Design and Development of Biomass Pellet Burner for Frying Namkeen Crunchy Sticks & Wheels

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Abstract

In this paper experiment on biomass pellet burner is done. In this paper first design was done by using technical terms. The simulation of design also done on ANSYS software and comparative analysis between fabricated product and simulated product is done. The result of technical analysis and cost analysis was done.

Keywords: Biomass pellet burner, Design, Development, Analysis

I. Introduction

From early period fuels such as Wood, LPG, CNG etc. are used in boilers, burners & stoves. When its burns carbon dioxide, monoxide, and other carbon compounds are emitted in the atmosphere it contributing to the greenhouse effects. Wood-fired heating systems typically have considerable amounts of particulate, carbon monoxide and other unburned gaseous emissions compared with systems fired by other system. So now a day's biomass is a potential alternative energy replacing of wood, gas & oil. The biomass pellets mainly replaced combustion of wood in boilers and stoves among the main causes of ambient air pollution, being considered today as the major global environmental health risk. [1].

So biomass pellet is one of the best option for fuel. so we decides biomass can used as fuel for our project which is low cost and easily available in the market, biomass pellet is made up of agricultural residues manufactured by dried leaves, fruit bunches, Cashew shells, jj during logging operations so-called "black pellets". Which is free from chlorine & sulphur and having higher heating value (4000-4500 Cal/kg) .biomass pellet has standard fuel having ash content below 2% and moisture below 10% [1].

Our experimentation is related with design & manufacturing of biomass fuel pellet burner. As per application the biomass pellet burner are contain hopper, feeding mechanism (feeding screw & motor), combustion chamber, blower, thermostat & temperature control system. In biomass pellet burner biomass pellets are used as fuel.

Reduction in production cost by reducing fuel consumption is an inevitable trend for manufacturing industry to meet the strategic requirements of energy saving and environment protection. For conserve natural resources and minimize use of energy optimized design of burner is important for manufacturers in the present scenario. Fuel consumption reduction can be achieved by the introduction of better design, better manufacturing processes, better fuel and better use of burner fuel.

By using this modelling & analysis we are going to design biomass pellet burner so we can reduce fuel consumption. Finally it will help company to decrease production cost of crunchy wheels and sticks, so benefit of company in increase of sale by lowering cost of production with maintaining same quality of product. Also overall reduced load on environmental resources and carbon emission in the environment.

II. Literature survey

Debabandya mohapatra et al. [11] has discussed about various specific heat value at various temperature of basmati rice were measured Using differential scanning calorimeter. They have proven specific heat value at various temperature. With the help of this paper we find value of rice specific heat value at 1.27 to 4.83 kJ/kg. Which is related to row material [11].

Daniel Mulugeta et al.[13] has discussed about CFD analysis of porous medium burner for domestic cooking application for our project this paper is helpful for to calculating various physical parameters such as air flow rate, superficial gasification rate etc. which required for analysis.[13]

Joao Silva et al.[14] has discussed about CFD Modelling of Combustion in Biomass Furnace By this paper to understand CFD is efficient tool for the optimization of biomass combustion in burner and overall combustion mechanism reasonably predicts the emission of carbon monoxide and carbon dioxide inside the burner. In this paper optimization of industries furnaces computational fluid dynamics is an important and indispensable tool for understanding for instance the mixing between flue gases, combustion air and the pollutant formation. [14]

R.K. Rajput. [15] In this book author explained about thermodynamics, heat convection, conduction & radiation this book is helpful for our project for the finding of the material design and its properties and understood the burner required calculation formulae was taken by this book. [15].

Pamela Jagger et al.[8] has discussed about reviews of the experience of a for-profit firm in Rwanda promoting biomass pellets and a fan micro gasification improved cook stove as a clean cooking alternative to charcoal. Consumers purchase locally produced biomass pellets and receive the improved cook stove on a lease basis. The cost of the pellets and stove(s) is lower than the cost of cooking with charcoal in the urban setting where theirs study takes place. [8]

III. SELECTED BIOMASS PELLET

So biomass pellet is one of the best option for fuel. so we decides biomass can used as fuel for our project which is low cost and easily available in the market, biomass pellet is made up of agricultural residues manufactured by dried leaves, fruit bunches, Cashew shells, coconut shells ,trees tops, agricultural wastes, and branches discarded during logging operations so-called "black pellets". Which is free from chlorine & sulphur and having higher heating value (4000-4500 Cal/kg) .biomass pellet has standard fuel having ash content below 9% and moisture below 9% [1].

IV. MODEL OF BURNER

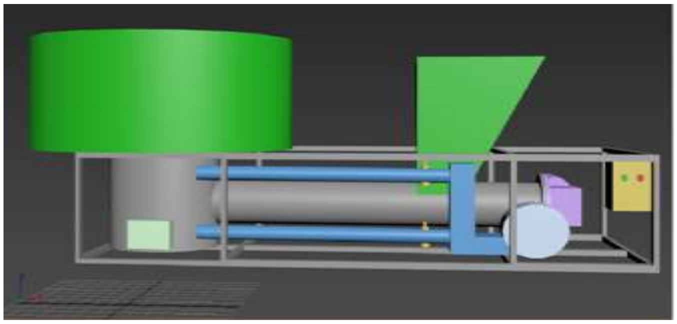

Fig. 1: Front view of proposed design of burner

V. DESIGN AND CALCULATION

For designing of biomass burner we can calculated following parameters as follows,

A. Calculation for Stoichiometric Air-Fuel Ratio:

Table – 1
Calculated A/F

Composition	*Mass per Kg of Fuel*	*Oxygen req./kg of pellets*
C	*0.5799*	$0.5799\times\frac{32}{12}= 1.5464$ *kg*
H_2	*0.0588*	$0.0588\times 8= 0.4704$*Kg*
O_2	*0.18*	*0.18 kg*
N_2	*0.0083*	-
S	*0.0013*	$0.0013\times\frac{32}{32}=0.0013$ *kg*
Ash	*0.0831*	-
		Total O_2*=2.1981kg*

O_2, required/kg of pellet = 2.1981 Kg (Where air is assumed to contain 23.3% of O_2 by mass), Air required/ kg of pellet = 9.4217 kg

Stoichiometric A/F ratio = 9.4217/1

B. Practical Temperature Reading:

For preparing of crunchy sticks and wheel Frying in 5kg Palm oil of one batch (400 gm.) in deep pan using traditional clay heating system required near about 60 sec.-

Table – 2
Practical Temperature Reading

PROCESS	*PALM OIL*	*TEMPERATURE*	*TIME*	*MATERIAL*
ADDING	*5 kg*	*140℃*	-	*400 gm.*
FRYING	-	*145℃*	*25 sec*	-

REMOVING	-	*150*℃	*15 sec*	-
NEXT BATCH PREPARATION	-	*140*℃	*15 sec*	-

C. Energy Input:

Company using tradition heating system for that they used 30kg fuel (wood saw dust) for 5 hours we know the wood heating value is 3000 kcal/kg so they used 90000 kcal per day (5hr) on this basis for 1 hr they used 6 kg fuel by this fuel we compare pellet as fuel to wood, for that we required 22.5 kg for 5 hr hence for 1hr burner required 4.5 kg pellet. So fuel consumption rate (FCR) is, [3]

$$\mathbf{FCR} = 4.5 \text{ kg/hr}$$

D. Energy Demand –

this refer to amount of heat that need to be supplied by burner for frying a wheels and sticks, using formula [3]

$$\mathbf{Q_n = FCR \times HV_f \times \xi_g}$$

$$Q_n = \mathbf{4.5 \times 17074.9 \times 0.4}$$

$$\mathbf{Q_n = 30734.82} \text{ KJ/hr}$$

E. Reactor Diameter –

This refer to the size of reactor and a function of fuel consumed per unit time (FCR) to the specific gasification rate (SGR) of biomass material which is 50 to 210 kg/m-hr [3] reactor diameter formula [3],

$$D^2 = \left(\frac{\mathbf{1.27 \times FCR}}{\mathbf{SGR}}\right) \qquad \dots (2)$$

$$= \left(\frac{\mathbf{1.27 \times 4.5}}{\mathbf{130}}\right)$$

$$D = 20.96 \text{ cm}$$

F. Height of Reactor –

this refer to the total distance of from the top to the bottom of reactor basically this refer required time to operate gasifier (T), the specific gasification rate (SGR) and the density of biomass material (ρ).calculated by following formula [3]

$$H = \left(\frac{\mathbf{SGR \times T}}{\boldsymbol{\rho}}\right) \qquad \dots (3)$$

$$H = \left(\frac{\mathbf{130 \times 1}}{\mathbf{420}}\right)$$

$$H = 30.95 \text{ cm}$$

G. Airflow Rate –

Airflow rate required for combustion was estimated to determine the size of fan required to air flow the air flow per unit mass of fuel is dependent on stoichiometric air (theoretical air) required to burn pellet. Air flow rate can be computed using formula [3]

$$AFR = \frac{\boldsymbol{\varepsilon} \times \mathbf{FCR \times SA}}{\boldsymbol{\rho_a}} \qquad \dots (5)$$

$$AFR = \frac{\mathbf{0.35 \times 4.5 \times 9.4217}}{\mathbf{1.25}}$$

$$AFR = 11.8713 \text{ m}^3/\text{hr}$$

H. Superficial Gas Velocity _

$$\text{Superficial gas velocity } (v_s) - \frac{\mathbf{AFR}}{\textbf{area of inner combustion chamber}}$$

$$Vs = \frac{\mathbf{11.8713}}{\mathbf{0.2726}}$$

$$Vs = 43.5484 \text{ m/s}$$

I. Find the Thickness of Burner

For calculating burner wall thickness, First we have assume burner thickness with distance in which we have using two material consist of four layer. After first layer there is air gap so we here calculate six various temperature value. On this basis we calculate first (t_1) to last (t_6) wall temperature. If last wall (t_6) temperature is below 60℃ then our design will be safe. [15]

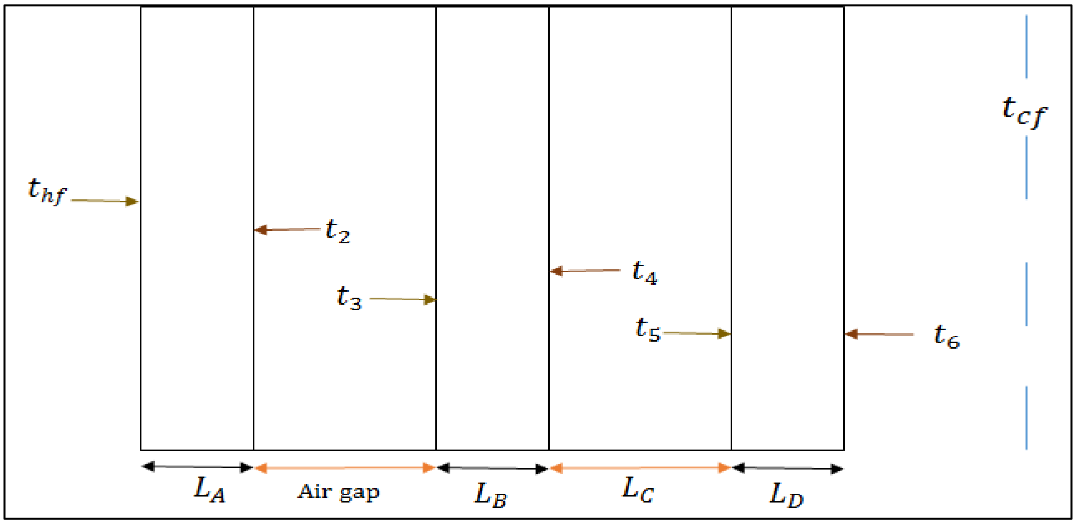

Fig. 2: Thickness of burner

Solution,
Thickness of M.S. L_A = 5mm
Resistance of air gap to heat flow = 0.16 K/W
Thickness of M.S. L_B = 5 mm
Thickness of Insulating material ceramic fiber (L_C) = 30 mm
Thickness of M.S. L_D = 5 mm
Heat transfer coefficient from the outside wall surface to the air in the room,
h_{cf} = 18 w/m^2 ℃

Thermal conductivity:
M.S. K_A, K_B, K_D = 46.2 W/ m℃
Insulating Material Ceramic Fiber K_C = 0.003 W/ m℃
Temperatures:
inner combustion chamber temperature t_{hf} (t_1) = 1000℃ ;
Atmospheric temperature near to wall t_{cf} = 30℃ .
Heat transfer coefficient from the outside wall surface to the air in the room,
h_{cf} = 18 W/ m℃
Rate of heat loss per m^2 of surface area, Q :

$$Q = (t_{hf} - t_{cf}) \div \left\{ \frac{L_A}{K_A} + \text{Air gap resistance} + \frac{L_B}{K_B} + \frac{L_C}{K_C} + \frac{L_D}{K_D} + \frac{1}{h_{cf}} \right\}$$

$$Q = (1000 - 30) \div \left\{ \frac{0.005}{46.2} + 0.16 + \frac{0.005}{46.2} + \frac{0.03}{0.003} + \frac{0.005}{46.2} + \frac{1}{18} \right\}$$

Q = 94.95 W (Ans.)

ii) Temperatures at Interfaces t_2, t_3, t_4, t_5,

$$Q = 94.95 = \frac{(1000 - t_2)}{\frac{L_A}{K_A}} = \frac{(1000 - t_2)}{\frac{0.005}{46.2}}$$

∴ t_2 = 999.98℃ (Ans.)

Also, $$Q = 94.95 = \frac{(t_2 - t_3)}{\text{Air gap resistance}} = \frac{(999.98 - t_3)}{0.16}$$

∴ t_3 = 984.78℃ (Ans.)

Again, $$Q = 94.95 = \frac{(t_3 - t_4)}{\frac{L_B}{K_B}} = \frac{(984.78 - t_4)}{\frac{0.005}{46.2}}$$

∴ t_4 =984.76 ℃ (Ans.)

Again, $$Q = 94.95 = \frac{(t_4 - t_5)}{\frac{L_C}{K_C}} = \frac{(984.76 - t_5)}{\frac{0.03}{0.003}}$$

∴ t_5 =35.26 ℃ (Ans.)

iii) Temperatures of outside surface of the wall, t_6

$$Q = 94.95 = \frac{(t_5 - t_6)}{\frac{L_D}{K_D}} = \frac{(35.26 - t_6)}{\frac{0.005}{46.2}}$$

∴ t_6 =35.24 ℃ (Ans.)

So, we assuming design is safe that is outside wall temperature is 35.24 ℃ which is below than 60℃ .

J. Thermal Analysis of Biomass Pellet Burner

For thermal analysis we have used ansys software which is used to simulate computer models of product simulation of product is important before product fabrication because it shows all results same as the running model. The Geometry, Meshing, Define boundary condition, Solver setup, Results are done on software. The thermal analysis of wall given in fig. below.

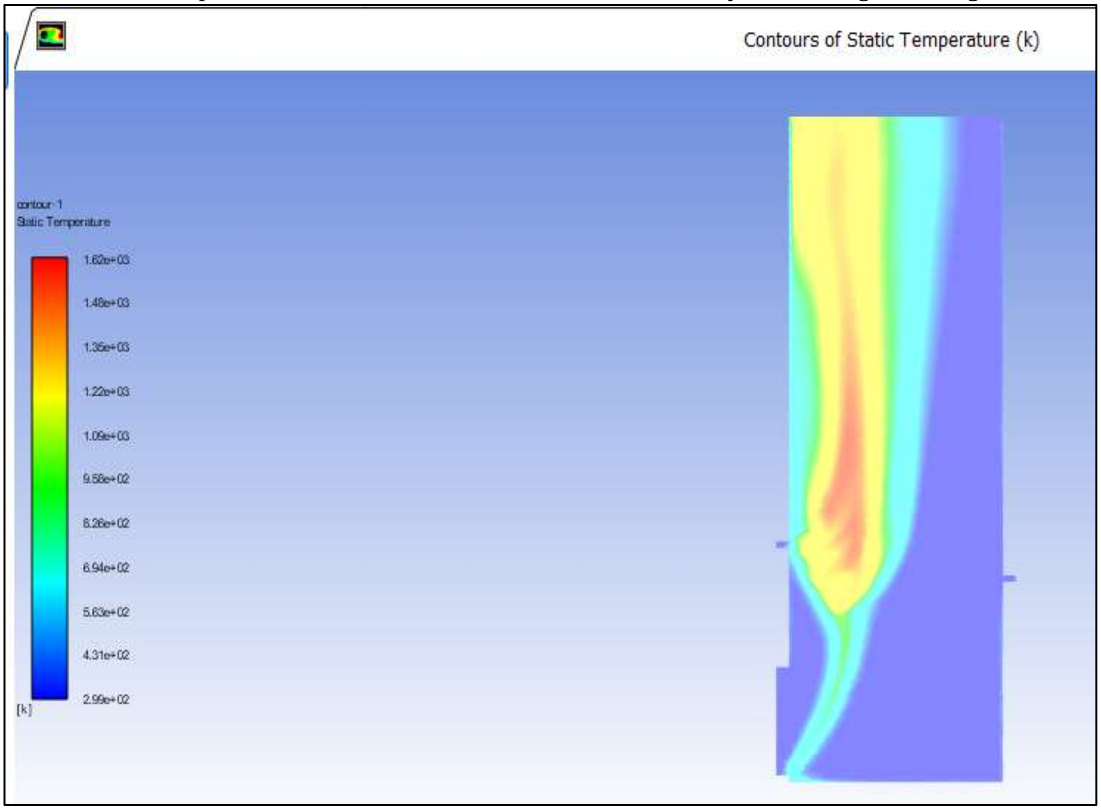

Fig. 3: final results of burner simulations

From Above fig. we got following results
Red zone shows maximum temperature of inside burner flame is 1350℃
Blue zone shows minimum temperature of inside burner near to wall is 950℃
Top flame temperature from outside of burner is 950℃
Calculated all design parameter

Table – 3
calculated all design parameter

Sr.	*Design parameters of burner*	*Values*
1.	*Height of reacting chamber*	*310 mm*
2.	*Diameter of reacting chamber*	*210 mm*
3.	*Total Air flow rate of primary and secondary air*	*350 CFM*
4.	*Mass flow rate of fuel flow*	*4.5 Kg/hr*
5.	*Superficial velocity of gas*	*43.54 m/s*
6.	*Inside burner temperature (red to blue)*	*1350℃ to 950℃*
7.	*Outside flame temperature*	*950℃*
8.	*Outside wall temperature of burner*	*35.24℃*
9.	*Thickness of M.S material*	*5 mm*
10.	*Thickness of insulating material*	*30 mm*
11.	*Total burner diameter*	*360 mm*
12	*Total height of burner*	*400mm*

VI. FABRICATED MODEL

All the parts are fabricated by the using calculation and analysis results and selecting material. we finally fabricated best model of biomass pellet burner which is ready for testing .

Fig. 3: final assembly of burner with pot locator

A. *Testing of Model*

For testing of model we here taking a three batch for first batch, second batch and third batch we for first batch and second batch we take here same temperature and for third batch we take different temperature.

B. *Batch Reading*

For Frying process we set 150℃ for frying crunchy sticks, for that we set 8 sec during this time 1.3 sec motor is on and 6.7 sec is off mode. It consumes pellets for 8 sec time is 8.15 gm. Temperature rises at 25℃ (atmospheric temperature) to 150℃ in duration of 11 min.

Table – 4
Batches reading of frying churchy sticks and wheels

Process	*Palm Oil (Kg.)*	*Temp. (℃)*	*Time (Sec.)*	*Sticks/ wheels. (gm.)*	*Pellet consumption (gm.)*
Pre-heating (25℃ – 150℃)	*5*	*150℃*	*660*	_	*874.5 to1000*
Batch-I Adding	-	*150℃*	*5*	*400*	-
Frying	-	*150℃*	*10*	-	-
Removing	-	*150℃*	*15*	-	*39.75/ batch*
Batch-II Adding	-	*150℃*	*5*	*400*	-
Frying	-	*150℃*	*10*	-	-
Removing	-	*150℃*	*15*	-	*39.75/ batch*

C. *Differentiate Results of Simulation Model and Fabricated Model*

Table – 4
Simulation and fabricated model results comparison

Sr. No	*Contents*	*Simulation results*	*Fabricated result*
1.	*Flame height*	*500 mm*	*550mm-600mm*
2.	*Inner temperature of wall*	*1350℃-950℃*	*1000℃*
3.	*Outer wall temperature*	*36℃*	*42℃*
4.	*Outside burner flame temperature*	*950℃*	*1000℃*

Table – 5
Final result of biomass pellet burner as compare to traditional clay heating using wood as a fuel.

Sr. No	*Contents*	*Clay heating system using wood as fuel.*	*Biomass pellet burner*
1.	*5 hr working per day required fuel*	*30 kg*	*25 kg*
2.	*Namkeen wheels and sticks making kg/day*	*150 kg*	*230 kg*
3.	*Required electricity per day*	*No*	*1-2 unit (10 Rs)*
4.	*Fuel price*	*6 Rs/kg*	*9 Rs/kg*
5.	*Total cost per day for making frying food for 150 kg.*	*6180 Rs.*	*Rs. 6156*

VII. CONCLUSION

This study provides the development of enclosed biomass pellet burner specially designed for commercial food manufacturing industries. It provides mechanism in which as compare to traditional clay heating in which wood as fuel on which biomass pellet burner is best option which efficiency and applicability could be maximized. The biomass pellet burner has inner diameter is 210mm. and including overall dimension such as insulation wall outer wall is 340 mm. height of reactor chamber is 300 mm overall dimension such as including ash collecting height is 400mm and specific fuel consumption of 4.8 kg/hr. The performance efficiency of the stove was evaluated using oil boiling test and thermal efficiency of 20% was obtained. As compare to clay heating system to biomass pellet burner we have fried extra 105 kg of wheels and sticks. Per day (for 5 hr.) which is profitable.

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