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COMPARATIVE STUDY ON FLEXIBLE POT-STOVE WITH BIOMASS USED MODERN KITCHEN STOVE(MKS)

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ABSTRACT

Over 145 million Indian households use traditional cook stoves for their daily cooking and depend on biomass fuels such as wood, dung, or agricultural residues that cause health-threatening levels of indoor air pollution, according to the World Health Organization (WHO). While currently not perceived as a major threat by most, household air pollution is actually responsible for around 500,000 deaths in India every year. To put the seriousness of this problem in context, TB which is the biggest killer disease in India is responsible for 5.5 lakh deaths in a year. The efficiency and combustion is important to reduce the smoke, Even an open fire is often 90% efficient at the work of turning wood into heat energy, but only a small portion reaches about 10-40% of released heat energy to the pot stove. Improving combustion efficiency does not appreciably help to use less fuel. Improving heat transfer efficiency to the pot makes a lot of difference. Biomass used Modern Kitchen stove incorporates an inner combustion chamber and outer casing design. A fan is mounted on to the outer casing to increase or force the air into the chamber required for combustion and heat transfer. Hence Fabricating a Biomass Stove with a design that helps in efficient heat transfer of combustion gases and effective heat distribution of practical stoichiometric air helps in increasing the rate of fuel combustion, stove efficiency and also reduces the smoke.

Key words: Biomass, Flexible Pot stove, Modern kitchen stove, Efficiency and combustion of stove

I.INTRODUCTION

Biomass is the organic material which has stored sunlight in the form of chemical energy. It includes wood, wood waste, straw manure, sugar cane pulp and many other byproducts from a variety of agriculture process. Biomass is a renewable source of energy because the energy comes from the sun. Fuel wood is the first biomass resource and, indeed, the first energy source to be used by human beings in igniting the first fire by rubbing sticks together. The adoption of biomass-based energy plants has been a slow but steady process. As per the

Forest Survey of India (FSI) 2013 assessment, the total forest and tree cover of India is about 78.92 million hectares, which is 24.01 per cent of the country's total geographical area.

While there is an increase in the total forest cover of the country, there is a decrease in the growing stock .The main reason for declining growing stock is the conversion of Moderately Dense Forests into Open Forest, which has resulted in sever depletion of growing stock, according to the FSI report 2013.

1 a. ON THE BASIS OF THEIR ORIGIN, AGRICULTURE BIOMASS CAN BE CLASSIFIED AS

(a) Field based residue

(b) Process based residue

- **Field based residues** are plant materials that remain in farm after removal of the main crop produce (e.g. straw, stalks, sticks, leaves, fibrous materials, roots, branches, twigs).
- **Process based residues** (agro-industrial residues) are by products of post-harvest processes of crops, namely, cleaning, threshing, sieving, and crushing.

1.a.1 TYPES OF BIOMASS RESOURCES

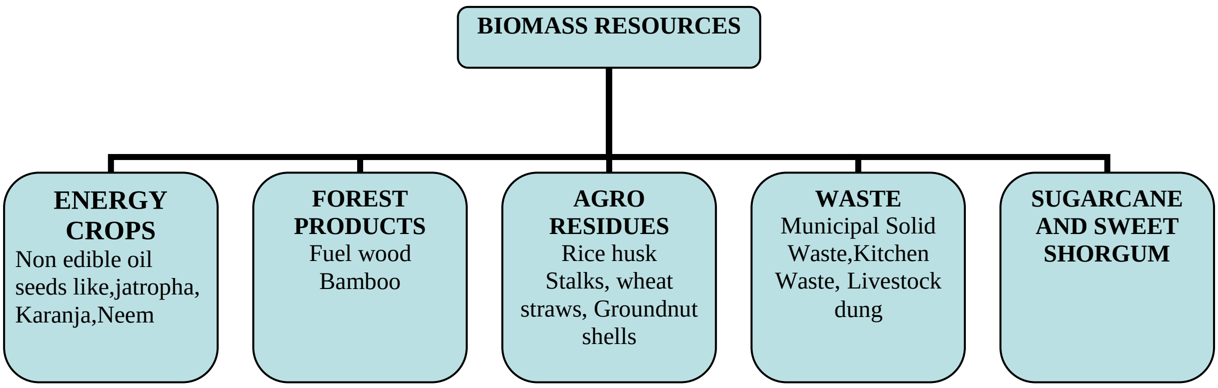

Fig 1.Different types of biomass resources

Fig 1 shows the different resources of biomass as many as 95% of rural homes across six energy-deficient states (Bihar, Jharkhand, Madhya Pradesh, Odisha, Uttar Pradesh and West Bengal) still use traditional fuel, such as firewood, dung cakes and agricultural waste for cooking, says a new Only 14% households in rural areas across the six states surveyed used biogas, LPG (liquefied petroleum gas), electricity or natural gas as their primary source for cooking, according to the Access to Clean Cooking Energy and Electricity – Survey of States.

1.a.2 BIOMASS USED STATES IN INDIA

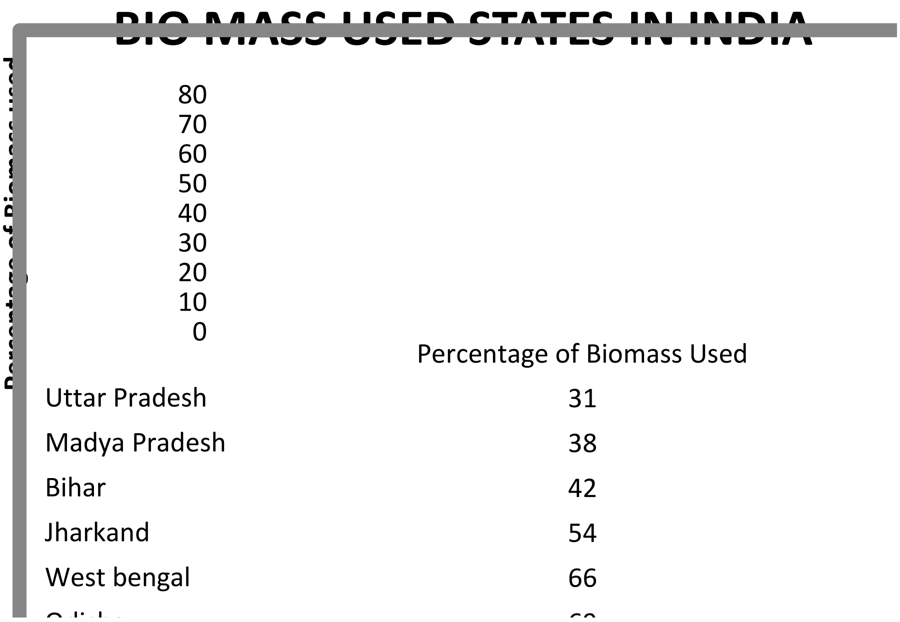

Fig 2.Biomass used states in India

Data from ACCESS Report

Figure 2 shows the percentage of biomass used in the different states in india in that odisha states mainly used biomass in the larger scale.

1.a.3 COMPARISION OF ENERGY USAGE IN URBAN AND RURAL AREAS

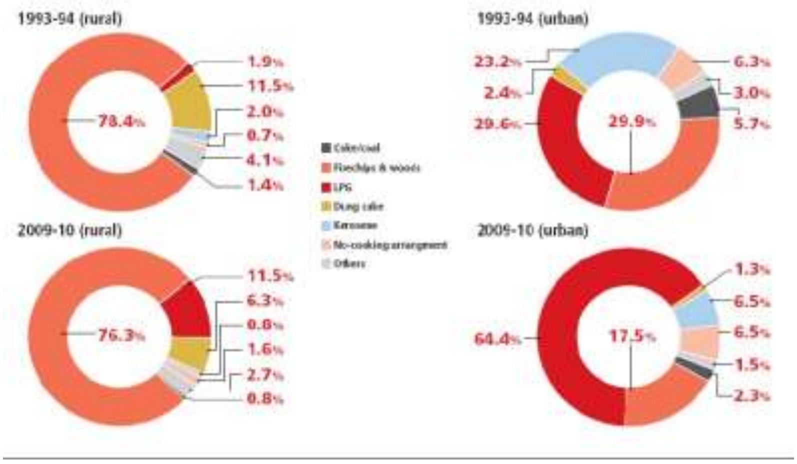

Fig .3 Comparison of energy usage in urban and rural areas

Figure 3.Clearly depicts that in urban areas the dependence on biomass (fire chips and wood) has reduced in the past two decades. There has been a transmission to liquefied petroleum gas .Accepted widely due to its clean combustion and low maintenance but the rural sector has been depending mostly on biomass to satisfy their energy need. Liquefied petroleum gas is not used mainly due to its high cost. Due to extensive dependence on biomass stove and inefficient stove capability, the users are exposed to incomplete combustion gases that are toxic

1 b. RECENT TRENDS IN BIOMASS STOVE

Nowadays to increase efficiency and reduce the indoor pollution, the design of the biomass stove has been improved to enable complete combustion and reduce heat losses. The stove designer job is to keep the fire clean and force as much energy into the pot.

A few notable design motives are as follows

- Insulating the combustion chamber
- Increase the velocity of hot gases passing the vessel's bottom (use of a fan).
- Providing good draft.
- Heating the smoke that escapes from combustion chamber (secondary air supply).

1 .1 RELATED WORKS IN BIOMASS STOVE

Traditionally available biomass stove is made up of locally materials like clay, cement and bricks. Nowadays metals have been considered as construction materials due to their ease of machinability, resistance to thermal stress, impact strength etc. In order to make the stove portable heavy insulating materials like clay, fire wood are not used instead a ceramic inner combustion chamber is used or else the base metal is coated with ceramic, to maintain the combustion temperature. Mathematical modeling has been used effectively to formulate the design of biomass stove, using equations of momentum and energy. Computational fluid dynamics has been used to study the process. Design is formulated to allow a two stage combustion process. A mini sized fan is used to push in sufficient air to allow clean and efficient combustion.

II. PLAN AND DESIGN OF THE PROJECT

Below steps are followed for the plan and design of the project

- Collecting existing local stoves for testing and evaluation
- Investing existing stove performance
- Developing and improved the design parameters
- Testing the prototype and its re modification
- Producing developed stove

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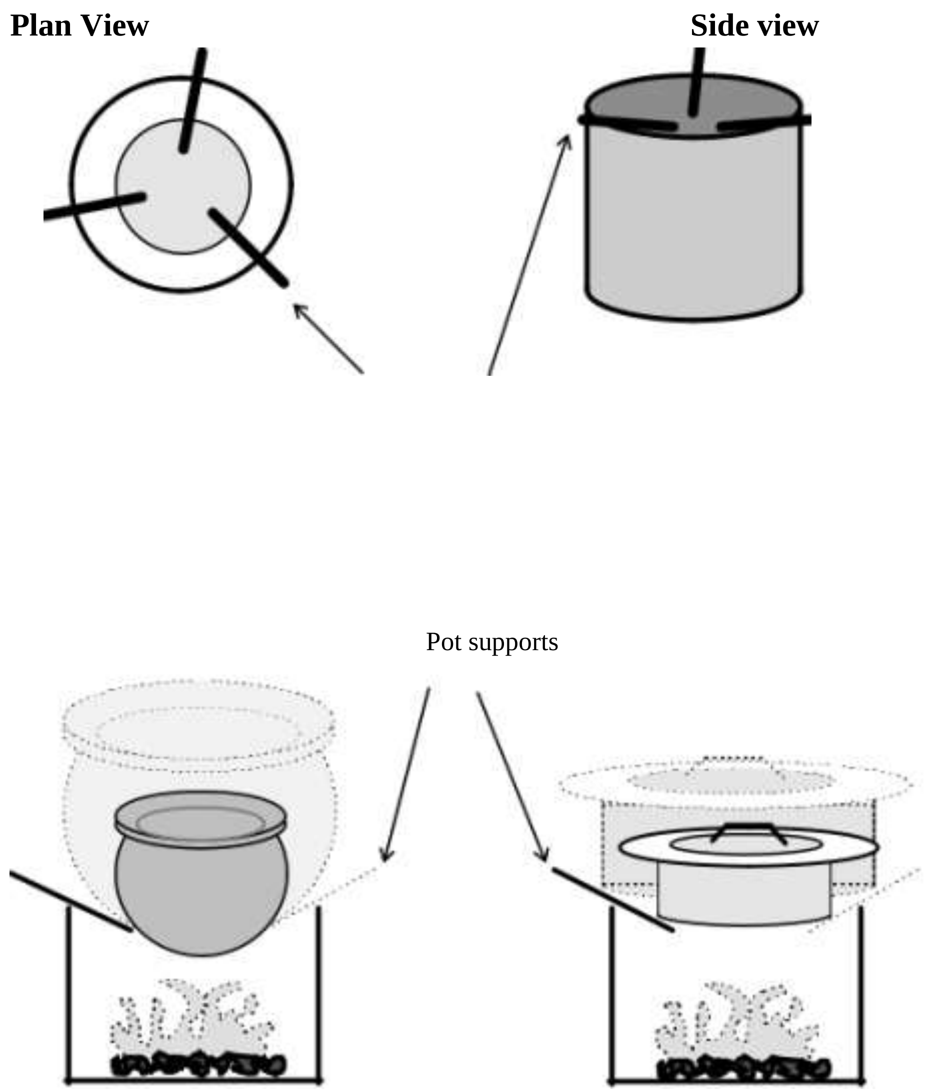
2.1 FLEXIBLE POT-STOVE INTERFACE DESIGN

The importance of flexibility with regards what cooking utensils can be used with a stove have already been discussed in Section 2.4.1. Figure 3 below shows the most commonly used method of allowing multiple sizes and shapes of pot to fit onto a stove. In this section some of the theory behind fuel efficient heat transfer to the pot is discussed, and ways of incorporating user needs with fuel-saving designs.



Pot size / shape flexibility

Fig.4 Flexible Pot Stove

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III. DESIGN PARAMETERS CONSIDERED FOR MODERN KITCHEN STOVE (MKS)

Following a two stage combustion process in combustion chamber need for two stage combustion process, since practically there is overlapping in the stages of combustion the chances of escape of volatile gases before complete combustion is more. Therefore following two stage combustion process helps to increase combustion efficiency.

3.1 DESIGN OF INNER COMBUSTION CHAMBER TO ALLOW

a) Primary air flow b) Secondary air (heated) flow

- Secondary air - primary air

Fig. 5 Design of inner combustion chamber

Primary air – Is supplied to the fuel mixture along with ignition required for Combustion. Due to inhomogeneous distribution of air in the stove, stoichiometric air is not sufficient for complete combustion practically. Hence smoke exits from the ignition mixture, before complete combustion. Leading to emission of toxic vapors.

Secondary air – If excess air is supplied to the top of combustion chamber where smoke exits, then the smoke can be heated once more before exit there by ensuring complete. Both primary and secondary air is circulated by a mini fan incorporated within the stove casing**.** The fan is powered by a dc battery.

3.2 FABRICATION OF INNER CHAMBER

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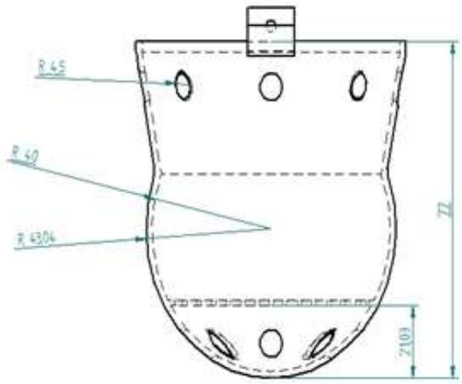
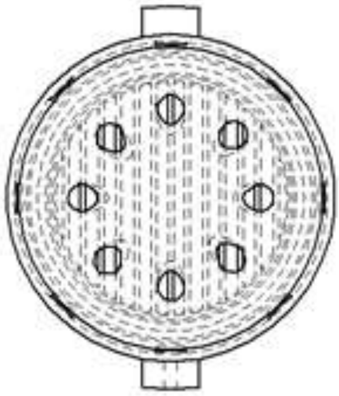


Front view



Top View

Fig.6 Representation of inner combustion chamber

A circular cross-section is used at the bottom end of radius 40cm but the upper end is made into a increasing tapering end of circular resection. The purpose of tapering at its top end is to increase the resection of contact of secondary air, so as to extract more heat from the combustion chamber.

Grid plate is placed at height 21.03 cm from bottom end to allow enough primary air from all sides to enter from underneath.

Material used

Fig. 7 Ceramic coated combustion chamber

Stainless steel can be used to make the inner combustion chamber due to its easy machinability and thermal resistance but it's a very good heat conductor hence heat losses occur. So insulating the chamber is required, Pearlite can be used for its insulating property and relatively cheap price but its weight ratio is high so it is not preferred.

3.3 DESIGN OF OUTER COMBUSTION CHAMBER

Although the inner combustion chamber is insulated, heat losses do occur which is inevitable. Hence the outer chamber needs to be designed, in such a way that the clearance between inner chamber and outer chamber must allow enough heat extraction by secondary air before entering into the inner chamber. Therefore a convex

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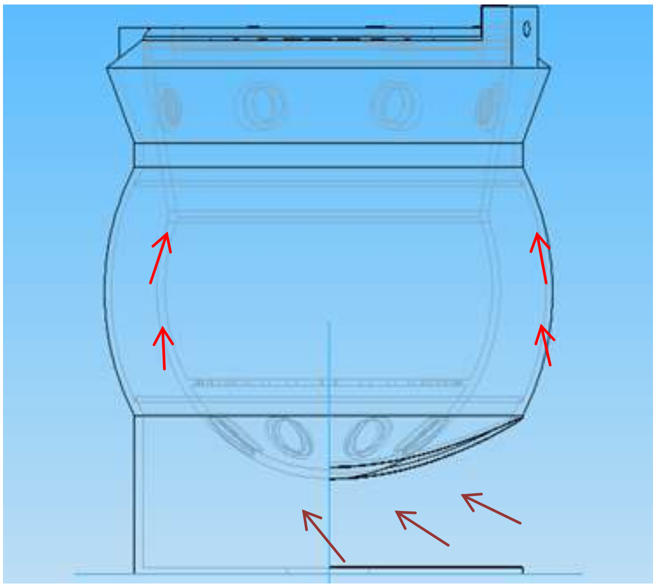
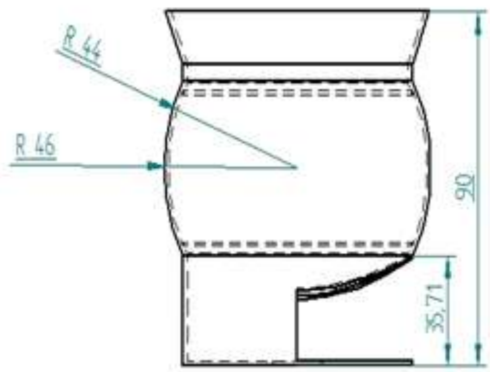
surface is used to cover the inner circular shape. The top end of the outer chamber is made of increasing tapering circular resection to allow all the secondary air to enter into the inner combustion chamber, in a short span. The top extreme end is sealed to the inner chamber by a cover plate, to prevent interference of atmospheric air.

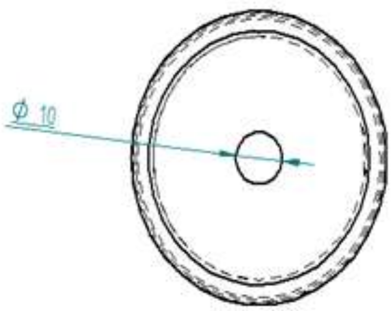


Secondary air **rimary air**

Fig.8 Design of outer combustion chamber

3.4 DESIGN OF OUTER COMBUSTION CHAMBER





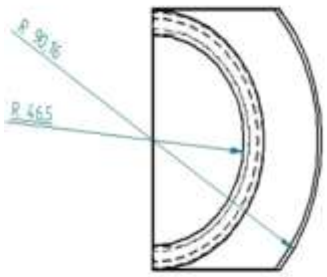
Front View **Top View**

Fig.8 Representation of outer combustion chamber

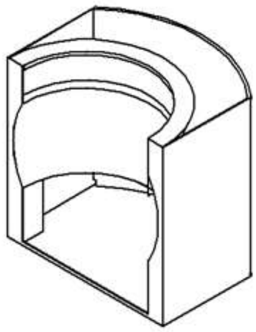
Material used

Stainless steel or any sheet metal can be used to machine the required shape as shown above. The middle section has a radius of 46 cm and this cross-section is maintained from a height of 35.7 cm from bottom. A Hole at the bottom of 10 cm is made to fix a mini fan.

3.5 DESIGN AND FABRICATION OF FLUE GAS ENCLOSE



Top View



Isometric View

Fig.9 Representation of flue gas enclose

A figure 9 show the flue gas encloses is required to hold the copper tube that brings the sample flue gas and also the sensor that detect flue gas composition (not shown in diagram). The design of the encloses should be able to absorb the heat that is lost from the outer combustion chamber and absorb heat from the copper pipe. In order to increase the heat transfer rate air circulation is provided by a fan within the casing (not shown in the diagram).The circulated heat absorbed air must be sent as primary air to the inner combustion chamber. The only way through which the atmospheric air enters the stove is through the the top opening of the inner combustion chamber.

Material used

To retain the heat within the chamber it's better to go with an insulating material like ceramic. If stainless steel is used heat conduction is more hence losses are more. The outer diameter is of 90.16 cm circular cross section. The top inner and outer lining is open to atmosphere.

3.5 DESIGN AND FABRICATION OF FLUE PIPE Collector

The need for collecting the exhaust gases is to enhance the efficiency by studying the composition to regulate enough air for combustion. But the temperature of flue gases are close to 200-230 Celsius, the sensors cannot work under such high temperature they get damaged when exposed to such temperature .Hence there is a need to reduce the temperature of flue gases, this is done by a pipe of solenoid type so as to increase the area of flow to cool the gas. A mini fan used, is useful in circulating the air.

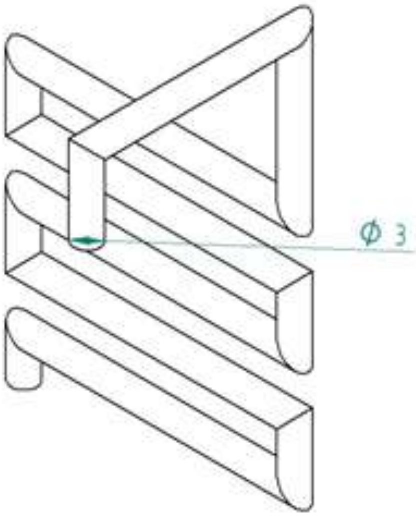


Fig. 9 Flue Gas Enclose pipes

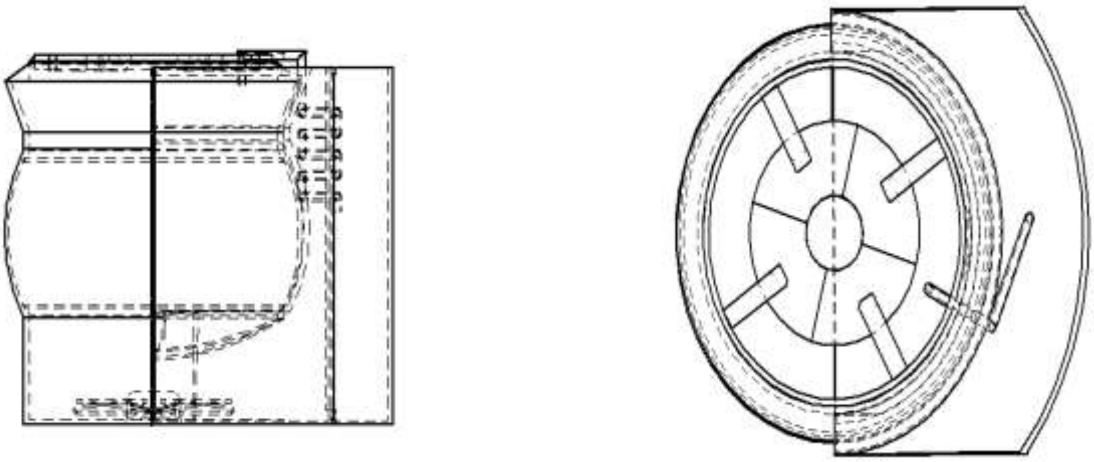
Material used

Only a small sample of flue gas is required for analysis. So a small tube of diameter 3cm, copper tube of solenoid shape is used.

3.6 PROBLEMS DUE TO COOLING OF FLUE GAS

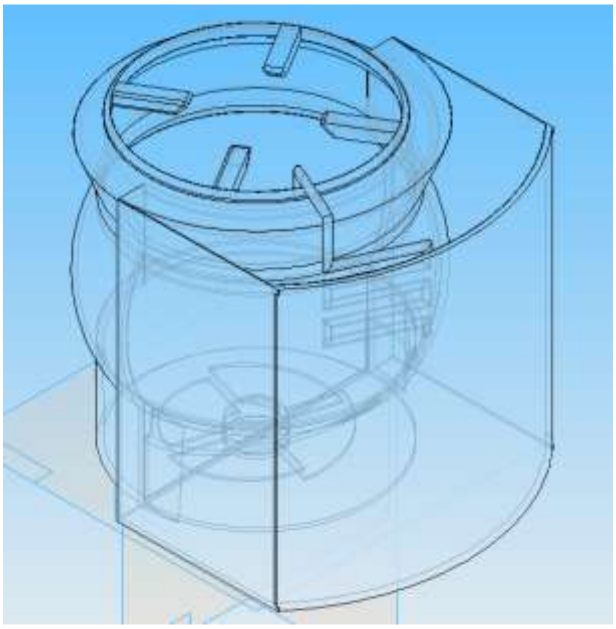
Due to cooling of flue gas the composition at the reduced temperature changes due to condensation of water vapor.

3.7 FINAL ASSEMBLY VIEW



Front View **Top View**

Fig.10 final assembly view of Biomass used Modern Kitchen Stove



Isometric View

Fig.11 Final assembly view

IV. FORMULA USED FOR POWER AND COOK STOVE EFFICIENCY

Calculate the firepower and efficiency of each of cook stoves

Calculate the firepower and efficiency of each of cook stoves Firepower is energy released by the burning fuel at unit time. So for any phase of combustion, firepower can be calculated as follows:

Fire power (W) = $(M_{ci}- M_{cf})*H_c$/Time……………….. (1)

Where: P = power (W)

M_{ci} = Initial mass of charcoal in the cook stove (g)

M_{cf} = Final mass of charcoal in the cook stove (g)

H_c = Energy content of charcoal (29000J/g)

Time = Time of combustion phase (s)

Efficiency is the ratio of energy absorbed by water in the cooking pot to energy released by the burning fuel. In the hi-power and low-power phases, the water has different properties and energy absorbed by water and is calculated using a different equation. They can be divided into the energy required to raise the temperature of water and energy required to evaporate the water. So the efficiency can be expressed as follows

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During Hi-power phase: Efficiency (%) = $M_wC_w(T_f\text{-}T_i)/\ (M_{ci}\text{-}\ M_{cf})^*H_c$……………….(2)

During low-power phase: Efficiency (%) = $H_w(M_{wi}\text{-}M_{wf})/\ (M_{ci}\text{-}\ M_{cf})^*H_c$……………..(3)

Where: M_w = average water mass in the cook pot from pre-start to first boiling

C_w = heat capacity of water (4.184J/g o C)

T_f = temperature of first boiling (^oC)

T_i = initial temperature of the water in the pot (^oC)

H_w = heat of vaporization of water (2260J/g)

V.RESULTS AND DISCUSSIONS ON THE BASIS OF DESIGN OF TWO DIFFERENT STOVES

SL .NO	DESIGN AND PERFORMANCE PARAMETERS	FLEXIBLE POT STOVE	BIOMASS USED MODERN KITCHEN STOVE(MKS)
1	Materials used	Clay, Mud, Sand	Stainless with inner ceramic fiber coating
2	Fuel used	Charcoal, Wood	Wood pellets, any dry type of biomass evenly sized
3	Thermal Radiation	Captured	Captured to heat secondary air
4	Efficiency	20%	35%
5	Fan	Not used	Used mini size fan
6	Size of fuel	Small	Small
7	Ash content	More	Comparatively less
8	Soot formation	Occurred	Comparatively less
9	Toxic, Unburnt Volatiles	Released	Reduced by heating
10	Solar panel	Not used	Used for electricity production for fan
11	Chimney	Yes	No
12	Applications	Heating water, cooking purposes	All cooking and heating purposes

VI.CONCLUSION

The design and performance consideration of two different stoves have been studied, from the design of flexible pot stove and biomass used modern kitchen stove (MKS),the design and performance parameters are extremely satisfied in modern kitchen stove by increasing the efficiency, reduced the smoke and toxic vapors. Even the Modern kitchen stove is ecofriendly in nature for the cooking purposes.

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