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A Comparative Evaluation on the Performance of Updraft Gasifier Fuelled with Rice Husk, Corn Cobs and Wood Chips

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***Abstract*- Biomass is an alternate source of energy which is vastly available in nature and easily accessible. In India, biomass is in use from a long time which is cheap but it emits tiny, rich in silica ash particles in the flue gases. An innovative technology is required to burn the biomass to generate the cleaner gases. In this work, an attempt is made to increase the efficiency of the gasifier and to produce a cleaner hydrogen gas which is user-friendly, eco-friendly and economical gasifier stove. The major objective of this work is to compare the performance of the gasifier for different feed stocks like rice husk, corn cobs and wood chips. Performance results show that during gasification of biomass, wood chips gives the maximum gasifier run time at an air velocity of 2.56m/sec. Under best operating conditions, the percentage of char yield from the rice husk, corn cobs and wood chips is 32%, 13.05% and 9.9% respectively. The analysis indicates the gasification of biomass is the best technical viable option to reduce the use of fossil fuel in domestic purpose for cooking and heating applications.**

Keywords- Biomass, Gasification, Updraft gasifier, Performance Analysis

I. INTRODUCTION

Petroleum and Crude oil are proposed to be very costly[1], and it is increasing day-by-day and it will be kept on increasing. This has expanded the interest for the sources of renewable vitality in the world. An alternative nonconventional fuel technique has become more prominent with increased usage and depletion of energy such as fossil fuel. Use of widespread local renewable sources is best economical option to reduce pollution, provide rural employment and save conventional energy. Many of the issues such as increase in energy security, fuel price and global warming concerns associated with petroleum fuels can be minimized by bio-fuel development and providing clean gaseous fuels and liquid fuels [2]. Abundant quantity of useful energy is available throughout the India in the biomass energy. Biomass sources of energy offers energy security, reduce emissions, and rural employment[3]. The traditional availability of biomass is in the solid form. The solid biomass includes plant waste, forest waste, food waste, animal waste, municipal waste, corps residues and vegetable seeds. By selecting the appropriate method, biomass can transformed over into heat and power.

The main problems associated in biomass gasification is the conditioning the producer gas such that it matches the final application. During the gasification, production of useful gas includes the generation of many toxic by-products like NO_X, SO_2 and fly ash and tar are also formed [4]. Another major problem related to the application of biomass gasification technologies is the removal and disposal of ash. Therefore, using the producer gas for the applications purpose, the main impurities present in the gas should be removed.

II. GASIFICATION PROCESS

Gasification turns slow or null value feedstock in a new marketable fuel. The gasification process is as shown in the Fig.1. From the chemical side, the gasification is the partial burning of the fuel in the reactor. The whole process can be divided as

- The Pyrolysis or de-volatilization steps [5] where fuel is thermal degraded in gas, condensable compounds and char.
- The tar and gas yield in the process is subject as thermal degradation.
- Char is gasified by carbon dioxide or steam.
- The sub products (gas, tars and char) are partially oxidized.

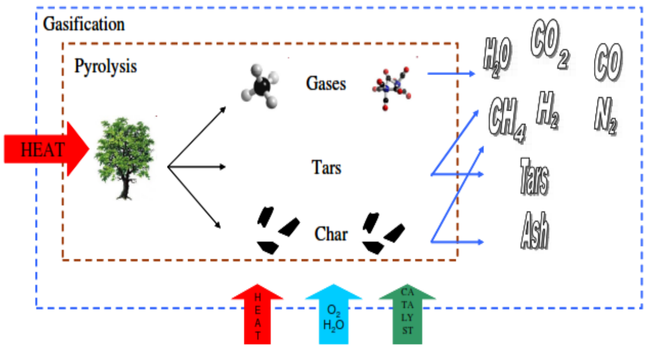

Fig.1 Gasification Process

III. GASIFICATION TECHIQUES

The producer gas produced in fractional or partial burning of biomass is called gasification. Gasification takes places at high temperature in the presence of oxidation agent or it is also called as gasifying process agent. The reactor zone in the gasification procedure is known as a gasifier. Gasifier is classified based on the type of bed and flow.

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A. Updraft gasifier

Updraft gasifier is the most straight forward and most established type of reactor, it is likewise referred to as counter current gasifier. Biomass is feed at the top of the gasifier and the oxidizing agent such as oxygen/air/stem enters at the base of the gasifier. The gas delivered in the gasifier streams in the upward direction and leaves the gasifier at the top. Fig.2 shows the schematic representation of the updraft gasifier. In this procedure the char produced is collected at the base of the gasifier bed. The gas created in the gasifier exits at the temperature range between 300-800^{0}C [6]. The dust substance is the gas delivered is low because of the low gas speed.

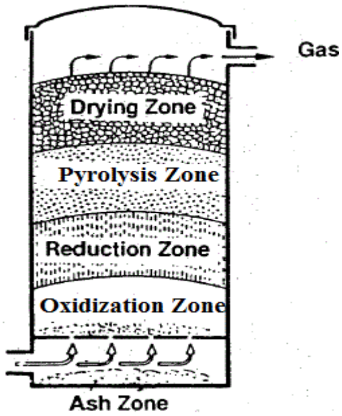

Fig.2 Updraft Gasifier

IV. CONSTRUCTION OF UPDRAFT GASIFIER

The updraft gasification system consisting of reactor, char collecting chamber, centrifugal separator, stove and burner.

A. Reactor

Reactor is the unit containing biomass to be gasified. The char chamber is welded to the reactor at the bottom and the cyclone separator or gas cleaning unit at the top with the help of flange coupling. Gasifier reactor is fabricated with the help of two concentric cylinders, in between the cylinders asbestos are used. The gasifier chamber is shown in the Fig.3. A lid is provided at the top with hinged joints and a clamp to close the lid so that the reactor is gas tight. Non-metallic gasket and the two plates of thin steel is used on either side and it is kept between the lid to avoid leakage and reactor.

Fig.3 Front View and Side View of Reactor

B. Char chamber

Char chamber contain grate and char removal tray. Gasifier reactor is welded above char chamber so that burned biomass is passed through grate and gets collected in char removal tray by gravity. At backside of char chamber, it has fan box which consist of two fans for oxidization of biomass. Char chamber has an opening door at the front side through which grate and char removal tray can be taken out of the chamber for char disposal. Fig.4 shows the grate and char chamber of the gasifier.

Fig.4 Char Chamber and Grate

C. Gas cleaning

Gas cleaning unit consist of cyclone separator is as shown in the Fig.5. Cyclone separator is connected with gasifier reactor with the flange coupling. At the bottom of the cyclone separator a dust collector is provided with the cork to remove dust. At the top of the cyclone separator a gas is inserted which direct the gas to the burner after cleaning. Whole gas cleaning unit is completely insulated with glass wool which is covered with an aluminium plate.

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Fig.5 Cyclone Separator

D. *Gasifier burner*

Biomass gasifier stove has two plate burners as shown in Fig.6. These burners are attached to the gas duct with the gas flow regulating globe value in between. Burners are of different size, large one is 130mm and smaller one is 115mm in diameter. These burners and valves are cover with stove frame with steel plates. At the top of the both burners pot supports are mounted. The complete assembly of the updraft gasifier is as shown in the Fig.7.

Fig.6 Updraft Gasifier Burner

Fig.7 Assembly of the Updraft Gasifier

V. MATERIAL AND METHODS

In updraft gasifier, air flow rate, gas flow rate, operating time, amount of biomass consumed, temperature and pressure at various points were monitored in each run. The data was used to compute the air fuel ratio, equivalence ratio, specific gasification rate and specific gas production rate. Methods for various determinations are.

A. *Temperature measurement*

The gasifier is fitted with Chrome k-sort thermocouple to check temperature of gas at the gasifier reaction zones, producer gas inlet and outlet temperature of the cyclone separator and atmospheric temperature of the gasifier. The temperature inside the gasifier was measured by nine thermocouples which are placed at the angle of 90^0 to circumference of the reactor cylinder. The stem type thermocouple used in the reactor to measure the temperature.

The temperature variation in the oxidization zone is measured by three thermocouple T_1, T_2 and T_3 are measured at the distance of 300mm from the grate, In the reduction zone the temperature T_4, T_5 and T_6 are measured at the distance of 550mm from the grate and in the Pyrolysis zone temperature T_7, T_8 and T_9 are measured at the distance of 800mm from the grate.

B. *Pressure measurement*

Pressure taps is provided to measure the pressure in the gasifier. Pressure tap is connected at the end of the cyclone separator. Glass u tube manometer is used to measure the pressure of the gasifier and the orifice meter respectively.

C. Air flow and gas flow measurement

The air flow and gas flow is measured by using the anemometer. Anemometer is a device which is used to measure the flow in the gasifier. The anemometer fan is kept perpendicular to the direction of air and gas flow velocity is measured.

VI. TECHNICAL SPECIFICATION OF GASIFIER

TABLE I Technical Specification of Updraft Gasifier

Design	Updraft Gasifier Stove
Fuel	Rice Husk, corn cobs and wood chips
Loading Capacity	4kg/batch
Operation time / batch	50 min to 70 min
Sheet metal type used for reactor	2 mm Mild Steel
Fan rating	12 volt and 0.81 amps
Gas cleaning system	Cyclone separator
Burner type	Plate-type burner, 2Nos.
Burner diameter	115 mm and 130 mm with 49 and 57 holes respectively
Insulation material	Glass wool
Thickness of insulation	25 mm
Air flow adjustment system	Using Voltage regulator

VII. EXPERIMENTAL PROCEDURE

At the start-up of each experiment, small amount of char was placed over the grate following by feedstock. Biomass of about 1 kg is filled in the reactor by opening top lid. Biomass is ignited using burning piece of paper or by using small amount of kerosene at the top of the reactor then reactor lid is closed and clamped tightly. Biomass is gasified inside the reactor that produces flammable gaseous fuel within 1 to 2 minutes. The reactor uses DC power from the rechargeable battery to operate fans. The forced draft fans supplies air required for gasification of biomass. The producer gas is then passed through gas cleaning unit that is cyclone separator. In cyclone separator dust and fly ash present in the gas gets settled down at dust collector, clean gas from insulated gas duct is directed to stove with two burners of different sizes. Burner valves are opened so gas start to come out of burner. At the burner top gas is ignited to generate luminous blue flame like LPG gas. Household can do cooking using two burners with support in batch for 50 to 70 minutes.

After complete combustion of biomass present in the reactor, battery power is disconnected from fan. Burner valves are closed to avoid smoke from burner. Char chamber door is opened then grate is removed so that all burned biomass char is collected on the char removal tray. Char removal tray is taken out for char disposal. Again grate and char removal tray is placed back then char chamber door is closed for next run. Fig.8 shows the complete assembly of the updraft gasifier.

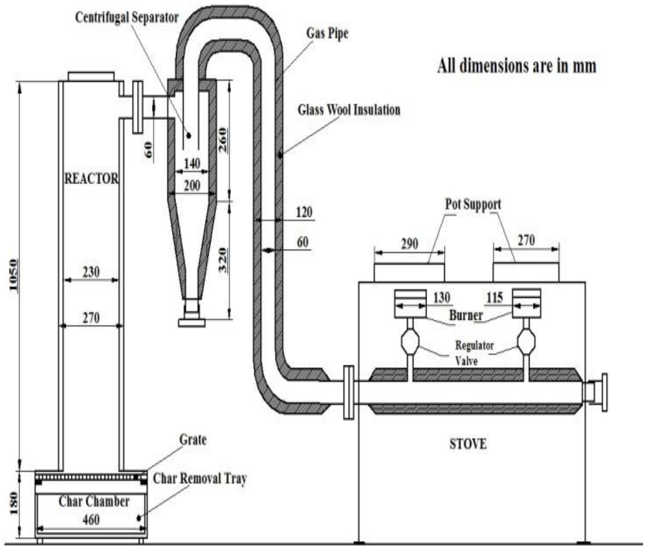
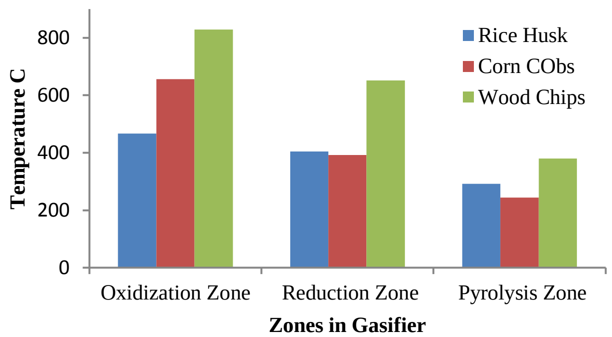


Fig.8 Schematic Drawing of Updraft Gasifier

VIII. RESULTS

A. Comparison of temperature distribution in the gasifier

All of the temperature profile shares the same trend as shown in the Graph 1, temperature increases first along the height of the gasifier, reaching the peak value in the oxidization zone of the gasifier. After that the temperature decreases gradually in the reduction zone and dropped significantly in the Pyrolysis zone. The peak temperature occurs in the oxidization zone of the gasifier since the char oxidation occurs when there is abundant supply of oxygen at the bottom of the gasifier. Above the oxidization zone the oxygen concentration decreases and the most of the reaction that occurred in this zone were endothermic process which decreases the temperature. After air is completely used in the reduction zone, in the Pyrolysis zone organic materials were chemically decomposed by heat in the absence of oxygen.

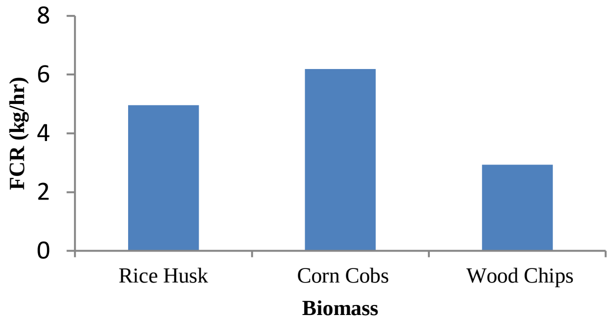


Graph 1. Temperature Distribution in the Different Zones of Gasifier

The lowest temperature occurred in the drying zone in which the moisture in the fuel was removed by absorbing heat from the gases. Peak temperature in the combustion and reduction zone was slightly higher for wood chips than the rice husk and corn cobs.

B. *Comparison of fuel consumption rate of different biomass*

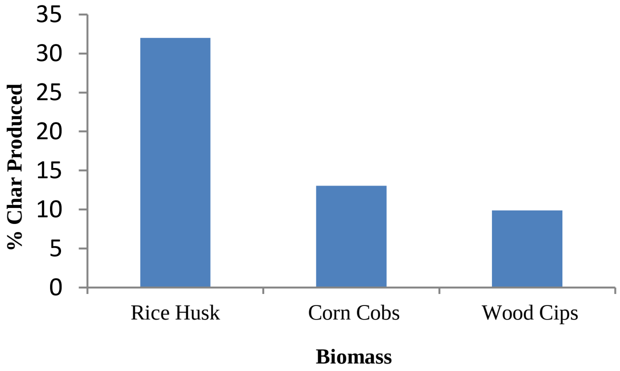
The average fuel consumption rate (FCR) of rice husk, corn cobs and wood chips are shown in the Graph 2. The maximum fuel consumed when comparing by rice husk and wood chips is corn cobs. The fuel consumed by the corn cobs is 6.19kg/hr., rice husk is 4.958kg/hr. and the minimum fuel consumed by wood chips is 2.934kg/hr. Thus from the comparison it indicates rice husk and wood chips consumes less fuel per hour then the corn cobs.



Graph 2. Fuel Consumption Rate of Different Feedstock

C. *Comparison of percentage of char produced in the gasifier*

The average percentage of char yield for the rice husk, corn cobs and wood chips as shown in the Graph 3. From the graph, it clearly indicates the percentage of char yield in the rice husk is more than the corn cobs and wood chips. The average char yield from the rice husk is 32%, corn cobs is 13.05% and from the wood chips is 9.9%.



Graph 3. Percentage of Char Produced by Different Feedstock

IX. CONCLUSION

This project work shows the great potential for the biomass energy to convert it into a useful gas similar to the LPG gas and emission free producer gas. This technique gives a value addition chain for the biomass usage. In the experiment, as the supply of air flow rate increases in the gasifier the fuel consumption rate increases and with increase in equivalence ratio the production of the producer gas increases continuously and char production rate decreases. From the experiment it is concluded that the corn cobs consumption rate is more than rice husk and wood chips, and the char produced from the rice husk is higher when comparing to the wood chips and corn cobs.

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