Improvement in the Design of Biomass-Based Gasifier Stoves

P. R. Sonarkar, pravin.svnit@gmail.com; E. A. Mardikar, eeshaan.mardikar@gmail.com; A. S. Chaursia*, aschaurasia@che.vnit.ac.in

Department of Chemical Engineering, Visvesvaraya National Institute of Technology, Nagpur - 440010, India

*Corresponding Author

Abstract: India produces tonnes of renewable agricultural biomass every year, primarily used as a cooking fuel. Currently this biomass is not effectively utilized because of inefficient combustion of biomass, high cost of gasifier stoves, etc. This study aims to design stoves for maximum fuel efficiency with minimum emission of obnoxious gases economically. For this, the commonly used models of natural-draft type gasifier stoves of two designs are remodelled and assessed to know their efficiency and limitations for biomass feed-stocks which includes saw dust, rise husk, coconut shells and wood pellets. It is found that modified TLUD type design offers cleaner emissions and has more fuel efficiency than SR-Agni design. Future study entails analytical and computational research on the present models of stoves for suitable optimization through a combination of alterations in design and biomass composition.

Keywords: Gasifier Stove, Biomass, Cooking, Gasification, Optimization.

1. Introduction

Biomass has always been an important energy source for the country considering the benefits it offers. It is renewable, widely available, carbon-neutral and has the potential to provide significant employment in the rural areas. The current availability of biomass in India is estimated at about 500 million metric tonnes per year, [2].

This biomass is already being used as fuel for cooking food by its combustion either in conventional open fire or in biomass gasifier stoves. However, combustion in conventional open fire is not controlled and results in production of smoke and other forms of harmful gases such as carbon monoxide. Therefore, gasifier stoves allow for cleaner cooking than traditional cookstoves and hence more preferred.

2. Biomass Gasifier Stoves

Gasifiers are essentially devices that enable converting solid fuel to gaseous fuel by a thermochemical conversion process. This process involves substoichiometric high temperature oxidation and reduction reactions between the solid fuel and an oxidant such as air.

Thermal conversion processes for biomass involve some or all of the following processes:

Pyrolysis: Biomass + Heat; Charcoal, oil, gas
Gasification: Biomass + Limited oxygen; Fuel gas
Combustion: Biomass + Stoichiometric oxygen; hot combustion products

Gasifier stoves are metallic biomass-fuelled cooking stove designed in a way that the fuel is converted into combustible gases through intense heating which then burns with a clean flame [3].

Though combustion of biomass in the present models of gasifier stoves is superior to conventional open fire combustion, the gasifier stoves too suffer from a range of limitations like:

a) Difficulty in manufacturing.
b) Expensive materials required for manufacture.
c) Works only with a certain type of fuel.
d) Inefficient combustion leading to release of obnoxious gases.
e) Insufficient opening for air inlet leading to leading to incomplete oxidation and lower conversion, etc [1].

Our study aims to reduce these inefficiencies. Since almost all the gasifier stoves in the world run on the principle natural draft flow, we will use only these types of stove in our study fallowing two types of stoves has been design in present study:

1) SR Agni Gasifier Stove
2) Modified Top Lit Updraft (TLUD) Gasifier Stove-

3. Experimental Setup

3.1 Modified SR Agni Gasifier Stove

The raw biomass materials that have been selected for the study of combustion are sawdust and rice husk. The raw rice husk and sawdust have been taken from the outlet of the industries usually contains moisture. Thus, prior to the combustion of biomass, it was dried in the sunlight to reduce the moisture content to less than 10 wt. %. The stove fabricated for carrying out the experimental studies is the modified SR Agni stove as shown in Fig.1 it is commonly used for cooking purposes in the rural areas. It is the model of stove used in our experiments. It is a natural updraft gasifier. This stove is manufactured from galvanized iron. It is light in weight, portable and resistant to high temperature flames.

The dimensions of the stove are:
Length: 16.8cm
Diameter: 14cm
L/D ratio: 1.2
Diameter of the side hole for air circulation: 5.5cm
Diameter of the hole in the lid for flame output: 4.5cm

Figure 1: SR Agni Stove

Other Requirements:
Matchsticks- To light the flame
Cotton dipped in kerosene- to augment the flame
Weighing Machine- To observe the change in mass of the burning feed

3.2 Modified TLUD Gasifier Stove

The raw biomass materials that have been selected for the study of combustion are wood and coconut shells. The biomass used was dried for several hours under sunlight to obtain feed having moisture content. Modified TLUD stove as shown in fig. 2 is constructed using two concentric cylinders having a difference of more than 6 cm in their diameters. The cylinders are attached to each other in a way that the top of inner cylinder is at a lower height than the top of the outer cylinder. The inner cylinder has a mesh structure at its bottom which acts as secondary air inlet while the tube hole on the side acts as the primary air inlet. The outer cylinder also takes in air from the gap provided below the tube hole. Any biomass (which is less than 20% humid) can be used as fuel, filled up to the neck of the inner cylinder. Initially, the top layer of the fuel is ignited. On the start of the process, air enters via primary and secondary air inlets, the primary inlet helps in the upward draft lifting of the gasified biomass and the secondary inlet below the fuel layer helps in gasification of the biomass.

The dimensions of the stove are:
Length: 24 cm
Diameter: 22 cm
Inner Dia: 15 cm
L/D ratio: 1.6
Diameter of the side hole for air circulation: 7 cm
Diameter of the hole in the lid for flame output: 10 cm

Figure 2: Modified TLUD Stove

4. Experimental Procedure

4.1 Modified SR Agni Stove

A cylindrical pipe is placed in the middle of the stove so that no biomass can enter the area within it. A pre-defined weight of the sample biomass is taken such that it fills the stove up to 90% of its length. Then, a small portion of this biomass is added in the stove around the cylindrical pipe and compressed and made uniform with the help of a leveller.

Then the second portion of biomass is added and the procedure is repeated again. This routine is replicated till the biomass is filled up to the required height of the stove. After this, the cylindrical pipe is slowly removed from the stove taking precaution that the biomass remains stable in its place. The lid of the stove is placed on it to limit the amount of flame rising upwards. A puncture is dug through the biomass from the air circulation hole on the side of the stove so that it reaches up to the centre of the feed. Then the stove is put on a weighing machine and the flame is ignited in the stove by putting a lighted kerosene dipped cotton plug in centre though the puncture. The alighted biomass starts burning and generates a high rising flame through the hole provided on the lid. The flue gases are created due to the combustion of the feed and the weight of the feed decreases with time. Two such experiments are performed in which saw dust has been taken as the feed in the first run while rice husk is the feed in the second run.

4.2 Modified TLUD Stove

The biomass fuel is broken into small sized blocks. This is done for easy ignition. Measured quantities of these blocks are stacked in the inner cylinder of the gasifier along with hay. Here, we make use of hay and cotton soaked in kerosene (few drops) for the better fuel combustion. Two such experiments are performed in which wood blocks have been taken as the feed in the first run while coconut shells are the feed in the second run. The stove is lit from the top by matchstick.

5. Results and Discussion

The experiments are carried out to gauge the effectiveness of various biomass to be used as fuel for different stoves. This is done by studying the variation of mass of feed with time. If the biomass shows steady decline in its mass with time, it is an indication of good combustion capacity and is more suitable to be used as feed in the stove.

In modified SR Agni stove on plotting the curve as shown in Fig. 3 and Fig. 4 between mass of feed as function of time it is observed that saw dust shows appreciable decrease in mass as compared to rice husk. Thus, sawdust has clear advantage over rice husk and is more suitable to be used as feed in the stove.

For the modified TLUD stove the same methodology as above has been followed and from the graphs shown in Fig. 5 and Fig. 6 , it is clear that both the feeds show significant decrease in mass with time and thus both the biomass are appropriate fuels for the stove.

Though the modified TLUD stove is costlier to build than the modified SR Agni stove, it is more suitable for service in the long run. The modified SR Agni stove requires the biomass to be in the form of fine particles to be used as feed which limits the raw materials that can be used as potential fuels while in the modified TLUD stove, there is no such caveat. Also, a complex procedure is involved prior to burning the feed in the SR Agni stove whereas in TLUD stove the feed can directly burn after adding it in the stove. More importantly, better fuel consumption and flame output is obtained in the modified TLUD stove as compared to the modified SR Agni stove.

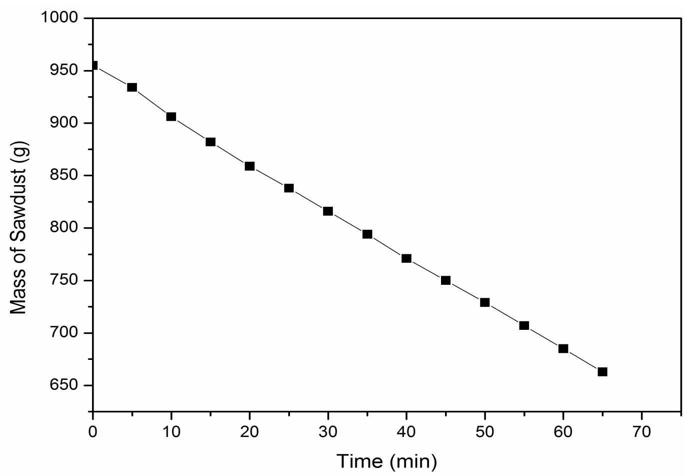

Fig 3. Mass of saw dust as function of time

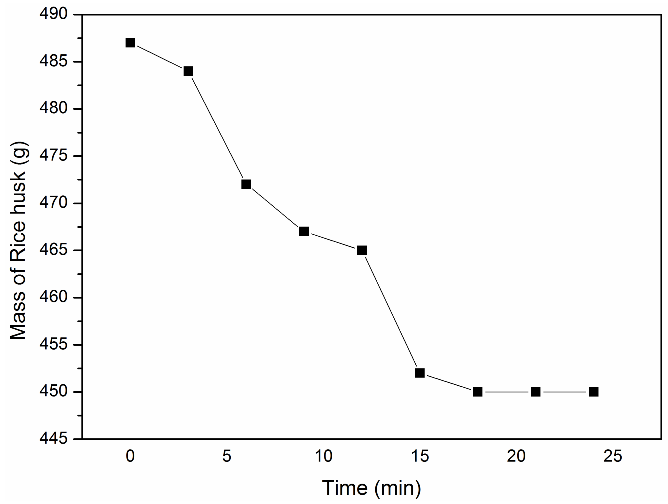

Fig 4. Mass of rice husk as function of time

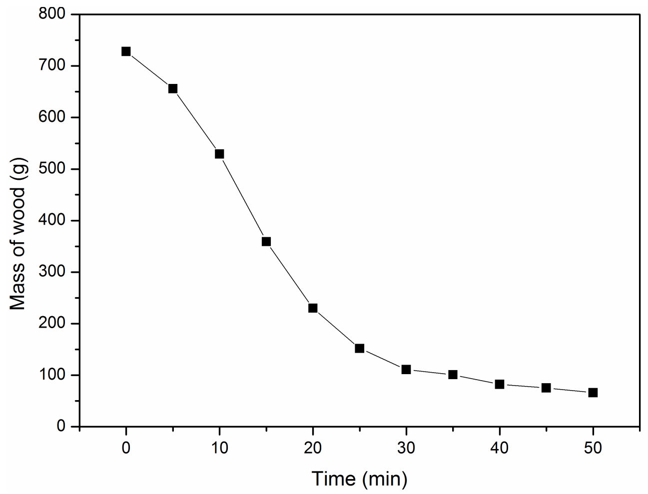

Fig 5. Mass of wood as a function of time

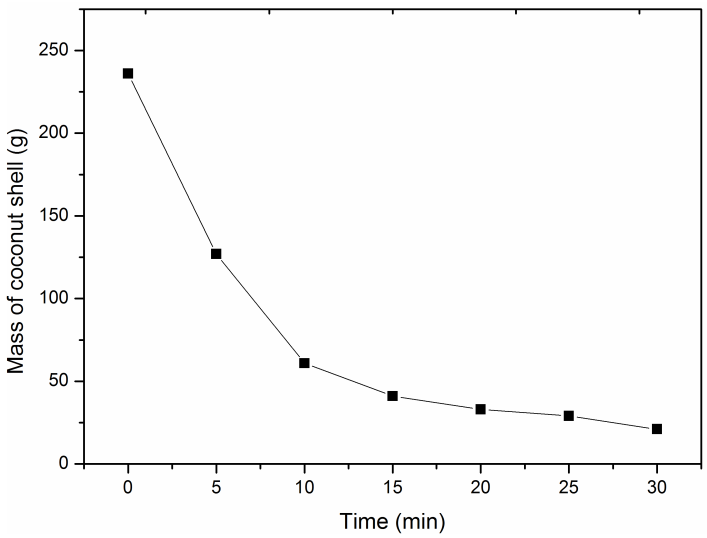

Fig 6. Mass of coconut shells as a function of time

6. Conclusions

It is concluded that modified TLUD stove design is efficient than SR Agni stove due to better consumption of feed and better flame output for longer time duration.

7. Acknowledgement

We owe our deepest regard and gratitude to Dr. Narendra S. Chaudhari Director, V.N.I.T, Nagpur for support in funding this project and providing all the lab facilities to carry out our research work.

8. References:

[1] Dessie Tarekegn Bantelay, Nigus Gabbiye, 2014, Design, manufacturing and performance evaluation of house hold gasifier stove.

[2] Ministery of New and Renewable Energy.2012. Biomass power and cogeneration programme http://www.mnre.gov.in/schemes/grid-connected/biomass-powercogen/

[3] Technology Factsheet. Gasifier Stoves. http://www.gvepinternational.org/sites/default/files/factsheet_gasifier_web_final.pdf