EXPERIMENTAL ANALYSIS OF THERMAL EFFICIENCY OF INCINERATOR USING KOLHAPUR MUNICIPAL SOLID WASTE

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ABSTRACT

Indian per capita waste generation is 0.2 – 0.6 kg/day, which is estimated to increase at 1.33% annually. As per estimates,1,27,486 TPD (Tons per day) municipal solid waste is generated in the Country during 2011-12. Out of which, 89,334 TPD (70%) of MSW is collected and 15,881 TPD (12.45%) is processed or treated. Municipality used the landfill as the main solution to deal with the MSW, however the rapid growth of MSW volume leads to that the new high efficient MSW treatment method are needed to replace the landfill. One of these methods is waste incineration with energy recovery which has an aim to minimize waste volumes as well as generate power.

The paper revels evaluating the thermal efficiency of incinerator ,designed for Kolhapur municipal solid waste. The prototype incinerator, designed gives the maximum efficiency of 61% having fuel MSW calorific value 1601.29 Kcal/Kg. Incineration, if properly designed, is an efficient way to reduce the volume of waste and demand for landfill space. Incineration reduces the need for landfill space to 5%, while the ash can also provide an inexpensive for environment-friendly fertilizers and aggregate for construction.

Keywords:* *Incineration, Municipal Solid Waste, Grate Fired Furnace, Waste yo Energy.

I INTRODUCTION

About 80% of the global energy demand is met by fossil fuel and less than 15% comes from renewable resources such as biomass, wind, hydro and solar. Therefore, one of the major challenges for today's scientist is to give answer and find ways to meet the ever increasing energy demands and at the same time minimize the side-effects of combustion such as global warming, acid rain, formation of dioxins, depletion of ozone layer, etc. One way to meet a part of this need is to increase the use of renewable energy sources like biomass, wind, solar, hydro and geothermal. The biomass fuel is normally classified into different classes depending on its origin. They are woody (tree, bark), herbaceous (straw, grass), agriculture waste and residuals (sugarcane, wheat, oats, corn) and refuse-derived fuels and organic waste materials (food, saw dust), municipal solid waste e.t.c. Municipal solid wastes are the organic and inorganic waste materials such as product packaging, grass clippings, furniture, clothing, bottles, kitchen refuse, paper, appliances, paint cans, batteries, etc., produced in a society, which do not generally carry any value to the first users. Knowledge of the sources and types of solid wastes as well as the information on composition and the rate at which wastes are generated/ disposed is, therefore, essential for the design and operation of the functional elements associated with the management of solid wastes.

II DESIGN AND EXPERIMENTATION

Performance evaluation of Prototype model at Department of Technology (DOT), Shivaji University, Kolhapur (SUK) is carried out. The raw material for Incineration is municipal solid waste which is collected from MSW dumping site located at Bavada, Kolhapur. The calorific value is 1601.29 Kcal/Kg(estimated using bomb calorific meter at DOT) is established for fuel MSW ,the waste available in heterogeneous mixture with variable moisture content. The methodology to evaluate the performance of the Prototype Model is developed as above based on existing formulae available for the thermal power plant. Data from the selected time span is taken and recorded in blank data forms. The measurements are taken for real value experimentation and results are evaluated for the given test conditions.

There are different types of incinerator but out of all types incinerator the moving grate incinerator is more appropriate technology for energy generation. Because in moving grate technology mostly mass burn incinerator is gives more benefits over the other type of incinerator. The size of the incinerator is designed for process steam requirements for nearby textile industry from Ichalkaranji..

$$= 4.18\ (100\text{-}30) + 2201.6 + 2.25\ (110\ \text{-}100) = 2516.7\ \text{KJ/Kg}$$

Hence for 40 Kg steam generation we require 100668 KJ/hr. If we have the fuel having calorific value 1601.29 Kcal/Kg then for 40 Kg steam generation 19 Kg/hr fuel is require (estimated). Hence we decide the make a prototype model for 10 Kg steam generation and it requires the quantity of fuel MSW is 5 Kg/hr.

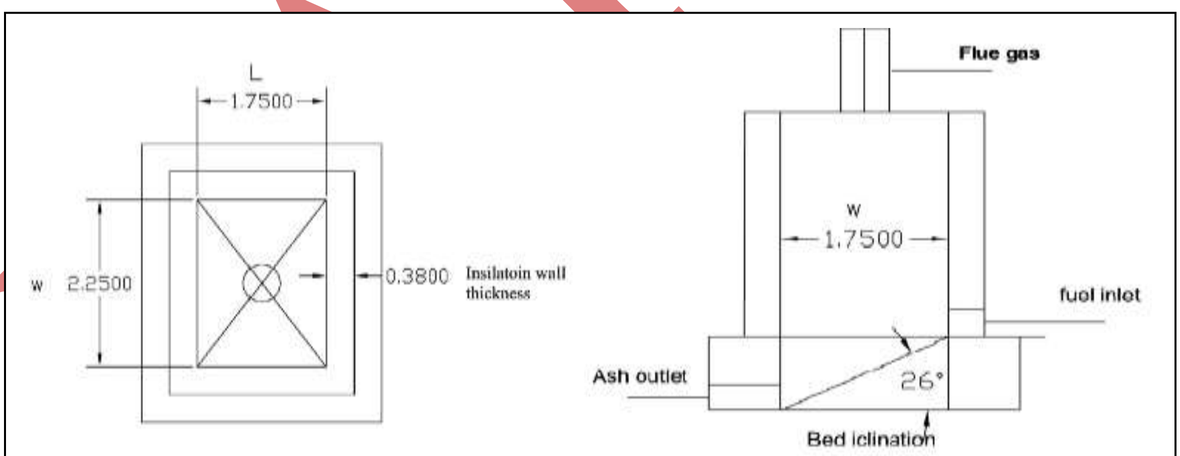


Fig. 1 of top view and side view of prototype model

2.1 Design Considerations and Specifications

1. The quantity of steam require for flake machine is 40 kg per hour at pressure 2 bar and 110 ° C temperature.
2. Ambient temperature of water is 30^{o}C
3. Heat require to generate 1 Kg of steam = $C_{pw}\ (100 - T_1) + H_{fg} + C_{ps}\ (T_2 - 100)$

   Where, C_{pw}= Specific heat of water(4.18 KJ/Kg), C_{ps}= Specific heat of steam(2.25 KJ/Kg), T_1= Ambient temperature of water, T_2= Final temperature of water, H_{fg}= Latent heat of steam(2201.6 KJ/Kg)

4.Amount of heat require to generate 1 Kg of steam is 2516.7 KJ/Kg.

5. Length to width ratio . L:W = 1:1.3

6 Hence W = 2.25 and L = 1.75

7.The refectories furnace bricks are used for construction of the incinerator and 5mm mild steel sheet is used for bed of incinerator.

8.A Kg of waste hold 300g C ~ 25 mol C (300g/ 12g/mol) and 43g H ~ 43 mol H (43g/ 1g/mol). Hence the overall reaction of C and H with oxygen yield CO_2 and H_2O

$$C + O_2 = CO_2 \quad \text{i.e.} \quad 25 \text{ mol C} \sim 25 \text{ mol } O_2 \sim 25 \text{ mol } CO_2 \text{ and}$$

$$H + \tfrac{1}{4} O_2 = \tfrac{1}{2} H_2O \quad \text{i.e.} \quad 43 \text{ mol H} \sim 10.75 \text{ Mol } O_2 \sim 21.5 \text{ mol } H_2O$$

9.The required amount of combustion air for excess air ratio (λ) in range 1.5- 2.0 would be 4.52 -6.03 Nm^3/kg. only 0.63 Nm^3/kg ate used in the combustion process. The remaining part, 3.9 -5.4 %, is diluted the flue gas. With a dry air density of 1.293 kg/Nm^3, 5.85 – 7.80 kg of air is needed for 1 Kg of waste.

10.Ror prototype model 30 Nm3/Kg air is provide for combustion. Where the rate at which air supply is 10 -15 m/sec.In prototype model air is provided from the bottom of combustion bed.

2.2 Experimentation for Calculating Thermal Efficiency of Furnace

Thermal efficiency of furnace is calculated using formulae as follows.

$$\textbf{Thermal efficiency of furnace} = \frac{\textit{Heat in stock}}{\textit{Heat in fuel consumed of heating stock}} = \frac{\text{He}}{\text{Hin}} \quad \ldots\ldots\ldots\ldots\ldots(1)$$

The quantity of heat to be imparted (He) to the stock can be found from,

$$\textbf{He} = \textbf{m} \times \textbf{Cp} \, (T_F - T_a) \ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where ,b m = Weight of the stock in kg, Cp = Mean specific heat of stock in kCal/kg°C, T_f = Final temperature of stock desired, °C, Ta = Initial temperature of the stock before it enters the furnace, °C, He = Quantity of heat of stock in

$$\textit{Heat in fuel consumed of heating stock} = \textbf{Hin} = \textbf{q X GCV} \ldots\ldots\ldots\ldots (3)$$

Where, q = Quantity of fuel used per hour in kg/hr, GCV = gross calorific value of the fuel in kCal/kg of fuel

The efficiency of furnace is depend upon the heat in stock (flue gas), specific heat of flue gas, flow of flue gas e.t.c and it may affected by the percentage of moisture in fuel, decreased air supply e.t.c.. Hence thermal efficiency of furnace is calculated by considering all this factors. The prototype model is designed for 5 Kg/hr fuel supply and it is also tested for 6 Kg, 7 Kg, and 8 Kg fuel supply per hour.


I


II


III

Fig. 2 I= experimental setup, II & III = temperature sensor with digital meter and positioning of sensor in furnace, burning of fuel in incinerator, measurement of flue gas velocity using pitot tube manometer.Experimentation carried out at Department of Technology Shivaji University Kolhapur (MS,India)

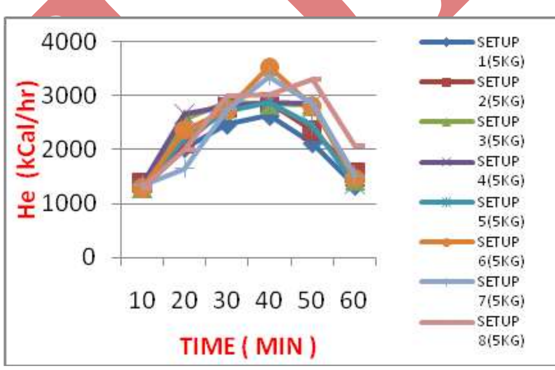
III DATA ANALYSIS AND RESULTS

A assessment of the potential of recovery of energy from MSW through different treatment methods can be made from a knowledge of its calorific value and organic fraction. In thermo-chemical conversion all of the organic matter, biodegradable as well as non-biodegradable, contributes to the energy output. The measurements are taken for selected time span and results are evaluated for the given test conditions. It is true that such performances can be evaluated for the power plants in operations for more than 10 years and up to 20-25 years. Such conditions are not available in practice. Based on input parameters and the output parameters measured during the test periods the performance is given as under.

As shown in fig. no. 3 the higher efficiency of furnace was 44.06% (at 40 min) where heat in flue gas was also high i.e. 3528 Kcal/hr (at 40 min). The both reading were taken in setup no.6. Lower efficiency of furnace was 15.93 % (at 10 min) where heat in flue gas was also low i.e. 1276.11 Kcal/hr (at 10 min) in setup no.5.

As shown in figure no.4 fuel supply 5Kg, 6Kg, 7Kg, and 8 Kg per hour gives maximum efficiency 37.45 % , 43.35 %, 52.57 %, 61.93 % respectively. Higher efficiency of furnace was 61.93 % (at 30 min) where heat in flue gas was also high i.e. 7934.4 Kcal/hr (at 30 min) in 8 Kg/hr fuel supply setup, which is highest efficiency as compared to all setups. The 8 Kg/hr fuel supply gives the average maximum efficiency for one hour was 43.22 % and at same time in 8 Kg/hr fuel supply we got the highest temperature of furnace was 783 ° C and in 5 Kg/hr fuel supply we got the highest temperature of furnace was 545 ° C.

Figure no. 6 shows the behavior of furnace efficiency with variation in moisture content of municipal solid waste Higher efficiency of furnace was 31.65 % (for 5 Kg/hr) at 25 % moisture content in fuel. Lower efficiency of furnace was 25.25 % (for 5 Kg/hr) at 38 % moisture content in fuel



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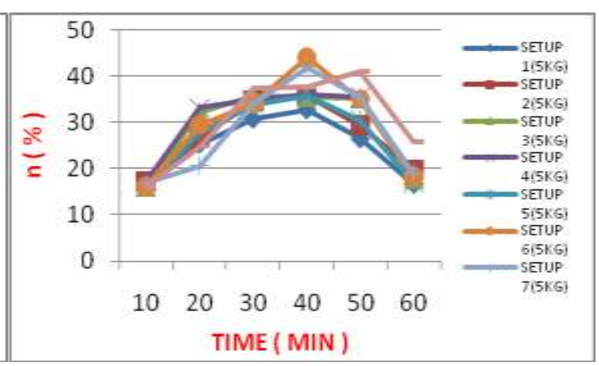

Fig. 3 a) Heat in flue gas of furnace with respect to Time for each set of 5 Kg fuel

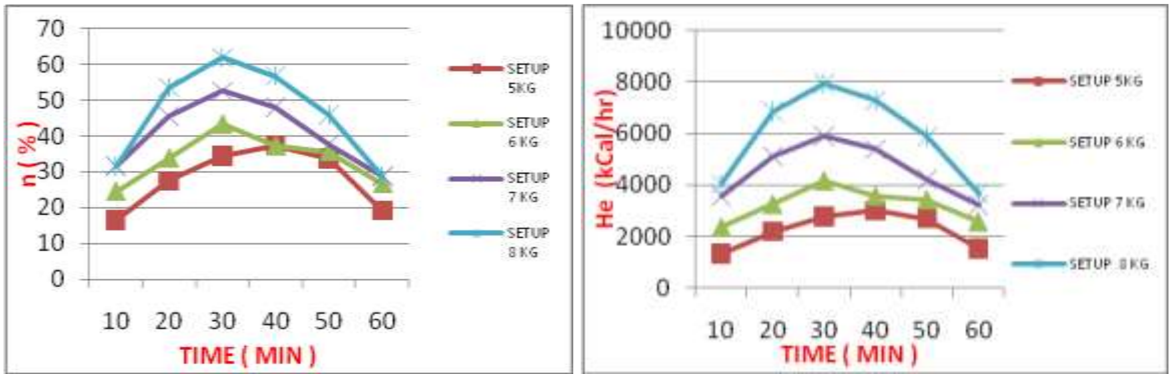

Fig. 4 a) Efficiency of furnace with respect to Time and b) Heat in flue gas of furnace with respect to Time for 5 Kg, 6 Kg, 7 Kg and 8 Kg fuel MSW

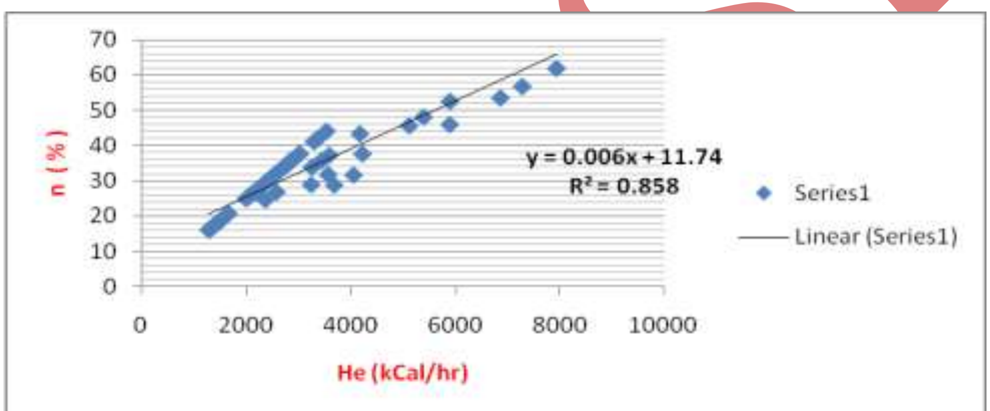

Fig. 5 Quantity of heat of stock (air) in kCal with specific efficiency for that heat

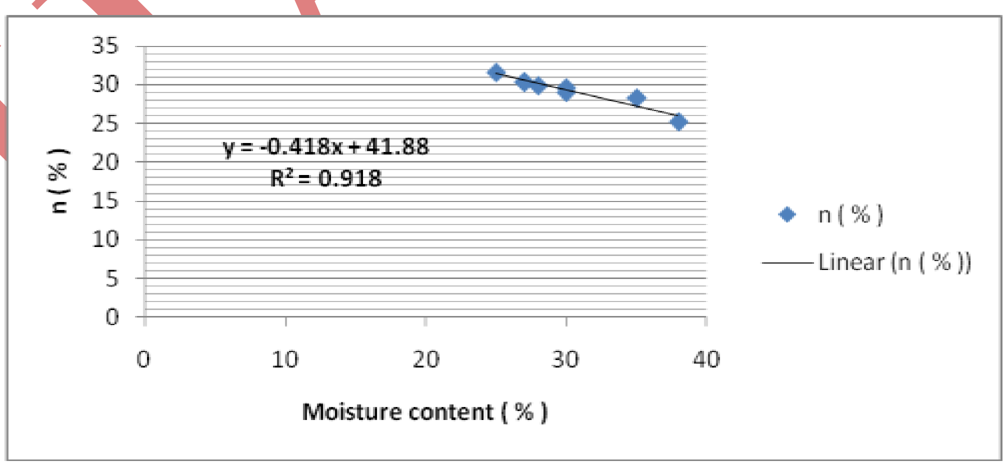

Fig. 6 Efficiency with respect to Moisture content for each set of 5 Kg fuel MSW

IV CONCLUSION AND RECOMMENDATION

The quantity of moisture present in municipal solid waste directly affects the temperature, thermal efficiency of furnace and quantity of ash of furnace. Low moisture content in fuel gives the higher efficiency of furnace and simultaneously responsible for low ash formation because low moisture content directly support for efficient burning of municipal solid waste which lead to attain the maximum temperature of furnace. The maximum efficiency 0f 61.93% is achieved without segregation of raw MSW . Higher the moisture content less is the thermal efficiency of furnace. Hence the low moisture content or dry waste should be used for incineration technique. The incarnation process can be used for MSW for heat and power generation without segregating the raw materials provided the moisture content and excess air in furnace designs are controlled .

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