Performances Evaluation of Force Draft Gasifire Based Cook Stove

Er. Ranjit Powar1 Er. Paris Yadav2 Er. Manish Chavan3
1,2,3 Assistant Professor
Dr. D. Y. Patil CAET Talsande, Maharashtra, India.

Abstract— The article highlighted the performance evaluation of forced draft gasifire based cook stove. The design and development of forced draft cook stove was carried out at Dr. UPCAET Jalgaon. The performance of cook stove take place for three different biomasses i.e. Pellet, Tur and Neem. It was found that the volatile matter, fixed carbon contain higher in the Pellet as compare with Tur and Neem. Ash content in Tur is higher as compared with the Pellet. The burning capacity of pellet is less than that of Tur and Neem. The combustion zone rate for pellet, Neem and Tur were found to be 0.100, 0.120, 0.175 m/h respectively.

It was observed that hot water condition was more superior to that of cold water condition. The thermal efficiency obtained from the cook stove for pellet 40.33 per cent, Neem 36.47 per cent and Tur 33.43 per cent. The results of controlled cooking test (CCT) shown the specific fuel consumption of a stove were 1, 1.2 1.44 kg/kg for pellet, Neem, and Tur. The total power output of the cook stove for pellet, Neem and Tur were found to be 3, 2 and 1.8 KW respectively.

Key words: forced daft cook stove, thermal efficiency, CCT, power output

I. INTRODUCTION

Biomass is one of the main energy sources for the mankind. Estimate indicates that 10-15 per cent of the world’s primary energy could come from biomass by the year 2050 (www.mnes.nic.in). Biomass contributes over a third of primary energy in India. It delivers most energy for the domestic use (rural - 90 percent and urban - 40 percent) in India (Bhattacharya et. al 1999). The biomass energy from agriculture has different forms like cropland, grassland, forest, roadsides, and agro-forestry etc. They estimated total available crop residues in India as 523.4 Mt/year and surplus as 127.3 Mt/year Pathak B.S. et al. (2004). The annual surplus crop residues of Cotton stalk, Pigeon pea stalk, Jute & Mesta, Groundnut shell, rapeseed & Mustard, Sunflower were 11.8, 9.0, 1.5, 5.0, 4.5, and 1.0 Mt/year, respectively. The residues of most of the cereal crops and 50 per cent of pulses are used for fodder. Coconut shell, stalks of rapeseed and mustard, Pigeon pea and Jute & Mesta, and Sun flower are used as domestic fuel (Bhattacharya et.al 1999). The total crop residues burnt in India as 71.6 Mt in selected states of country in 2001. The 40 per cent and 50 per cent of cotton and mustard stalks are available as surplus out of their total stalk generation of 29.4 and 9.4 Mt, respectively. Among the crop residues cotton stalk represent about 4 per cent of the total amount of residues SPRERI (2004).

The domestic cooking accounts major share of the total biomass energy used in Asia (Bhattacharya et.al 1999). However, use of biomass fuels in traditional stoves is characterized by low efficiency and emission of pollutants. In an effort to address these problems, many of the Asian countries have initiated national programmes to promote improved cook stoves. The Ministry of New and Renewable Energy (MNRE) launched National Biomass Cook stoves Initiative (NBCI) with an aim to enhance the availability of clean and efficient energy for the energy deficient and poorer sections of the India www. mnes.org.in. The biomass conversion and management technologies had very important role in rural development in India. These technologies offered a great challenge to the conventional sources and put to the service of rural people development, specially improved cooking stoves, biogas and producer gas (Alam 2000).

The gasifire stoves are more emission efficient in comparison with traditional cook stoves (Grover P.D. (2003). The capacity of natural draft gasifire based stoves ranges from 3kW to 20 kW; it is suitable for domestic as well as community cooking applications (Bhattacharya S.C et al (1999). Forced draft type gasifire stove, which use a small battery-operated blower to supply primary and secondary air, are more recent developments. The ultimate advantage is to obtained higher wattage for the same stove size, easier to start and operate, and flame control is much more effective in comparison with natural-draft stoves (Reed T.B et. al 2000).

II. MATERIALS AND METHODS

A. Selected biomass

The pellet, Neem and Tur were selected as fuel for performances evaluation of gasifire based cook stove.

B. Proximate analysis of biomass

The proximate analysis of pellet, Neem and Tur were done by following procedure

1) Moisture content

Electric oven available was used to determine the moisture content of pellet, Neem and Tur. A known quantity of sample was dried at 110 ± 5°C until constant weight was attained and the moisture content was calculated by using formula

\[\text{Moisture % (wb)} = \left(\frac{W_2 - W_3}{W_2 - W_1}\right) \times 100\]

Where,
\[W_1 = \text{weight of empty crucible, g}\]
\[W_2 = \text{weight of the crucible and sample, g}\]
\[W_3 = \text{constant weight of crucible and sample after drying, g}\]

2) Volatile matter

A known quantity oven dried sample of pellet, Neem and Tur samples were heated at 600 ± 25 °C for six minutes and then at 900 ± 25 °C for another six minutes in a pre-weighed open silica crucible in a muffle furnace. The amount of weight loss in the sample gives the volatile matter of the biomass sample estimated using the formula given below

\[\text{Volatile Matter % (wb)} = \left(\frac{W_2 - W_3}{W_2 - W_1}\right) \times 100\]

Where,
W₁ = weight of empty silica crucible, g  
W₂ = weight of crucible and sample, g  
W₃ = constant weight of crucible and sample after heating, g  
3) Ash content  
A known quantity oven-dried sample of pellet, Neem and Tur were combusted in a pre-weighted and closed silica crucible at 750 ± 25 °C for a minimum four hours in a muffle furnace. The amount is calculated using the formula given below 

\[
\text{Ash contain} \% (wb) = \frac{(W₂ - W₃)}{(W₂ - W₁)} \times 100
\]

Where,  
W₁ = weight of empty silica crucible, g  
W₂ = weight of crucible and sample, g  
W₃ = constant weight of crucible and sample after combustion, g  
4) Fixed carbon  
The amount of fixed carbon (FC) present gives a rough indication of the charcoal yield. Also, a higher FC material was generally better suited for gasification than a lower FC material. The fixed carbon was estimated by using the following formula:  

\[
\text{Fixed carbon} (\%) = \frac{\text{mass of the cook stove}}{\text{constant weight of crucible and sample after heating}} \times 100
\]

C. 2.3 Performances evaluation of cook stove (comparative study)  
The performances of cook stove were checked in three conditions like cold start, hot start and low power different parameter elaborated in test was comparing with each other  

1) High power, cold start  
The first phase begins with the stove, standard test pot, and water at room temperature and the stove is operated until the water reaches boiling temperature.  
2) High power, hot start  
The second phase begins immediately after the first phase with the stove hot and with the pot refilled with water at room temperature. The stove is operated until the water reaches boiling temperature. Results for the cold start and hot start can be compared to identify differences in performance between a cold and hot stove.  
3) Low power operation  
The third phase begins immediately after the second phase with the stove, pot, and water hot. The stove is operated to maintain the water temperature just below the boiling point, and results can be compared to identify differences in performance between low power and high power operation of the stove.  
4) Burning test  
The burning test was carried out by BIS standard. In which the combustion chamber fill with test fuel in honey-comb fashion up to third-fourth of the height of the cook stove in the pattern recommended. To achieve ignition temperature 10 to 15 ml of kerosene oil has been sprinkled on the fuel wood to the top of the cook stove and fires it by match box. The weight of the cook stoves along with fuel wood was measured before igniting the fire and again it was done after half an hour of burning the wood fuel as per the procedure given in BIS standard [1]. To calculate the burning capacity of the cook stove, the following equation is used [22]:  

\[
\text{Burning capacity} = 2(M₁ - M₂) \text{ kg/h}
\]

Heat input per hour = \[2(M₁ - M₂) \times CV \text{ kcal/h}
\]

Where,  
M₁ - initial mass of the cook stove with test fuel in kg,  
M₂ - mass of the cook stove, after burning the test for half an hour in kg  
CV - calorific value of kcal/kg,  
5) Ash contain  
After burning all biomass present in burning test the reaming ash contain in the combustion chamber as well as ash chamber was measured.  
6) Power output rating  
The power output rating of cook stove is a measure of total useful energy produced during one hour by the fuel. It shall be calculated as follows:  

\[
\text{Po} = F \times CV \times \eta / 360000 \text{ kW}
\]

Where,  
Po = Power output  
F = rate of consumption of fuel wood (kg/h)  
CV = calorific value of wood (or solid fuel), in kJ/kg  
\eta = thermal efficiency of the cook stove in percent  
7) Combustion zone rate, CZR  
The CZR rate calculated by following formula.  

\[
\text{CZR} = \frac{\text{Length of reactor(m)}}{\text{Total operating time(h)}}
\]

8) Water boiling test  
Thermal efficiency of a Cook stove may be defined as the ratio of heat actually utilized to the heat theoretically produced by complete combustion of a given quantity of fuel (which is based on the net calorific value of the fuel).  

Procedure  
(1) Before starting the experiment, take the initial readings of weight, volume of water, weight of wood, volume of kerosene and weight of empty aluminum vessel  
(2) Then the fuel wood available from farm cut in proper dimension as per BIS standard afterwards, the wood logs (1–2 kg) of proper dimensions were arranged in honey-comb manner inside the gasifire based cook stove models to be analyzed.  
(3) A known minimum volume of kerosene (which varies for different models) was poured over the wood logs to initiate the ignition process and fire was lighted by electrical heating system.  
(4) Aluminum vessels having known volume of water were placed on the cook after igniting the fire in the wood log placed in honeycomb fashion inside the cook stove.  
(5) The readings of water temperature, pot temperature, pot cover temperature, outer surface temperature of the cook stove, etc., were taken periodically after an interval of 5 min.  
(6) As the first pot reaches to the test temperature of about 80 °C, the second pot placed on the cook stove and the data was measured in the similar way as for the first pot.  
(7) The experiment was continued and the pot being replaced until the complete fuel wood consumed properly for water boiling/heating process.  

Thermal efficiency calculated by following formula

\[
\text{Heat utilized} = (n - 1)(Wx0.896 + wx4.1868)(f₂ - f₁) + (Wx0.896 + wx4.1868)(f₃ - f₂) \text{ kJ}
\]

Heat produced= \[4.1868 \times (\text{XxC₂)} \times \frac{\text{M₁ – M₂}}{\text{1000}} \text{ kJ} \]
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III. RESULTS AND DISCUSSION

A. Characterisation of Sample

The proximate analysis of raw materials were done which shows that the Pellet, Neem and Tur contains volatile matter were 72.16 per cent (d.b.), 71.78 per cent and 67.06 per cent, respectively and less amount of moisture content 6.0 per cent, 8.42 per cent and 12.72 per cent respectively. Ash content in pellet, Tur, Neem are 10.42 per cent, 15.45 per cent and 1.44 per cent. It was observed that pellet was found to be 72.16 per cent (d.b.), 71.78 per cent and 67.06 per cent, respectively and less amount of moisture content 6.0 per cent, 8.42 per cent and 12.72 per cent respectively. Ash content in pellet, Tur, Neem were 10.42 per cent, 15.45 per cent and 1.44 per cent. Bulk density of pellet, Tur, Neem were 1100 kg/m³, 18 kg/m³ and 300 kg/m³ respectively. Volatile matter evolves in the form of gas, hydrocarbon and tars. Higher volatile matter of the biomass makes it more acceptable for present demand of cook stove. Ash content and moisture content affect the heating value of pellet, Tur and Neem. Ash content depends upon the season and soil condition in which the plant grows.

B. Burning Capacity

The burning capacity of pellet, Tur and Neem were to be 3.12 kg/h, 3.10 kg/h and 4.52 kg/h respectively. It should be more as design consideration because the air flow rate in the combustion chamber was high as required. There is no any provision to control the rate of air flow of the fan.

C. Combustion Zone Rate

The combustion zone rate for pellet Neem, and Tur were found to be 0.100 m³/h, 0.120 m³/h and 0.175 m³/h respectively. Tur has more bulky i.e. its combustion rate is high as compared with pellet and Neem.

D. The Water-Boiling Test

The water boiling test carried out by pellet sample at two condition i.e cold water boiling test and hot water boiling test. The graph 1 show the graphical relation between the time verses increasing temperature of the water. It was seen that the water boil at hot condition in 2 minutes and water boil at cold condition in 5 min. It shows that hot water condition was more superior to the cold water condition. Because, it could be minimizes the initial thermal losses of the system. After reaches the water at saturation boiling condition then increasing time there would be not any significant increasing the temperature.

GRAPH 1. Comparison of hot and cold water boiling condition

1) Thermal Efficiency

The thermal efficiencies obtained from the cook stove from pellet 40.00 per cent, Neem 36.47 per cent and Tur 33.43 per cent. According to India standard developed cook stove was suitable for commercial application.

2) Control Cooking Test

The results of controlled cooking test (CCT) shown that the specific fuel consumption of a stove for Neem was 1, 1.2 and 1.44 kg/kg that mass of a pellet. The sudden and quick compositions of fuel were observed may be due quality and quantity supply for burning.

E. Power Output

The total power output of the cook stove for pellet, Neem and Tur were found to be 3, 2 kW and 1.8 kW respectively. It could be higher as mention in design consideration. The excess air supply in the combustion chamber creates non uniform and sudden burning of fuel, resulted in it more fuel consumptions.

1) Conclusion

It was observed that pellet was shown excellent results in the aspects of thermal efficiency and power output rating as compared with conventional fuel i.e. Tur and Neem. Pellet was also found convenient to handling.

LITERATURE CITED


