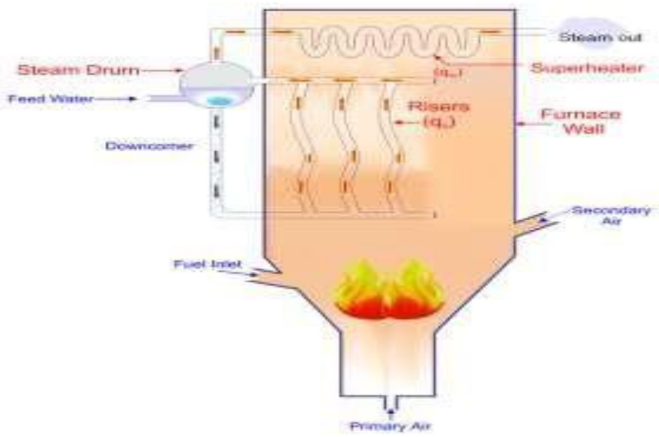


Figure 1. Water to Steam Circulation Loop [6]

The raw materials used in this study were kaolin, ball clay and hard wood sawdust. The sawdust in the mixture form uniform pores in order to allow heat energy stored in kaolin and it did not bloat while ball clay serves as binding agent. The ball clay was soaked in water for five days to allow it to dissolve completely in orders to separate colloids from pebbles. The kaolin was milled to powder form using ball mill and then sieved to particle size of diameter 2.5 mm. The ball clay was sieved to 1.0 mm and similarly powders of sawdust of particle size 2.5 mm. The study carried out had a composition of kaolin as 60% by weight while ball clay and sawdust are 30% and 10% respectively [8]. The mixture of these powders with water was then rammed into a rectangular specimen with dimensions (275 mm×130 mm×60 mm) as shown in Figure 2. The samples were sun dried for two weeks and then fired to 1200^{o}C in a kiln [6].

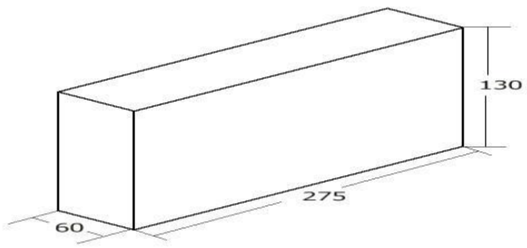


Figure 2. Refractory brick (Oladosu *et al.*, 2017)

The components of the furnace developed are feeder, riser, water tank, steam drum, and furnace chamber. Each of the component's fabrication process, design and measurement, material selection and cost were shown in Table 1., Fig. 3 and 4 show schematic diagrams of the developed PKS fueled combustion unit and exploded view of the boiler, respectively.

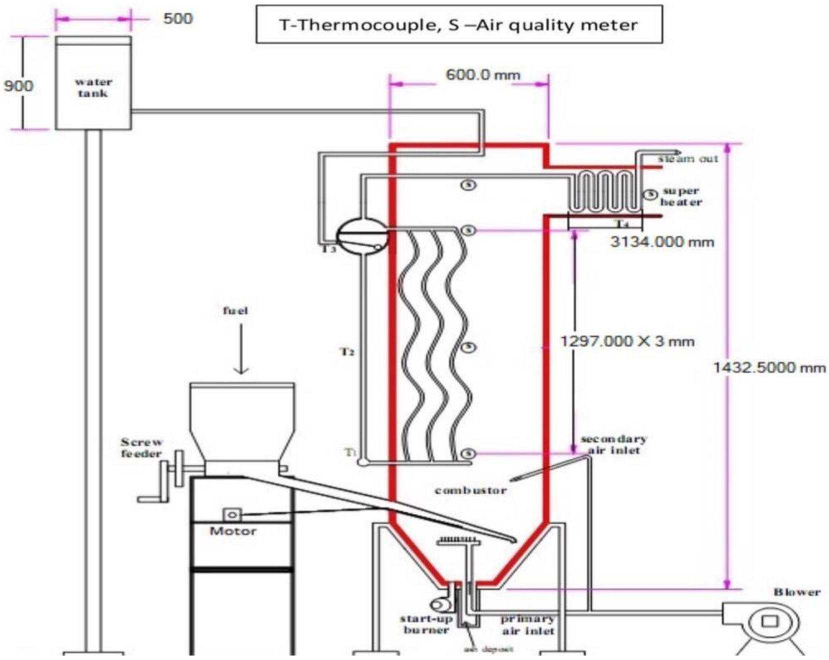
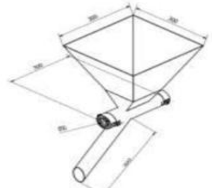
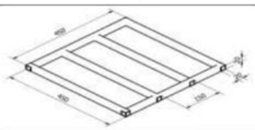
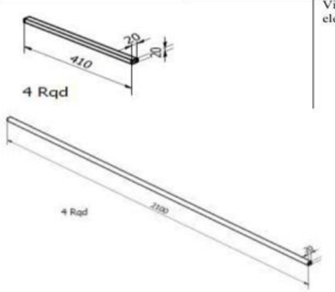
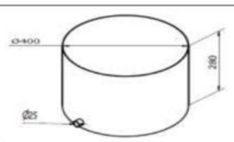
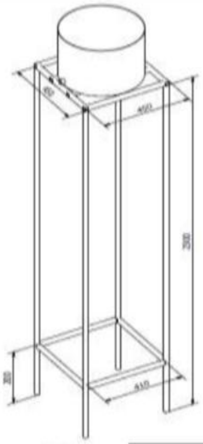
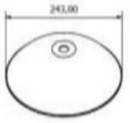
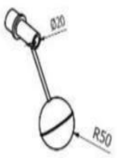
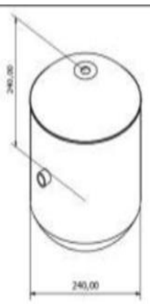
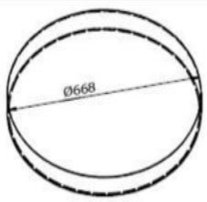
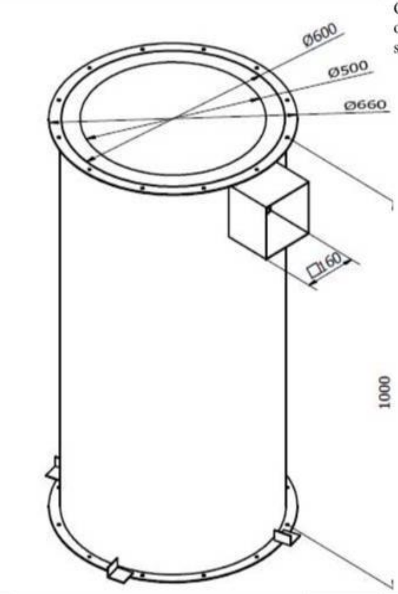
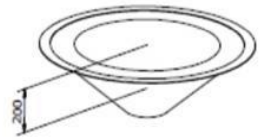


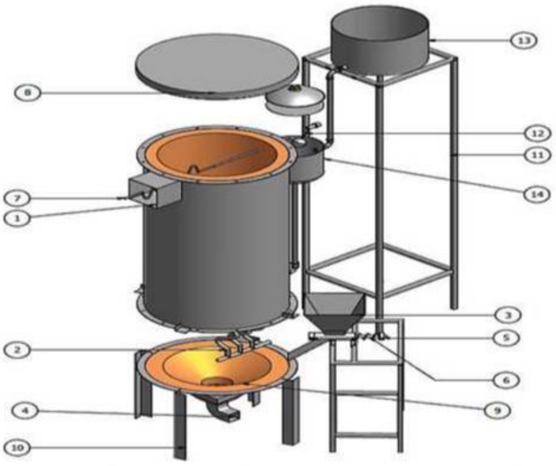
Figure 3: Schematic diagram of combusting furnace set up

Table 1: Fabrication process of the PKS furnace/ boiler

Assembly of hopper, auger housing, bearing housing and discharge pipe	Assembly of hopper unit using welding machine		Electrodes, ball bearings
Water tank frame	Cutting and welding of square pipe		Vice, hacksaw and electrodes
Tank support	Cutting and welding of angle iron to hold up water tank and brazing		Vice, hacksaw and electrodes
Water tank	Cutting and welding of steel plate		Chisel, hammer, anvil, drlling machine and electrodes

Assembly of water tank and frame			Electrodes,try squares
Drum cover	Cutting and drilling of steel plate		Shear cutting machine, drill bit
Steam separator	Cutting of steel plate		Spinner, hammer
Inlet water pipe control valve	Cutting and external thread of shaft		Tap and die ,drill bit, and hacksaw
Assembly of drum cover, steam water separator and inlet water pipe control valve	Drilling and welding of drum using welding machine		Electrodes,
Furnace lid	Cutting and welding of flat sheet plate		Hand shear cutter, electrodes, chisel and hammer, mild steel

Furnace	Cutting and welding, stack up the developed bricks to the wall furnace of		Galvanized steel, mixture of kaolin, ball clay, sawdust, and water,
Furnace bottom	Cutting and welding of cone shape		Mild steel, divider, protractor



Item	Qty	Part list
1	1	Superheater exit port
2	3	Riser
3	1	Hopper
4	1	Primary air inlet
5	2	Ball bearings
6	1	Auger
7	1	Superheater
8	1	Furnace cover
9	1	Bricks
10	1	Furnace stand
11	1	Water tank stand
12	1	Water level control valve
13	1	Water tank
14	1	Drum

Figure 4: Exploded view of the developed PKS Combusting Furnace Unit

The following areas were observed during the operating test process. These were volume of water turned to steam, mass of fuel used, temperature of the steam generated, pressure of the steam generated, time required for steam generation and efficiency of the boiler.

i. Volume of the water turned to steam: 10 litres of clean water was used for the performance evaluation. This was fed into the furnace through the feed water inlet on the boiler drum. The whole 10 litres were converted to steam in 1hour.

ii. Mass of fuel used: The total mass of fuel used was 3kg against the calculated mass of 2.309kg/hr, the variation can be traced to the moisture content of the fuel and losses in the system

iii. Temperature and pressure of the superheated steam generated: These parameters are very important in evaluating the performance of the system. Values of these parameters are recorded at intervals starting from the initial values before the test was carried out. The room temperature and pressure of the boiler were recorded to be 34℃ and 0Mpa respectively. As heat was added to the system, values of the temperature and pressure at specific time were recorded. Table below shows the values of these parameters at different timing intervals:

iv. Time required for the steam generated. The time at which steam was generated was recorded at 35 minutes. During the performance evaluation the thermometer and pressure gauge reading was recorded at interval of 10 minutes

III. RESULT AND DISCUSSION

The list of boiler's materials/components identified for design, fabrication and assembly were: steam drum; steam water separator; inlet water pipe control valve; ball bearing; water tank; riser; taps; hopper; super-heated exit spot; auger; furnace cover; refractory bricks; inlet water pipe control valve; and water tank stand (Fig. 5). The thermometer and pressure gauge readings recorded at interval of 10 minutes during performance test are presented in Table 2; while comparison between values obtained from this steam boiler and the standard are shown in Table 3.The can be observed that results were adequately within the standards (Tables 2 and 3).

Table 2: Temperature and pressure recorded at given time interval

Time (minutes)	**Pressure (Mpa)**	**Temperature (◦C)**
0	0	34
10	0.0103	58
20	0.0431	98
30	0.1896	120
35	0.2999	143
45	0.3014	160
50	0.3445	187
60	0.3861	200

Table 3: Comparison of the steam boiler results with the standard

Parameters	Values obtained	Standard boiler [6]
Exit temperature (◦C)	200	200-400
Pressure (Mpa)	0.39	0.35-4.0
Mass flow rate (kg/s)	0.023	0.023-0.05
Fuel feed rate (kg/h)	3	-
Pry/ Sec air ratio	40:60	-

IV. CONCLUSION

Fabrication of a palm kernel shell fueled furnace/boiler of 5kW was carried out. After components assembly, various tests were carried out. The test includes leakage test and operating test. At every joint it was tested for leakages by passing water through the tubes, water tank, steam collector to ensure water tight components. This is necessary in order to ensure a free leakage system when the system is functioning under severe conditions (between the range of temperature and pressure of which has been designed to function). Operation test was conducted after leakage test results were satisfactory. In operating test, a fuel feed rate of 3kg/hr produced maximum steam temperature, pressure and mass flow rate of 220℃, 0.39MPa and 0.023 kg/s respectively. The outcomes were adequate and within the standard range. Therefore the initial philosophy of mitigating unreliable energy supply in developing country has been achieved. Hence, the boiler is adequate and useful as an alternative source of energy.

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