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RESEARCH ARTICLE

DEVELOPMENT OF ECO-FRIENDLY RICE HUSK GASIFIER STOVE FOR DOMESTIC PURPOSE IN RURAL INDIA

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ABSTRACT

The prices of conventional fuel used for domestic purpose is rising day by day at a fast rate. Biomass is an alternative source of energy which is renewable in nature. Biomass is used for cooking purpose from several centuries. In India, simple rice husk stoves are in use from a long time which is cheap but it emits tiny, rich in silica ash particles in the flue gas. It causes health problems to the user. In this project, an attempt has made to design and fabricate a user-friendly, eco-friendly and economical rice husk gasifier stove. New rice husk gasifier stove generates luminous blue flame having thermal efficiency around 29% similar to LPG stove. This stove will be helpful for people in rice growing rural areas where abundant quantity of rice husk is available. The main objective of this work is to help rural families for whom LPG stove is not affordable and where indoor air pollution is common due to traditional cooking methods. This gasifier has ability to consume 3.5 kg of rice husk per batch and it operates 60 minutes to 80 minutes. By using this stove, one time meal for a family of 6-7 peoples can be cooked.

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INTRODUCTION

The prices of conventional fuel used for domestic purpose is rising day by day at a fast rate. Biomass fuel is an alternative source which has carbon, oxygen and hydrogen as basic components. Uses of widespread local rich biomass resources are best economical options to reduce pollution, provide rural employment and save conventional energy. In India, wood, agro waste like rice husk and straws, cow dung, garbage are the different types of fuels used in rural areas for domestic purpose, while LPG, kerosene and electric stoves are extensively used in urban areas. Biomass is used for energy consumption from several centuries. Even today bioenergy provides 10% of world primary energy supply (International Energy Agency 2015). Depending upon physical structure of biomass, it can be transformed into solid, liquid and gaseous fuel. Biomass from cultivated crops and Biomass from organic matter are the two main types of biomass. Biomass resources available in India are agriculture produce and process waste, wood, shrub, tree, sawdust, bark from forest clearing, wood waste from wood mill, urban organic waste, and urban wood waste etc.

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Problems associated with the use of biomass as a fuel in India

World Health Organization (WHO 2014) reported that all over the world 43 lakh people died due to household indoor air pollution in developing and under developed countries during 2012. Rural India is facing indoor air pollution due to burning of biomass like garbage, waste and agricultural waste in a crude manner which generates smoke, particulates, CO, CH_4 and many organic compounds including carcinogens. As a result, thousands of people are dying every year in India due to asthma, lung cancer, stroke, acute lower respiratory disease, ischaemic heart disease, chronic obstructive pulmonary disease.

Availability of rice husk in India

Directorate of Economics and Statistics indicates that India has produced 103.04 Million Tons of rice during the crop year Oct 2014 – Sept 2015 (Commodity Profile of Rice 2015). This amounts to nearly 20% of rice husk in weight (Rice Knowledge Bank 2015). Based on this data, it can be estimated that, 20.61 Million Tons of rice husk can be generated in India annually.

Status of rice husk as a fuel in India

In India, simple rice husk stoves are used from a long time. This is cheap but it emits tiny, rich in silica ash particles in the flue gas. It causes health problems to the user. A modern technology is required to burn rice husk that has to generate the cleaner flame. The cook stove principle should be modified into a gasifier burner that can generate clean flame. Rice husk is also utilized for process heat generation for rice drying. Recently in some rural places in India rice husk gasifier coupled with modified internal combustion engine are being used for small capacity (20kW to 70kW) electricity generation.

Rice Husk Gasification Process

Biomass gasification is a thermal conversion technology. In this technology, a solid-fuel such as wood, rice straw, rice husk, coconut shell and other agricultural residue is converted into a combustible gas. A limited supply of oxygen, air, steam or a combination acts as the oxidizing agent. The heat is generated by partial combustion of the biomass. The product gas consists of CO, CO_2, H_2, CH_4; small amounts of hydrocarbons, water, nitrogen (with air as oxidant) and small char particles, ash, tars etc. Fig 1 shows the gasification process of rice husk as a fuel. Heat required for gasification of rice husk is obtained due to partial combustion of rice husk which is controlled by supplying a limited amount of oxygen. This results in pyrolysis of rice husk which gives out a comustible gas known as syngas or producer gas.

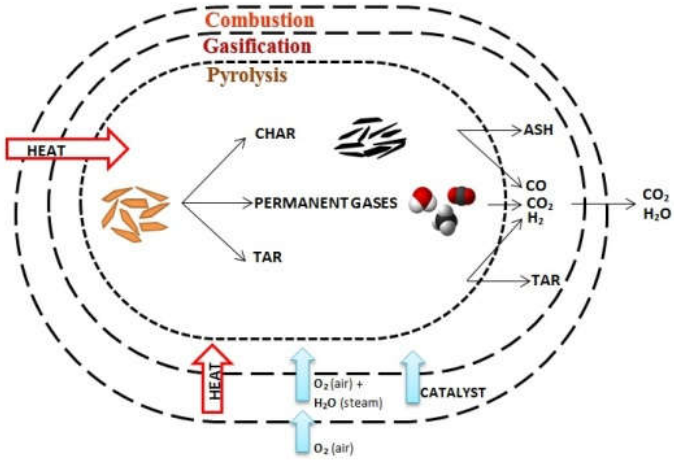

Fig 1. Rice Husk Gasification Process

Literature Survey

It is reported (FAO 2015) that the world paddy production in 2014 was 741.8 Million Tonnes. Asia has contributed about 674.4 Million Tonnes that is almost 91% of total global paddy production. To tap this potential, lab scale two stage rice husk gasifier dimensions (Kanatawan 2011) were found out by considering minimum fluid flow velocity, volumetric flow rate, and residence time. One of the researchers (Song *et al*., 1998) investigated the feasibility of rice husk gasification process with a controlled temperature (below 723^{o} C) to produce syngas for power generation and to recover amorphous silica material.

A researcher (Alexis 2005) has developed the rice husk gas stove that operates on a batch mode with controlled supply of oxygen to produce combustible gas. Indian Institute of Science, Bangalore (Mukunda *et al*., 2010) has developed a gasifier stove that uses high density pellets which are obtained from agricultural waste. Experimental results show that better efficiency and low emissions can be obtained with short visible flame by varying amount of secondary air. Rice husk is being utilized for electric power production in rural places of India under small-scale plants which is known as Husk Power System (Bhattacharyya 2014). It uses gasification technology in which rice husk is mixed with air and partial combustion process is carried out in a gasifier to produce producer gas.

MATERIALS AND METHODS

Fig 2 shows the schematic layout of the 3.5 kg /batch rice husk gasifier stove. The design of the stove was based on the principle of top-lit moving-bed updraft type gasifier.

The main reactor consists of two concentric mild steel cylinders of diameter 230mm and 270mm respectively. Both cylinders are of height 1050mm. Char chamber of 180mm x 460mm x 450mm is welded to the bottom of reactor. Char chamber has a grate and char removal tray. Two fans (12 volt, 0.81amps) are provided on the rare side of the char chamber. Gas tight door is provided at the front side of char chamber and a lid is provided at the top of reactor. A gasket is provided between lid and reactor to prevent leakage of gas. A cyclone separator is connected to the reactor through G.I pipe as shown in Fig 2. The cyclone separator is made up of mild steel. Gas duct made of G.I is inserted in the cyclone separator from top. The duct is connected to burners through globe valves. Gas duct and cyclone separator are insulated by glass wool which is covered with aluminum sheet. Table 1 shows the technical Specifications and materials used for rice husk gasifier stove.

Working of rice husk gasifier stove

The stove uses rice husk as a fuel. Rice husk of about 3 to 3.5 kg is filled in the reactor by opening top lid. Initiation of rice husk burning is done by using burning piece of paper or small amount of kerosene at the top of the reactor. Then, the rector lid is closed and clamed tightly. Rice husks are gasified inside the reactor that produces flammable gaseous fuel within 2 to 3 minutes. The reactor uses DC power from a rechargeable battery to operate fans. The DC source can be recharged using AC supply or solar panel. The forced draft fans supply air required for gasification of rice husk. The producer gas is cleaned by passing through cyclone separator. The cyclone separator separates dust and fly ash present in the gas. Both will get settled down at dust collector. Clean gas is allowed to flow through insulated duct and then it reaches two burners of different size. Flow of gas to the burners is regulated by operating globe valves. At the burner top gas is ignited to generate luminous blue flame like LPG. Households can do cooking using two burners with pot support in batch mode for 60 to 80 minutes. Battery power is disconnected from fan after complete combustion of rice husk present in the reactor. Burner valves are closed to avoid smoke from burner. The grate is removed to collect char and tray is cleaned. Again grate and

char removal tray is placed back then char chamber door is closed for next run.

RESULTS AND DISCUSSION

Rice husk gasifier performance has tested by using boiling water tests. Initially, water boiling test for a quantity of 1 liter and 2 liter were conducted by keeping low flame on a single burner. Similarly water boiling test for a quantity of 1 liter and 2 liter were conducted by keeping medium and high flame on a single burner.

The obtained results are tabulated in Table 2. The results show (Fig. 3) that the time required for boiling 1 liter of water has been decreased by 1.3 times when burner has switched from low flame to medium flame. Similarly time required for boiling 1 liter of water has been decreased by 2 times when burner has switched from low flame to high flame. Table 2 and Fig 4 indicate that rice husk consumption has been increased marginally from 3 kg/hr to 4 kg/hr when burner is switched from low flame to high flame.

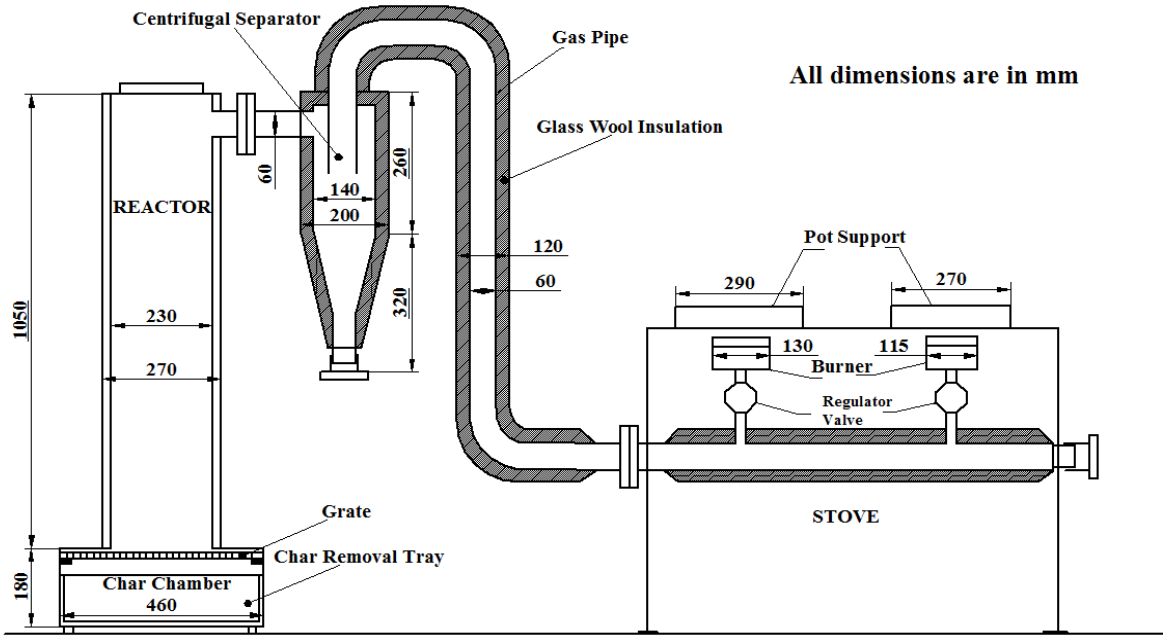

Fig 2. Schematic layout of rice husk Gasifier stove

Table 1. Technical Specification and materials for Rice Husk Gasifier Stove

Sl. No	Items	Specifications / materials
01	Fuel	Rice Husk
02	Loading Capacity	3.5kg /batch
03	Operation time / batch	60 min to 80 min
04	Sheet metal type used for reactor	2 mm Mild Steel
05	Sheet metal type used for reactor guard	0.8 mm Stain Steel
06	Fan rating	12 volt & 0.81 amps
07	Power supply system for Fan	DC supply 14 amps battery
08	Gas cleaning system	Cyclone separator
09	Burner type	Plate-type burner, 2 Nos.
10	Burner diameter	115 mm and 130 mm with 49 and 57 holes respectively
11	Insulation material	Glass wool
12	Thickness of insulation	25 mm
13	Gasket material	Non metallic
14	Air flow adjustment system	Using Voltage regulator
15	Air flow rate	6.5 Kg/hr
16	Volume flow rate of air	8.225 m^3/hr
17	Superficial air velocity	5.5 cm/sec
18	Ignition system	Top lit

Table 2. Water boiling test results

Parameters		Run 1- Low	Run 2- Medium	Run 3- High
Fuel Consumption Rate (kg/hr)		3	3.5	4
Ignition Time (min)		1	1	1
Gas Generation Time (min)		4	3	2
Time to Boil Water (min)	1 Litre	6.8	5.4	3.5
	2 Litre	13.8	11	7.9
Using a digital thermometer with k type thermocouple	Gas Temperature (°C)	95	98	100
	Temperature beneath the Pot (°C)	330	350	400
Specific Gasification Rate (kg/hr–m^2)		73	85	97
Thermal Efficiency (%)		24	29	22
Char Production Rate (kg/hr)		0.9	1.05	1.2

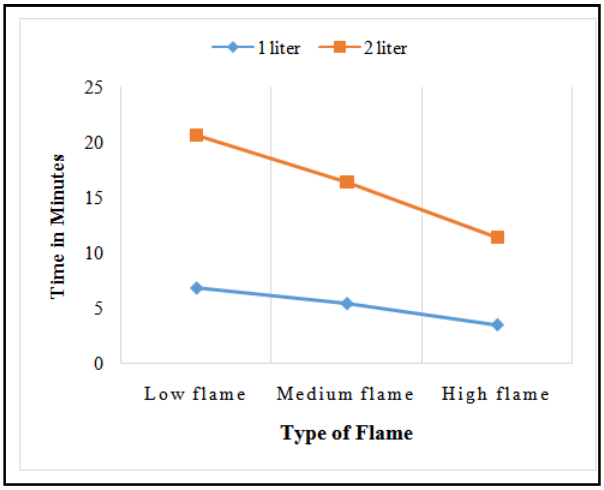

Fig. 3. Effect of Type of flame on time required to boil water

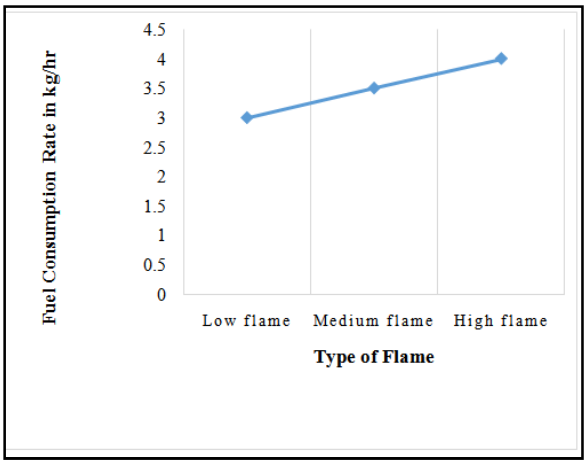

Fig. 4. Effect of Type of flame on Fuel consumption rate

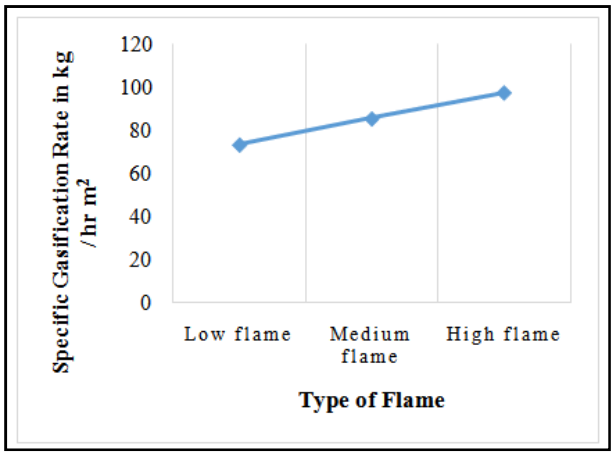

Fig. 5. Effect of Type of flame on Specific gasification rate

Table 2 and Fig 5 also indicate that specific gasification rate has been increased from 73 kg/hr-m^2 to 97 kg/hr-m^2 when burner is switched from low flame to high flame. Table 2and Fig 6 also indicate that thermal efficiency has been increased from 22% to 29% when burner is switched from low flame to medium flame and it has decreased from 29% to 24% when burner is switched from medium flame to high flame.

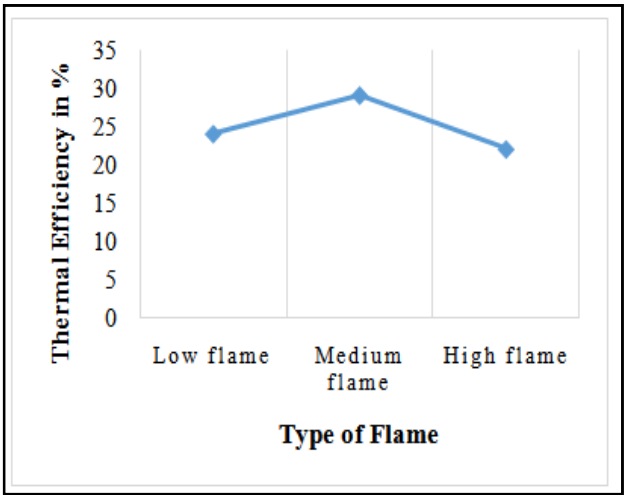

Fig. 6. Effect of Type of flame on Thermal Efficiency

Conclusion

It has been concluded that this stove will fulfill domestic cooking energy requirements of the rural people of India for whom LPG stove is not affordable and where indoor air pollution is common due to traditional cooking methods. This gasifier has ability to consume 3.5 kg of rice husk per batch and it operates 60 minutes to 80 minutes. By using this stove, one time meal for family of 6 - 7 peoples can be cooked. This stove has thermal efficiency of 29% which is much comparable to that of LPG.

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