# An Experimental Study on Biomass Gasifier for Burner System

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***Abstract*-An Experimental study on biomass gasifier for burner system is presented in this paper. Biomass gasifier is developed and tested by using coconut shell as fuel for producing bio-gas. The generated bio-gas is directly used in burner system for combustion process and heating applications. The activated carbon is a waste product in this process, which is highly in demand for water purification system and can, sold to neutralize the fuel cost. In this work a Biomass Gasifier is designed, fabricated and commissioned to get biogas with carbon monoxide & carbon dioxide.**

***Keyword-Biomass gasifier; Biogas burner; Bamboo combustion; Coconut shell combustion; Overall Efficiency; Activated Carbon***

## I. INTRODUCTION

Energy is an important issue in the present scenario of the world and there is always a need in the renewable energy for sustainable growth. The rapid expansion of industrial sectors leads to the increases of energy consumption. But, the existing supplying systems are limited by fossil fuel stock (Avdhesh Kr.Sharma, 2009). A majority of industries use furnace for their process heat applications, which is powered by electric power or fossil power. Energy crisis and environmental damage are concerned. The researchers are recommending an alternative fuel and efficient conversion techniques to overcome those problems. Biomass gasifier is a device used to generate gas cheaper than other fuels. (Fletcher et al., 2000).

When a coconut tree field is developed, coconut shell, coconut coir can be used as fuel. The output will be bio-gas and activated carbon. By following this plantation method, there is no need to cut other trees and always a large amount of trees are being cultivated. This is considered to neutralize the carbon dioxide generated by the combustion of this gasification system. In this paper experimental results of developed biomass Gasifier for burner system are presented.

## II. BIOMASS GASIFICATION THEORY

The production process of bio-gas (producer gas) which is called gasification, is a partial combustion of solid fuel (biomass) and it takes place at temperatures about 1000°C. The reactor is called a gasifier. The combustion products from complete combustion of biomass generally contain nitrogen, water vapor, carbon dioxide and surplus of oxygen. However in gasification where there is a surplus of solid fuel (incomplete combustion), the products of combustion are combustible gases like Carbon monoxide (CO), Hydrogen ($H_2$) and traces of Methane and non-useful products like tar and dust. The production of these gases is by reaction of water vapor and carbon dioxide through a hot layer of charcoal. Thus the key to gasifier design is to create a condition in which

a) Biomass is reduced to charcoal

b) Charcoal is converted at suitable temperature to produce CO and $H_2$.

### *A. Reactions in the Gasifier*

The reaction of the gasification process is given below (Donald, 1998)

Gasification:

$C + O_2 \rightarrow CO_2$ - 393.5 kJ

$C + H_2O \rightarrow CO + H_2$ + 131.3 kJ

$C + 2H_2O \rightarrow CO_2 + H_2$ + 90.2 kJ

$C + CO_2 \rightarrow 2CO$ + 172.4 kJ

Partial oxidation:

$C + 0.5O_2 \rightarrow CO$ - 110.5 kJ

Water gas shift:

$CO + H_2O \rightarrow CO_2 + H_2$ - 41.1 kJ

Biomass gasifier produces bio-gas (producer gas from wood) and it is used to fire the product in the furnace. By using the bio-gas, the temperature can be raised to 1000°C. If the bio-gas reaches the temperature of 400°C when entering the furnace, the energy used in the furnace will be less by 30%. (Pengmei, 2007)

## III. ENERGY PLANTATION FOR THE BIOMASS GASIFIER

The problem in biomass is the demand of wood. Wood is obtained through cutting of trees which causes ill-effects to the environment. Cutting of trees leads to afforestation. To overcome this quandary, fast-growing bamboo is used for energy plantation for it grows 1 feet per-day. This bamboo tree can be cut when needed and can be utilized for the partial combustion in the biomass gasifier.

Highest bamboo production per-acre per-year is 40 to 60 tons/ac /year. 1000 plants can be planted in an acre. Low ash content in wood is 1%. The biomass has got average energy of 16720kJ/kg. Less storage space is enough for raw material as compared to paddy straw and husk and other agri wastes. Cost of bamboo biomass is the lowest (less than Rs 430/ton) when it is cultivated in self-owned land. Amount of Carbondi-oxide absorbed is 80 tonnes per-acre per-year. Water requirement is about 2000mm, rain water included. Growth is very aggressive during monsoon season and can reach to 1 to 1.5ft /day. It can reach height up to 65 feet. Life-span of the tree is more than 100 years. And the yield is once in 2 years.

### *A. Biomass Gasification System Model*

Figure 1(a) shows biomass gasification system (186 $kW_{th}$) with the coconut shells as input fuel. The availability of coconut shell in the rural area is more and with less moisture. The downdraft gasifier generally uses coconut shell as fuel. The generated bio-gas is sent to cyclone for removing its moisture and then the combusted bio-gas is used in burner. The waste from product of the activated carbon is used in water purification process

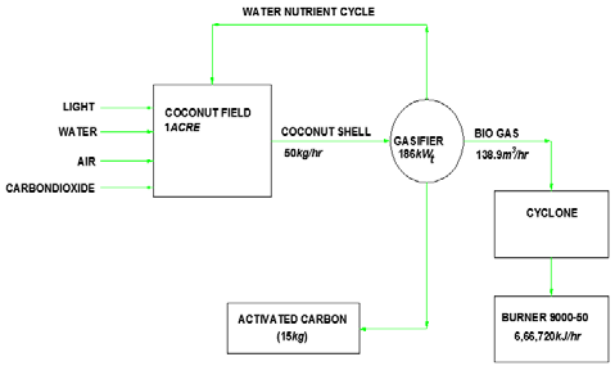


Figure 1 (a) Model representation of biomass gasification (coconut shell for testing)

The figure 1(b) shows the model details of the biomass Gasifier (186$kW_{th}$) that use bamboo wood as fuel input for a long-term running. Also, fast-growing bamboo can also be used for faster biogas generation.

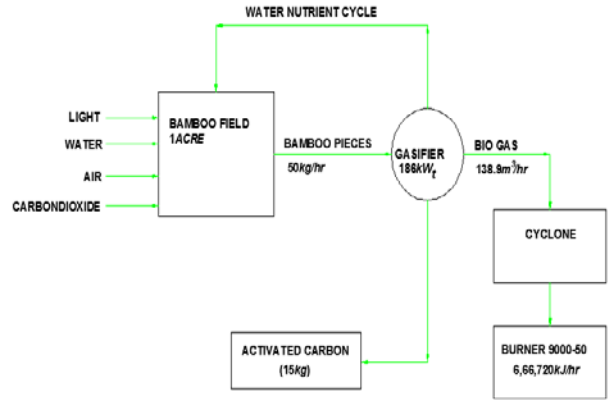


Figure 1(b) Model representation of biomass gasification (bamboo for testing)

### *B. Biomass Gasifier Design*

The bio-gasifier is designed to give thermal energy output of 6,66,720 kJ/hr through burner. The volume of the producer gas is 136.9m3/hr. The fuel input for the Gasifier is coconut shell of 50kg/hr.

#### *1) Energy Balance*

The energy from the wood is converted into gas and it is sent to the burner for burning. As to the basic theory of gasification, the wood calorific value is 16720 kJ/kg. For 1kg of wood, the volume of gas generated is 2.738m3. Calorific value of biogas is 4274 kJ/m3 with efficiency of 70%. Energy obtained from the Gasifier is 232 kWth.

#### *2) Specifications of the Biomass Gasifier*

The type of gasifier is down draft. The input to the gasifier is 50kg/hr of wood. The wood for gasifier is coconut (for testing). For permanent usage bamboo can be used. The gas output from the gasifier is 136.9$m^3$/hr of bio-gas. The temperature of the gas obtained is 300˚C to 400˚C. The pressure obtained from the gasifier is 50 to 200 mm of water column. The calorific value of biogas produced is 4274 kJ/$m^3$ (air gasification). The temperature of the gaisifier is 700˚C-1000˚C. The energy obtained is 232$kW_{th}$.

## IV. BIOMASS GASIFIER CONSTRUCTION

Biomass gasifier construction and drawing is realized with a combustion temperature of 1150℃. A cyclone is installed after the gasifier. Cyclone can withstand a temperature of 600℃.

### *A. Structure*

The biomass gasifier is of down draft type. The gasifier will be a double-throat system. Combustion zone throat is of 360mm and pyrolysis zone throat is of 400mm. The total height of the gasifier is 4.5m. The advantage of downdraft gasifier is that it is flexible to adopt the gas production. The gasifier is fabricated with 5mm thick Mild Steel sheet with required Mild Steel structures. A boiler housing jacket is provided after the outer diameter of the refractory in the firing zone area.

### *B. Refractory*

The refractory is divided into 4 parts .The hot face of the gasifier will be of CUMI M45 (45% alumina) castable. This insulation castable is constructed in reduction zone, combustion zone and pyrolysis zone. In drying zone there is no insulation.

### *C. Bottom ash Discharge*

At the bottom of the gasifier a mechanical mechanism is provided to extract the activated carbon and ash to get the biomass down slowly from the top of the gasifier. The ash is made to fall in the water seal which acts as an air-tight sealing and a safe discharge of ash.

### *D. Cleaning of Gas*

Cyclone is provided to remove the ash particles that are sucked from the bottom of the down draft gasifier. So the clean gas goes to the burner for burning. Figure 2 shows the total cross section of the double throat down draft biomass gasifier.

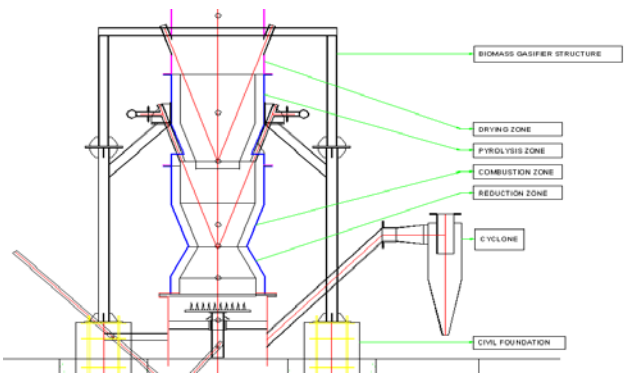


Figure 2 Sectional view of the biomass gasifier

Figure 3 Experimental setup of the biomass Gasifier

Figure 3 shows the final setup of the biomass gasifier after fabrication. It was installed at premises of ISSOJECT Burner Private Limited Hosur, India for evaluation.

## V. RESULTS AND DISCUSSION

The Coconut Shell is used initially to test the Gasifier and its feed rate is 30 - 50 kg/hr. The rate of air supplied by the blower to the gasifier is 68 $m^3$/hr.

### *A. Gasifier Zone Temperatures*

The gasifier zone temperat ures are initially measured and are shown in the Figure 4 with respect to time. It is noted that, at 750°C in reduction zone the gas is obtained and it proves the basic theory of gasification.

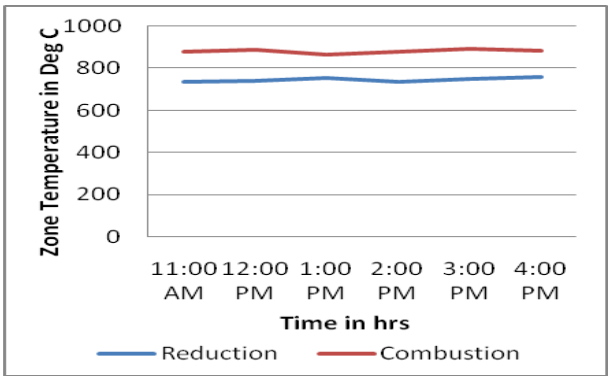


Figure 4 Gasifier zone temperatures with time

Figure 5 shows gasifier surface temperature with respect to time and it is understood that, the surface temperature in shell is 150°C. This proves that the refractory insulation is optimum for 1100°C.

### *B. Gasifier Surface Temperature*

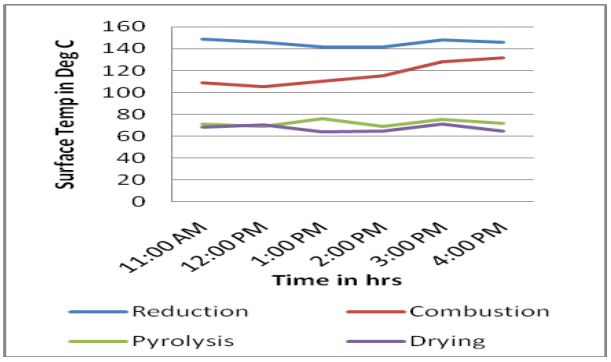


Figure 5 Gasifier surface temperatures

### *C. Gas Analysis*

Figure 6 shows exhaust gas analysis with respect to the time and it is understood that, 14% Carbon Monoxide is obtained in the producer gas. The range of Carbon Monoxide to be obtained is 18%-24%.

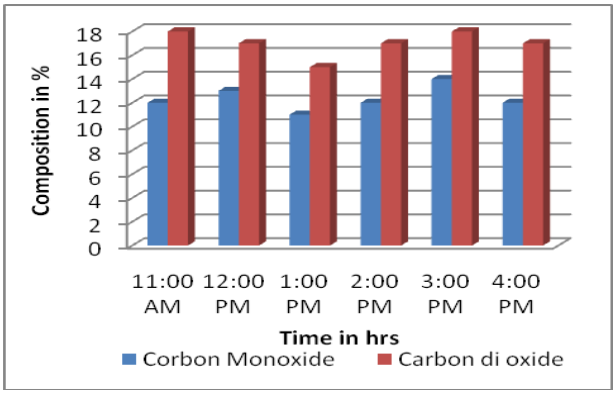


Figure 6 Exhaust Gas analysis

### *D. Pressure in the Gasifier System*

Figure 7 shows pressure variation in the gasifier system with respect to the time and it is understood that, the pressure got in the gasifier ring is 2-inch of Water Column, which means that the air input is 68 $m^3$/hr.

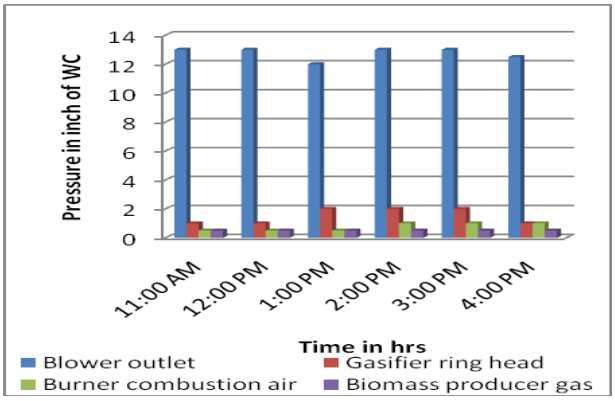


Figure 7 Pressure in the gasifier system

### *E. Burner Flame Temperature*

Figure 8 shows burner flame temperature variation with respect to time and it is understood that, the burner flame temperature in the burner is 874°C. It means this bio-gasifier is suitable for application from 900°C to 1000°C.

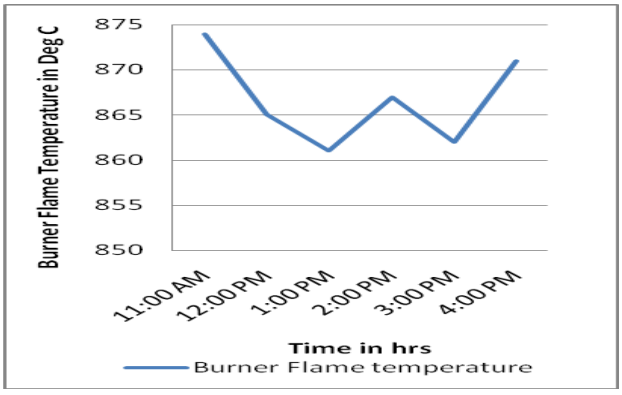


Figure 8 Burner flame temperature

The gas will be obtained after 150minutes. The top combustion zone temperature is 1122°C. If the temperature

reaches above 950℃, the CO will decrease. A better balance of the gasifier has to be followed to get a quality gas. The wood flow should be 40kg/hr - 50 kg/hr. The air should be $60m^3$/hr - $70m^3$/hr. The discharge should be every 60 min - 90 min. The temperature in the reduction zone should be in the range of 740℃ to 770℃ and in the combustion zone should be in the range of 850℃ to 950℃.The temperature in the combustion zone should be 850℃ to 950℃. The burner flame temperature reached is between 840℃ to 900℃. This will be suitable for the clay brick industries as the required temperature for the kiln is 900℃ to 1000℃.

## VI. CONCLUSIONS

In this work, the biomass gasifier system was developed and tested with coconut shell as fuel for burner system. It was found during the experimentation that the producer gas was obtained from developed biomass gasifier. The operating temperature of the gasifier noticed to the maximum range value of 900℃ to 1000℃. The biomass gasifier can also used in clay brick industry due to the required temperature for kiln of 950℃. It was also suggested that the developed biomass gasifier can be used in any thermal heating application. The further development study is to produce hydrogen in this setup. Hydrogen can obtained by reaction of carbon monoxide and steam in the reduction zone of the gasifier which is called water-gas shift reaction.

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