The International Journal Of Engineering And Science (IJES)
|| Volume || 3 || Issue || 12 || December - 2014 || Pages || 61-66||
ISSN (e): 2319 – 1813 ISSN (p): 2319 – 1805

Design, Construction and Performance Evaluation of Two Types of Improved Wood Cooking Stove

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ABSTRACT
A number of different design of improve wood cooking stove has for long been constructed from different part of the world. The main idea behind the development of this technology is to reduce the burden on forest and other biomass option as well as reducing their associated health risk and environmental pollution. It is therefore very much important to develop a more efficient design. Different ICS have different efficiency, it is of great importance therefore, to compare between the different types of design to minimize the amount of fuel wood consumed during cooking. In this paper, two model of improved cooking stove were constructed in piece from two different soil sample taken all within Sokoto State. A water boiling test was conducted and model A_2 happens to be more efficient.

KEY WORD: *kaolin, an organic binder.*

Date of Submission: 30 December 2014 — Date of Accepted: 10 January 2015

I. INTRODUCTION

In Nigeria today, fossil fuel (fuel, kerosene, diesel etc.) has become very much expensive that most of Nigerians cannot afford cooking with kerosene but rather go for what is most readily available (wood) for their domestic activities like cooking, smoking, simmering and warming the environment during cold season. The use of wood in place of fossil fuels and electricity is still one of the challenges not only facing Nigeria alone but most of the countries around the world. A survey conducted in a village 200 households, an estimate 621 ton of biomass fuels are burned using the three stone open fire in northern India [1].This value is about two order of magnitude compared to the 365 ton of biomass burned by the same household over the same period of time by an ICS. The large preference of wood as fuel is predicted upon the fact that, apart from wood as fuel, the other non-renewable sources of energy such as; petroleum, natural gas and liquefied petroleum gas (LPG) are no longer easy to come by in terms of cost and availability, the life time for these other alternatives is estimated to range from 15 years for natural gas and 300 years for wood [6]

It has been estimated that approximately half the world's population, depend on biomass fuels (wood, crop residue, animal dung, etc) as their primary domestic energy source [5][7]. Indoor air pollution from biomass was responsible for over 2 million deaths over the world, and about 2.7% of the global burden diseases originate from the use biomass fuel in cooking [8]. In Addis Ababa, a study revealed that the major environmental and health hazard evolve from homes using biomass [3]. Effort has been made by several researchers to device ways of reducing the amount of wood use in domestic activities to reduce desertification. Many improve wood cooking stove has been design which all have different fuel and thermal efficiency. A latest study in Kenya to compare between stove types, conclude that the rocket mud ICS reduce significantly the amount of wood consumed compared with the local three stone stove [4].The development of improved cooking stove (wood cooking stove) is not a recent development; several works have been done in the stove design. The research on ICS has for over 40 years been a topic of research, but still about 2.6 billion people cook over the open fire [5]. This research is aimed at comparing the percentage of wood consumed, time spent in cooking, specific fuel consumption, power consumed for boiling water, burning rate and thermal efficiency of two different types of improved wood cooking stoves.

II. MATERIALS AND METHOD

Materials: The materials used during this research include: Clay, Kaolin (an organic binder), Millet streak, Wood ash, Water, Knife (cutter), Soil compactor, Weigh balance, Digital thermometer, Pots, Stop watch, and Fuel wood.

However, four models of improved cooking stoves were constructed using two types of clay soil from different location (Wurno local government area in Sokoto state and Sokoto town) with varying porosity. Two different models of the improved cooking stoves were constructed using each of the clay soil samples.

III. METHOD

Porosity test: Porosity test was conducted for each of the soil samples by estimating the particle density and the bulk density of the soil samples. The particle density can be gotten by taking soil samples with a core sampler, pulverize, sieve and then dry the soil sample in an oven for 24 hours at 105^{o}c. A volumetric flask of a known volume (V_b = 100ml) was used. The weight of each of the soil samples after drying were measured, and then placed in the bottle containing distilled water.

Stove Design: First of all, mixture was made with moulded sticky mud mixed with millet streak and wood ash. Mixture was allowed to dry for sometime in natural environment. After that a desired shape was given to the structures with knife and hands. Again the structures were allowed to dry completely by keeping them under the shade for another 2 days and then fired in a kiln for about 2 hours at a very high temperature. After the firing process structures were rubbed with mud and water to fill up the cracks. Thus the stoves made with mud do not cost money. The dimensions of each of the stoves are: Length: 78 cm; Breadth: 38 cm; Height: 18 cm and Thickness: 4 cm.

Diagrams

Figure 1: model A_1

figure 2: model B_1

Figure 3: model A_2 and B_2

figure 4: the two models

Calculations

$$\text{Porosity} = 1 - \frac{\text{bulk density}}{\text{particle density}} \times 100$$

Porosity is a measure of how much ground water a soil can hold

Burn Rate, B.R.

$$B.R = \frac{\text{weight of fuel consumed}}{\text{time, t}}$$

Specific fuel consumption (SFC)

$$SC = \frac{Wfc(1 - X) - 1.5\,Wc}{Ww}$$

Power Consumed for boiling, PCB

$$PCB = \frac{Wf(1-X) - 1.5Wc}{60t} \times C_w$$

Thermal Efficiency

$$\text{Efficiency}, \eta = \frac{MwCp(Tb - Ti) + \Delta MwL}{MfB} \times 100$$

IV. Results and Discussion

a. Results

Porosity Test

Table 1: porosity test result

Measured Parameter	Wurno town soil	Sokoto town soil
Density of water	0.956 g/cm^3	0.956 g/cm^3
Particle density	2.28 g/cm^3	2.39 g/cm^3
Bulk density	1.12 g/cm^3	1.04 g/cm^3
Porosity	50.88%	56.49%

Table 2: performance evaluation result

Measured Parameter	Model A1	Model A2	Model B1	Model B2
Percentage of wood consumed	24.2%	28.57%	74.73%	61.5%
Time spent for boiling	7.40min	7.30min	26.52min	15.74min
Specific fuel consumption	0.12	0.14	0.43	0.31
Power consumed for boiling	157.12KW	155.36KW	35.46KW	48.80KW
Burning rate	0.15kg/min	0.18kg/min	0.13kg/min	0.23kg/min
Thermal efficiency	6.16%	4.98%	3.06%	2.88%

Figures

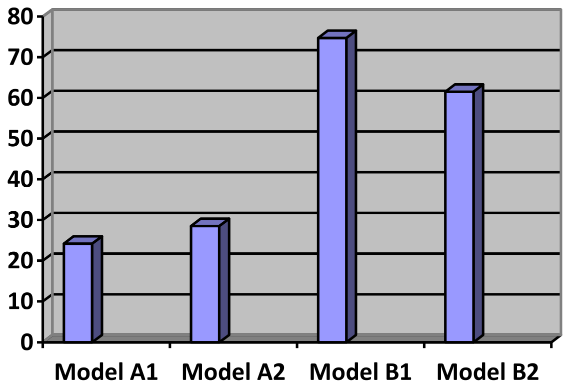

Figure 5: percentage of wood consumed (%)

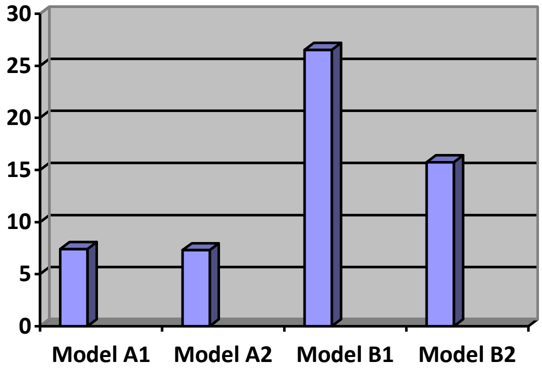

Figure 6: Time spent for boiling in minutes

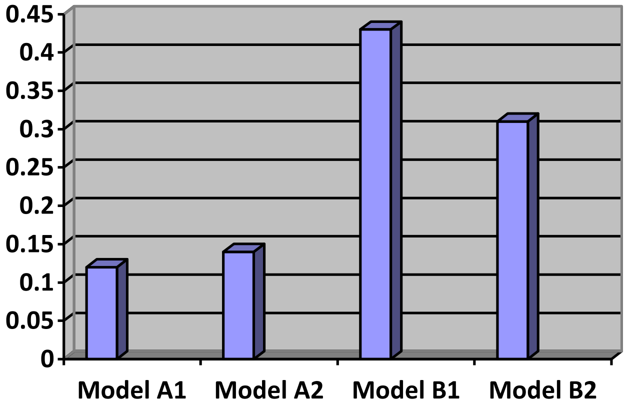

Figure 7: Specific fuel consumption

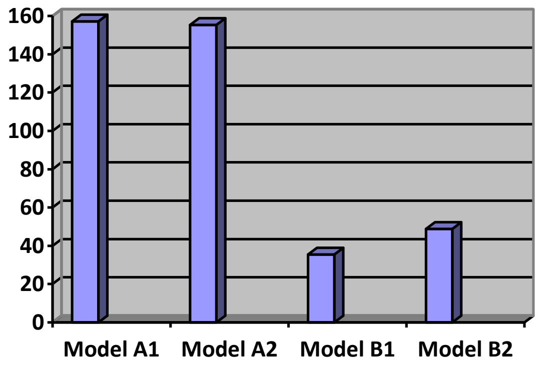

Figure 8: Power consumed for boiling in Kilowatt

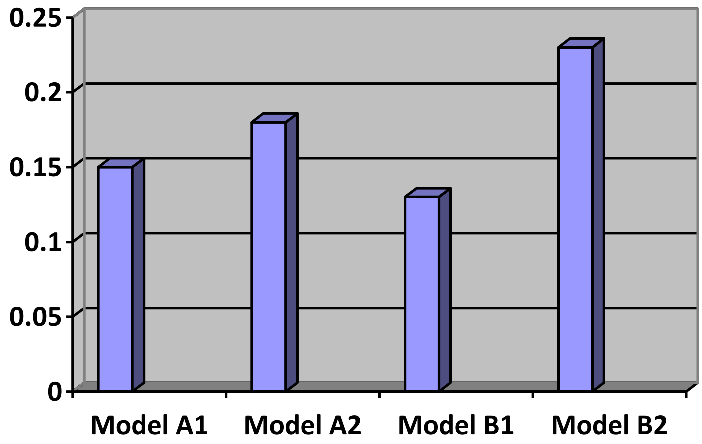

Figure 9: Burning rate in kilogram per minute

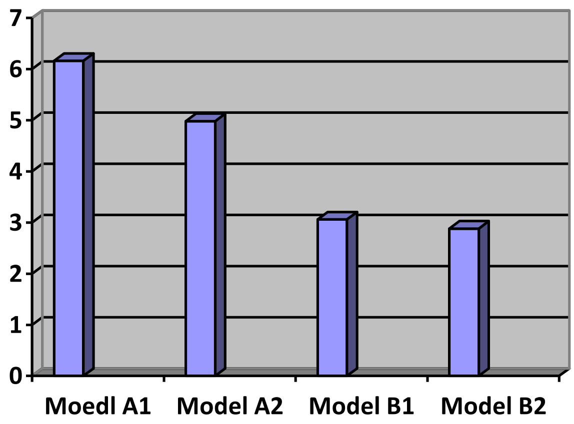

Figure 9: Thermal efficiency in percentage

V. DISCUSSION

Soils were taken from two different areas in Sokoto State; a lab test was conducted to determine the porosity of the soils. Two models of stove were constructed from each soil sample using the same dimension, pot holes size and fuel inlet. Basically four stoves were constructed from the two soils; each soil was used to construct a stove with chimney at the centre as well as a stove with chimney by the side. The reason for this is not to give any priority to a particular soil sample. The four stoves were fired under the same temperature and a water boiling test was conducted after two days of cooling. The result of the test is presented in table 2.

VI. CONCLUSION

Different parameter such as Thermal efficiency, Burning rate, Percentage of wood consumed etc were calculated and tabulated in table 2. Each stove design is constructed in pears having two different shapes. Model A_1 and B_1 are the stoves from Worno Local Government Area, whereas model A_2 and B_2 are stoves from Sokoto town. The type of soil used has little effect on the stoves efficiency, what really matters is the shape of the Improve Wood Cooking Stoves.The soil from Sokoto appeared to be more porous than the one from Worno, if one compares Model A_2 (soil from sokoto having chimney by the side) and model B_1 (soil from Worno having chimney at the center) it's obvious that Model A_2 is efficient despite the soil been more porous.

It was concluded that the shape has the greatest influence on the efficiency of an Improve Wood Cooking Stove. I therefore recommend that future designers of ICS should look well into the shape of any design.

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