Performance Analysis of the Constructed Updraft Biomass Gasifier for Three Different Biomass Fuels

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Abstract: *Gasification is the process in which a solid carbonaceous fuel is converted into combustible gas using partial amount of air. The gases which evolve are known as "producer gas". This gas is more suitable than the direct combustion of biomass. In this paper an updraft gasifier is constructed and is used to carry out the experiment. The waste material like bagasse (sugarcane waste), coconut shells and wood particles are used for the generation of producer gas. The sense of this paper is to study the effect of waste products in form of biomass. The performance of the gasifier is evaluated in terms of zone temperature with different air velocity. By taking the different fuels and varying the air flow rate the temperature of the zones are analyzed. The gas composition is not considered. The arrangement of tar is also seen in this apparatus. After analysis it is found that the coconut shell having maximum temperature for all three zones as compare to other two so coconut shell is the best suitable material for this gasifier.*

Keywords: *Biomass gasification, construction, updraft gasifier, temperature analysis.*

I. Introduction

Biomass is an organic material, including plant matter from trees, grasses, and agricultural crops. The chemical composition of biomass varies among species, but basically consists of high, but variable moisture content, a fibrous structure consisting of lignin, carbohydrates or sugars, and ash. Biomass is very heterogeneous in its natural state and possesses a heating value lower than that of coal.

Gasification is a more than century old technology, which flourished before and during the Second World War. The technology disappeared soon after the Second World War, when liquid fuel (petroleum based) became easily available. During the 20th century, the gasification technology roused intermittent and fluctuating interest among the researchers. However, today with rising prices of fossil fuel and increasing environmental concern, this technology has regained interest and has been developed as a more modern and sophisticated technology. A process of conversion of solid carbon fuels into combustible gas by partial combustion known as gasification. The resulting gas known as producer gas (with the composition of CO 15-20%, H_2 10-15%, CH_4upto4%, N_2 45-55%, CO_2 8-12%), is more versatile in its use then the original solid biomass. The equipment used for this gasification process is known as gasifier. Gasification is primarily a thermo-chemical conversion of organic materials at elevated temperature with partial oxidation. In gasification, the energy in biomass or any other organic matter is converted to combustible gases (mixture of CO, CH_4 and H_2), with char, water, and condensable as minor products. Initially, in the first step called pyrolysis, the organic matter is decomposed by heat into gaseous and liquid volatile materials and char (which is mainly a nonvolatile material, containing high carbon content). In the second step, the hot char reacts with the gases (mainly CO_2 and H_2O), leading to product gases namely, CO, H_2 and CH_4. The producer gas leaves the reactor with pollutants and therefore, requires cleaning to satisfy requirements for engines. Mixed with air, the cleaned producer gas can be used in gas turbines (in large scale plants), gas engines, gasoline or diesel engine.

1.1 Processes of Gasification: Four distinct processes in the gasifier -

1. *Drying*:- In this stage, the moisture content of biomass is typically reduced to be 5-35%.In drying zone the temperature is about 100-200°C.
2. *Pyrolysis*:-It is the first step in the combustion or gasification of biomass. When biomass heated in the absence of air to about 350-600°C,it form charcoal, gases and tar vapors.
   Biomass + heat → solid, liquid, gases products (H_2 , H_2O, CO , CO_2)
3. *Combustion*: - In this process the reaction between solid carbonized biomass and oxygen in the air, resulting in formation of CO_2. Hydrogen present in the biomass is also oxidized to generate water. Large amount of heat is released with the oxidation of carbon and hydrogen.
   $C + O_2 \rightarrow CO_2$
4. *Reduction*: - In absence of oxygen, several reduction reactions occur in the temperature range of 600-1000ºC. These reactions are mostly endothermic. The major in this category are as follows:
   $C + H_2O \rightarrow CO + H_2$
   $C + CO_2 \leftrightarrow 2CO$
   $CO_2 + H_2 \leftrightarrow CO + H_2O$
   $C + 2H_2 \leftrightarrow CH_4$

1.2 Classification of biomass gasifier: They are classified according to the way air or oxygen is introduced in it. There are three types of gasifier-

1.3.1) **Downdraft:** Biomass is introduced from the top and moves downward. Oxidizer (air) is introduced at the top and flows downward. Producer gas is extracted at the bottom at grate level.

1.3.2) **Updraft:** Biomass is introduced from the top and moves downward. Oxidizer is introduced at the bottom and flows upward. Some drying occurs. Producer gas is extracted at the top.

1.3.3) **Cross draft:** Biomass is introduced from the top and moves downward. Oxidizer is introduced at the bottom and flows across the bed. Producer gas is extracted opposite the air nozzle at the grate.

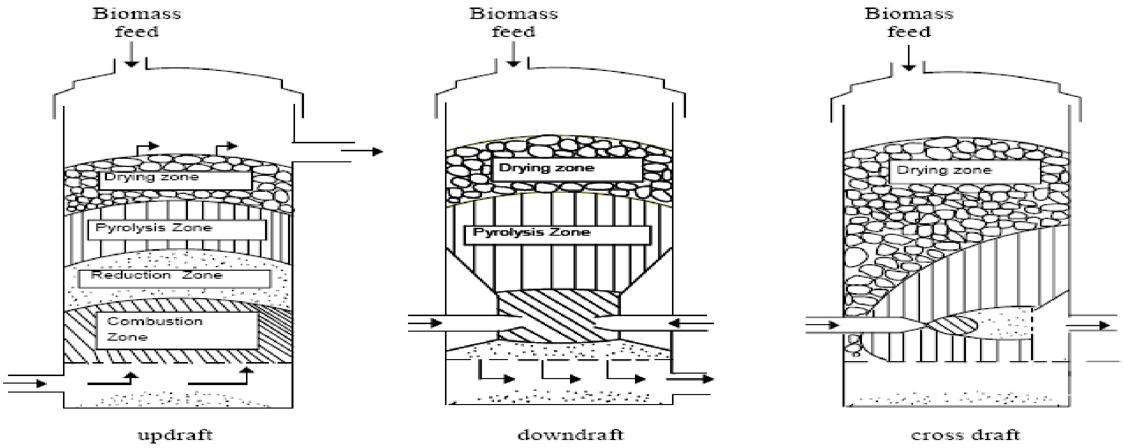

Fig. 1.1- Types of biomass gasifier

Our current work focused on the construction of updraft gasifier and performance analysis of the updraft gasifier. There are various biomass materials are available in the countries. Where in the following three bio mass materials which are commonly available and reliable were taken for performance analysis of the updraft gasifier – wood chips, sugarcane waste, and coconut shells.

II. Construction of Updraft Biomass Gasifier

The original aim with this gasifier project, were to build a compact and simple gasifier, that used inexpensive feedstock (like wood chips or mulch that is available very inexpensively, or even free), and produced high-quality gas. The research showed that the updraft gasifier design generally produced the best quality gas. Some gasifier designs are quite complex and difficult to fabricate, others much simpler. So naturally,we gravitated toward the simpler design. Thework originally aimed to building a simple open core design.

The basic structure of the gasifier is built around 13 inches inside diameter, 2.5mm thickness, and 21 inches long air tank of trucks, and a steel tube 5 inches in inside diameter, 3mm thickness, and 22 inches long. These dimensions are not really critical. The tube could be a little longer or shorter, and a little wider or narrower in diameter. The air tank (fig. 2.1 &fig 2.2) and steel tube brought from a scrap market. The purpose of the drum is to be the main body of the gasifier unit. It contains everything and collects all the gas, ash and char the unit will produce. The steel tube serve as a flame tube where the gasification processes takes place.

Fig.2.1-Air Tank (Top View)

Fig.2.2-Air Tank (Front View)

The work has been started by cutting a large hole in the top of the drum so the stainless steel flame tube can be inserted (figure2.4). The hole was made very oversize, a fortuitous decision as it turned out. The hole is offset to the side of the drum opposite the small bung. The large bung was sacrificed, since I wasn't planning on using it. Next I cut a flange from a piece of 1/8 in steel for mounting the flame tube into the drum. I installed clip nuts on the corners of the hole in the top of the drum, and drilled mating holes in the above flange. This would allow me to bolt the flange down to the top of the drum. Next, I made some angle brackets out of aluminum and bolted the flame tube to the flange. I left 6.5 inches of the flame tube sticking up above the flange. The rest protrudes down into the drum. Here the unit is being test fit on top of the drum. The holes in the ends of the angle brackets are over the clip nuts in the top of the drum.The high temperature silicone gasket material (figure2.5) is used to seal every crack, crevasse, joint and bolt hole in the gasifier.

Fig.2.3-Cutting of the air tank

Fig.2.4-Cutting flange for tank

Fig.2.5- Silicon gasket

Fig.2.6- Six numbers of j type copper tubes

Here I have installed the six j-tubes (figure 2.6). They are made of 1cm inside diameter, 0.5mm thickness, and 1foot length copper tubing. They are called j-tubes because they are shaped like the letter J. I used a large hose clamp cinched down tight to hold the tubes in place. The opening in the top of the drum needed to have a few notches cut in it to accommodate a couple of the j-tubes that stuck out too far.

The constrictor plate (figure 2.7) installed in the bottom of the flame tube. To make the plate I cut a circle out of a11 inch sheet steel that would fit in the bottom of the flame tube. Then I cut a 1.6 inch diameter hole in the center of the circle. To mount the constrictor in the flame tube, I welded three 1/4-20 nuts to the plate, and drilled passage holes in the flame tube for three 1/4-20 bolts. The manifold I made to cover the inlets of all six j-tubes. It was cut from a 6 in to 4 in steel AC duct reduction fitting. It slips down over the flame tube and covered all six j-tubes. A single air inlet fitting will be installed on the side of the manifold.

Fig.2.7-Constrictor plate

Fig.2.8- Updraft gasifier

After this, the gasifier is ready to use. But before starting the gasifier, it has been equipped with all the measuring instruments to take the readings.

III. Experimental Setup and Procedure

In this setup, the updraft biomass gasifier installed with the blower of different speeds, Anemometer, k-type thermo couples and digital temperature reader. First of all, the pulverized coal is heated with direct burning and this coal is used for the initial combustion of biomass fuel. This burn coal placed to the grate. Firstly, I used wood chips as a biomass fuel and filled the flame tube and closed the upper portion of the flame tube with the special type cap. The cap has two outlet valves for the producer gas. One is going to the burner and another to the nozzle.


Fig.3.1- Experimental setup of updraft biomass gasifier


Fig. 3.2- Experimental setup and burning flame in the burner

Further, blower is started with minimum speed of air inlet and the gasifier has been started. When the velocity of inlet air increases, the combustion presses of the gasifier become faster.This time the temperature of the three different zones of the gasifier increase greatly. The readings of different air velocity have been taken from the Anemometer and temperatures of three different zones taken from the Digital Temperature reader. This process continues with the other two fuels, sugarcane wastes and coconut shells.

IV. Results and Discussion

The gasification experiments were performed in the heat engine laboratory of the JEC, Jabalpur for three different biomass materials for the performance analysis of the constructed updraft biomass gasifier. The different velocity of air was measured with an Anemometer. The pyrolysis, reduction and oxidation zone temperature were also monitored with the aid of K type thermocouples.

The temperatures of the three different zones at different air velocities of the producer gas for these three materials were found out (Table 4.1, Table 4.2, and Table 4.3).

The comparison of Temperatures for these biomass materialswith respect to the air velocity are shown in the graph given below:

Table1: Different zone temperatures at different air velocities for wood chips.

Air velocities (m/sec.)	Temperature of Pyrolysis zone (˚C)	Temperature of Reduction zone (˚C)	Temperature of Combustion zone (˚C)
0.8	380	405	420
1.2	470	520	535
1.8	495	542	578
2.2	585	610	635

Table2: Different zone temperatures at different air velocities for Sugarcane waste.

Air velocities (m/sec.)	Temperature of Pyrolysis zone (˚C)	Temperature of Reduction zone (˚C)	Temperature of Combustion zone (˚C)
0.8	315	356	380
1.2	460	485	510
1.8	625	658	683
2.2	542	558	576

Table3: Different zone temperatures at different air velocities for Coconut shells.

Air velocities (m/sec.)	Temperature of Pyrolysis zone (˚C)	Temperature of Reduction zone (˚C)	Temperature of Combustion zone (˚C)
0.8	535	558	610
1.2	595	638	796
1.8	705	780	835
2.2	785	810	880

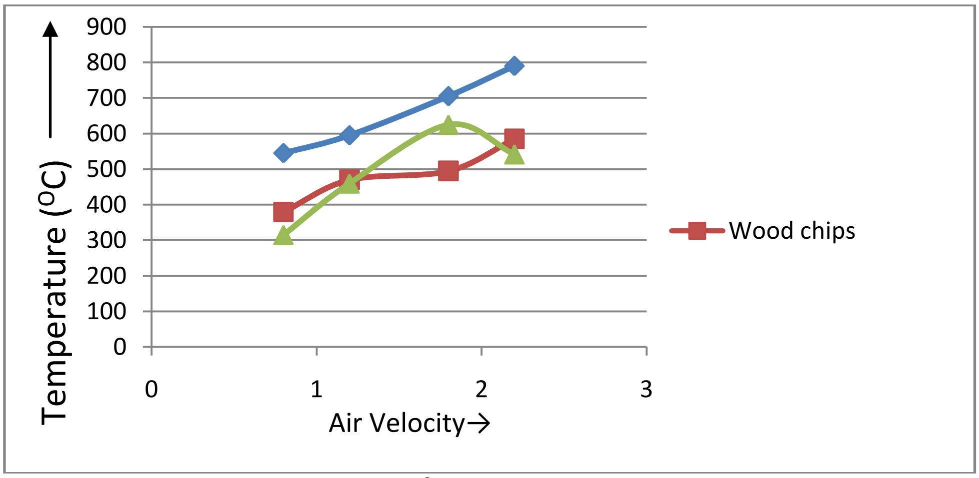

Fig 4.1: Comparison of *Pyrolysis zone* temperature (^oC) for different biomass materials with constant variations of air velocity (m/s).

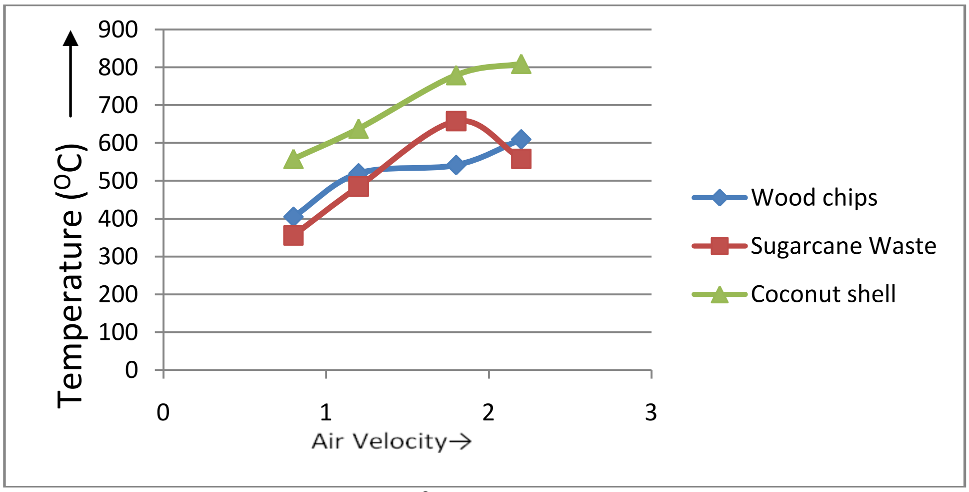

Fig 4.2: Comparison of *Reduction zone* temperature (^oC) for different biomass materials with constant variations of air velocity (m/s).

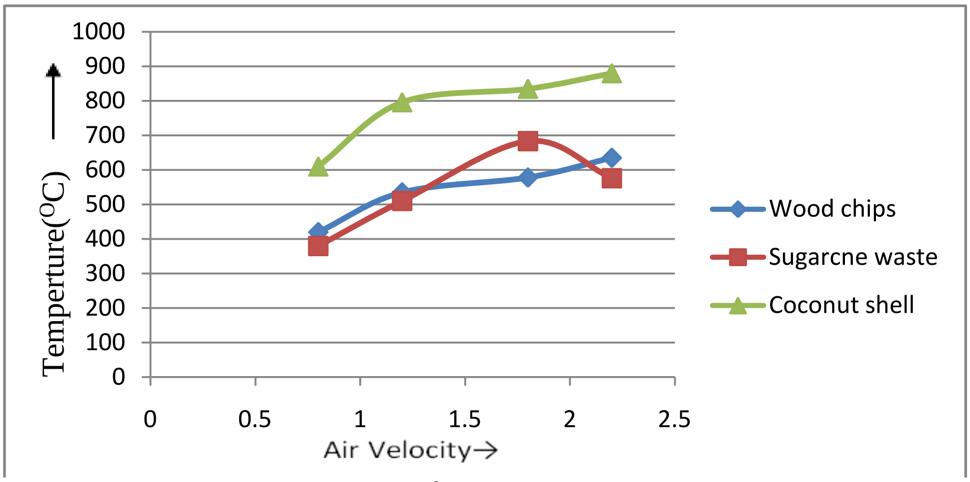

Fig 4.3: Comparison of *Combustion zone* temperature (°C) for different biomass materials with constant variations of air velocity (m/s).

By analyzing the graph, it is found that, when the air velocity increases from 0.8m/sec. to 2.2 m/sec, the pyrolysis, Reduction, and combustion zone temperatures also increases gradually. The temperature of the pyrolysis zone varies from 315˚C to 785˚C at the constant variation of the air velocity. The Temperature of combustion zone varies from 380˚C to 880˚C at the similar variation of the air velocity. The Temperature of Reduction zone varies from 356˚C to 810˚C at the similar variation of the air velocity.

The combustion zone temperature depends upon the heat released due to the biomass combustion and air flow rate. The increasing in combustion zone temperature means that there is greater amount of oxygen takes provides by increasing air velocity but also brings inert N_2, which acts as a heat barrier and reduces the temperature of the combustion and pyrolysis zone. The maximum value of temperature in pyrolysis and combustion zone represents the optimum amount of biomass consumption rate. From the analysis of previous papers, it is assumed that, at the optimum amount of biomass combustion, the amount of carbon monoxide and hydrogen produced are maximum and the fraction of carbon dioxide is minimum.

V. Conclusion

The experimental analysis for different biomass materials clearly show that the coconut shell having the greater temperature for all the zones as compare to the other two, when the air velocity increases. Maximum temperature of the different zones for coconut shell represents the optimum amount of combustion. The energy released will increase the rate of drying and pyrolysis. Optimum amount of biomass consumption rate is not only due to a higher combustion rate, but also due to the enhanced pyrolysis and drying rate. So, the coconut shell is best suitable material for the above constructed updraft biomass gasifier as compare to the other two. The coconut shell is one of the waste biomass and easily available material.

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