Design and Performance Analysis of Biomass Cook Stove

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***Abstract* — Now a days, many Indian households are cooking with inefficient and polluting biomass and coal cook stoves could yield enormous gains in health and welfare for the weakest and most vulnerable sections of society. At the same time, cleaner household cooking energy through substitution by advanced-combustion biomass stoves can nearly eliminate the several important products of incomplete combustion that come from today's practices and are important outdoor and greenhouse pollutants. In present, there are several biomass cook stoves made available, but those are less efficient due to incomplete combustion of fuel as well as desirable flame control is not achieved. The present paper gives a design of renewable and smokeless cook stove burning with blue flame and with proper flame control, thereby increasing the overall efficiency of cook stove.**

Keywords — Biomass Cooks Stove; Flame Control; Thermal Efficiency

I. INTRODUCTION

For harvesting energy, primary source is fuel. Conventionally the fuel used was wood, cow dung cake, coke, agro-waste etc. used for various applications in day to day life; but in very inefficient way. Wood being prime fuel is used extensively, since it is available easily and at least cost. By burning of wood it causes smoke, suspended unburnt carbon. These residues affect environment as well as human beings equally. It is needed to burn the fuel in hand as efficiently as possible causing fewer emissions and clean burning. Biomass is one of the primary fuels used all over the world. It is intensively used mainly for cooking, space heating and drying. Hence, Biomass cooking stove is the major thermal energy conversion device amongst the biomass fired technologies. Even now, 38% of world and 66 % of India's total populations are using biomass stoves to fulfill their cooking needs. There are many biomass cook stoves used for domestic as well as commercial purpose but facing incomplete combustion of producer gas and heat losses. So, prime focus is on making the stove more fuel efficient with less emission.

II. PROBLEM STATEMENT AND OBJECTIVES

Biomass cook stove designed fulfilling need of domestic as well as commercial use. Designed is carried out for making stove more fuel efficient with less emission. It is very difficult to achieve the blue flame of burning which indicates complete combustion of fuel. With this problem following objective were finalized:

1. To design a new kind of biomass cook stove, working fuel as sawdust pellets.
2. Achieve the blue flame to ensure the complete combustion.
3. Minimize the heat losses from the biomass cook stove.
4. Hence to increase thermal efficiency of biomass cook stove according to BIS.

III. DESIGN AND MANUFACTURING

Number of trials was performed on the existing cook stoves to find out parameters/parts of cook stove which are affecting the combustion and heat losses. After observation it is decided there is need to redesign the cook stove for complete combustion and to reduce the heat losses. From various parts of the cook stove accumulator and combustion chamber was decided to redesign.

A. Design of Accumulator:

The functions of accumulator are to accumulate the producer gas so as to increase its concentration and to achieve pressure drop to increase velocity of gas for proper mixing of secondary air with producer gas.

The accumulator is designed such that an air whirl has to create and this swirl helps in proper mixing of air and fuel which results in complete combustion of producer gas.

The main factors which affecting the combustion are time given for mixing of air and producer gas, temperature distribution inside the stove and turbulence of air fuel mixture. With the designed accumulator the time and temperature are optimized but for turbulence swirl plates are provided at the top of the accumulator. Designed accumulator is successful to achieve the consistent blue flame which indicates proper mixing of air and producer gas. Accumulator is again modified to reduced heat losses from the surface by providing an extra structure around it which contains the water. This water recovers the heat loses by radiation and convection from the surface of accumulator and it has been used for some other purposes.

Fig. 1: Actual view of Accumulator with modification

B. Design of Combustion Chamber:

In combustion chamber combustion of fuel (Sawdust pellets). The previous combustion chamber has only inner layer of cerawool, it is observed that inner chamber was getting red hot. To reduce the heat losses from inner chamber, it is manufactured with layer of coarse sand and heat resistance refractory material (Fire Clay) as shown in figure 2.

Fig. 2: Combustion Chamber

IV. EXPERIMENTAL WORK AND OBSERVATIONS

A. Generalized Working Of Biomass Cook-Stove:

1. Fill the combustion chamber up to its maximum capacity with pellets.
2. Add 10 to 15 ml of kerosene for pre-ignition of pellets.
3. Ignite the pellets with match stick or suitable equipment.
4. Turn on the fan and keep it on low speed.
5. Wait for 10-15 min till the flame bed is formed.
6. Regulate the fan speed according to the flame intensity.
7. After complete combustion of pellets wait till the cook stove is cooled completely.
8. Remove the ash and clinker with the help of tongs by removing the ash grate.
9. Clean the combustion chamber.

B. Burning Capacity Rate:

Heat input rate = 2 (M1 — M2) * CV kcal/h

Where,

M1 = Initial mass of pellets in kg

M2 = Mass of pellets after burning them for half an hour.

CV = Calorific value of fuel (4000 kcal/kg)

Table 1: Heat Input Rate Observations

Sr. no.	Particulars	Readings
1	Initial mass of pellets (M1) (kg)	2
2	Final mass of pellets (ash) (M2) (kg)	0.02
3	Start time	14:00
4	End time	14:52
5	Run time	52 min
6	Burning capacity rating	3.96
7	Heat input per hour (kcal/hr)	18276.92

C. Vessel Selection:

Heat input rate per hour of sawdust pellets was found to be 18276.92 kcal/hr. Hence dimension of vessel was selected as per BIS standards.

Table 2: Vessel selection

Sr. no.	Parameter	Readings
1	Heat I/P rate (kcal/hr)	18276.92
2	Vessel Diameter (mm)	540
3	Vessel height (mm)	285
4	Total mass with lid. (gm)	3190
5	Mass of water in vessel (kg)	50

D. Air Supply:

The air supplied through the air slot helps in combustion of pyrolised gases which results in propagation of flame.

- No of fans = 2
- Battery specification = 12V/4.5 A-hr
- Air discharge through fan = 23.73 cfm

E. Burning Fuel:

Biomass cook stove is ignited and for each experiment 2 kg sawdust pellets of 10 mm in uniform size is burned. Properties of sawdust pellets used are given in the following table.

Table 3: Properties of Sawdust pellets

Parameter	Bio-Pellets
Calorific Value (kcal/kg)	4400
Ash Content (%)	4-5
Toxic	No
Density (kg per cu. m)	400-500
Ignition Time (sec)	60-90
Carbon Credit	Yes
Cost/kg (Rs.)	18

The forced air is supplied through two slots to assist the pyrolysis process and propagate the flame. The Three reading was taken as given in below table 4. All the reading was recorded on the blue burning flame as shown in below figure 3.

Fig. 3: Blue flame

Table 4: Observation Table

Sr. No	Parameter	Readings		
		1	2	3
1	Raw material	Sawdust Pellets		
2	Pellet diameter(mm)	8	8	8
3	Moisture (%)	5	5	5
4	Bulk density(kg/m3)	536	536	536
5	Mass of cont. A (kg)(Ma)	7.2	7.2	7.2
6	Mass of container B (kg) (Mb)	1.7	1.7	1.7
7	Specific heat of Al (kcal/kg °C)	0.22	0.22	0.22
8	Mass of water in container A (kg) (Mwa)	50	50	50
9	Mass of water in container B (kg)(Mwa)	25	25	25
10	Mass of fuel consumed (kg) (Mf)	2	2	2
11	Initial temp. of water in cont. A (T1) (°C)	27	32	31
12	Initial temp. of water in cont. B (T2) (°C)	27	32	31
13	Final temp. of water in cont. A (T3) (°C)	69	73	72
14	Final temp. of water in cont. B (T4) (°C)	59	61	62

V. CALCULATION

Calculation of thermal efficiency as per guidelines given in BIS:

A. For Reading 1:

Heat absorbed by water in container A (Q1)
= Mwa *CP* ΔT
= 2100 kcal
Heat absorbed by water in container B (Q2)
= Mwb *CP* ΔT
= 800 kcal
Heat absorbed by container A, (Q3)
= Ma *CP* ΔT
= 66.528 kcal
Heat absorbed by container B, (Q4)
= Mb *CP* ΔT
= 11.968 kcal
Total heat utilized, (Q5)
= Q1 + Q2 + Q3 + Q4
= 2978.49 kcal
Total heat produced, (Q6)
= Mass of fuel*CV
= 8000 kcal
Thermal Efficiency (%)
= (Q5/Q6)*100
= 37.23%

B. For Reading 2:

Heat absorbed by water in container A ,(Q1)
= Mwa* Cp* ΔT
= 2050 kcal
Heat absorbed by water in container B, (Q2)
= Mwb* Cp * ΔT
= 725 kcal
Heat absorbed by container A, (Q3)
=Ma* Cp * ΔT
= 64.944 kcal
Heat absorbed by container B, (Q4)
= Mb* Cp * ΔT
= 10.84 kcal
Total heat utilized, (Q5)
= Q1 + Q2 + Q3 + Q4
= 2850.78 kcal
Total heat produced, (Q6)
= Mass of fuel*CV
= 8000 kcal
Efficiency (%)
= (Q5/Q6)*100
= 35.23%

C. For Reading 3:

Heat absorbed by water in container A ,(Q1)
= Mwa* Cp * ΔT
= 2050 kcal
Heat absorbed by water in container B, (Q2)
= Mwb* Cp * ΔT
= 775 kcal
Heat absorbed by container A, (Q3)
= Ma* Cp * ΔT
= 64.944 kcal
Heat absorbed by container B, (Q4)
= Mb * Cp * ΔT
= 11.59 kcal
Total heat utilized, (Q5)
= Q1 + Q2 + Q3 + Q4
= 2901.78 kcal
Total heat produced, (Q6)
= Mass of fuel * CV
= 8000 kcal
Efficiency (%)
= (Q5/Q6)*100
= 36.27%

Calculated results are tabulated as follows.

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Table 5: Calculated Results

Reading	Heat utilized (kcal)	Heat produced (kcal)	Thermal Efficiency (%)
1	2978.496	8000	37.23
2	2850.78	8000	35.63
3	2901.78	8000	36.27

VI. CONCLUSION

- Clear burning of solid biomass.
- More efficient use of biomass due to more complete combustion.
- Modified design of accumulator given consistent blue flame with satisfactory burning.
- The modified combustion chamber has given significantly restricted heat losses.
- The average thermal efficiency 36.5% is obtained, not less than 35% for forced draft type of biomass cook stove as mentioned in BIS.

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