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# PRODUCTION OF A PRODUCER GAS FROM WOODY BIOMASS USING $CO_2$ CAPTURING CHEMICALS

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## *ABSTRACT*

*In the past 30 years, the increasing global temperature is one of the greatest concerns of mankind. The use of biomass resources is one of the important components to reduce global warming. In many cases, where the petroleum prices are high or supplies are limited or there is a problem of global warming, the biomass gasification can provide an economically and environmentally feasible system, if the desired biomass feedstock is available easily. In 2013, US reported that of the total emissions, 98% of $CO_2$ emissions are of energy-related and about 40 % due to electricity generation. Since the fossil fuels which are non-renewable and polluting the environment, wood waste biomass is used, which is renewable and environmental friendly.*

*In present study, wood biomass of approximately size of 5 cms was used as a raw material and different chemicals were used to absorb $CO_2$. In this present work, 1 kW gasifier was used, where the production ratio of CO to $CO_2$ is 5:6. Various chemicals namely dolomite, olevin sand, manganese, calcium carbonate etc. were used to absorb $CO_2$, which in turn increases the quality of CO. By varying the quantity chemicals (15, 50, 100-600 g), the absorption of $CO_2$ was studied.*

*It was observed that by using 500g of calcium carbonate, the ratio of CO to $CO_2$ was found to be 3:2. The CO production rate was increased to 41.1%. The production of $CO_2$ was reduced to 21.1%. And also higher amount of hydrogen was produced i.e upto 21.5 %.*

***KEYWORDS:*** *Gasification, Producer Gas, Chemicals, $CO_2$ Absorption*

## INTRODUCTION

However currently, economic factor is one of the reasons for not considering gasification. Even though the cost of gasification is slightly higher, it is does not pollute environment because the $CO_2$ produced during gasification is cyclically consumed by new plants grown for energy. Thus, the net $CO_2$ emission in the environment is zero. Industrial units face difficulty to use biomass as a ready to use fuel in a sustainable manner. There are only few industrial groups considering this sector as business activity. Biogas is an attractive energy source, as it is rich in methane content. The important part is to meet the goals of biomass gasification technologies. In 2013, US reported that of the total emissions, 98% of $CO_2$ emissions are of energy-related and about 40 % due to electricity generation as shown in Fig. 1.

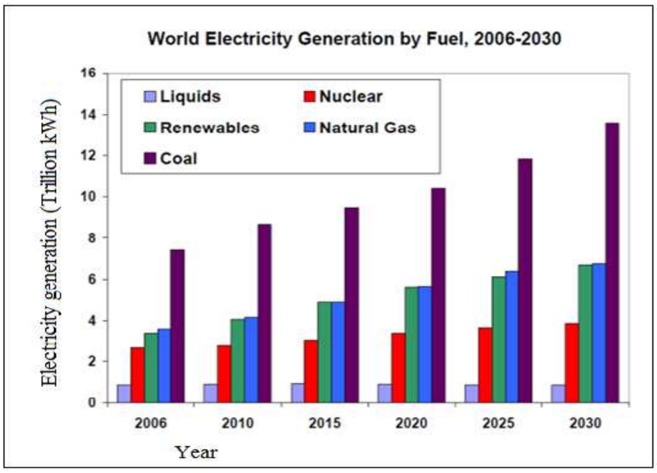


**Figure 1: World Electricity Generations by Fuel [1].**

Biomass need to be preprocessed before using it as a fuel to the gasifier. Depending on upon the type of biomass and its properties, different approach of processing is necessary for gasification applications. In most of the developing countries, agriculture wastes contribute largely for the energy mix, therefore it is important to develop effective methods for converting biomass residues to usable fuel [2].

Gasification is an incomplete combustion of biomass which produces gases that consists of carbon monoxide, hydrogen and traces of methane, termed as producer gas or synthesis gas. Gasification technology can be used in applications where the fossil fuel has to be replaced by biomass. The product gas contains impurities such as particulates, tar, sulfur etc., must be filtered and removed from the product gas before it is used for other applications. Syngas can be used for the specific application by changing the composition of gas and is achieved by reforming reactions.

Dr. Shashikant et al reviewed that due to environmental crisis biomass can substitute the fuel. He also mentioned that a biomass has great potential to reduce global warming [3]. Even though biomass generates about the same amount of $CO_2$ as fossil fuels, but the $CO_2$ gets cyclically consumed by new plants grown for energy. Thus, the net $CO_2$ emission in the environment is zero [4].

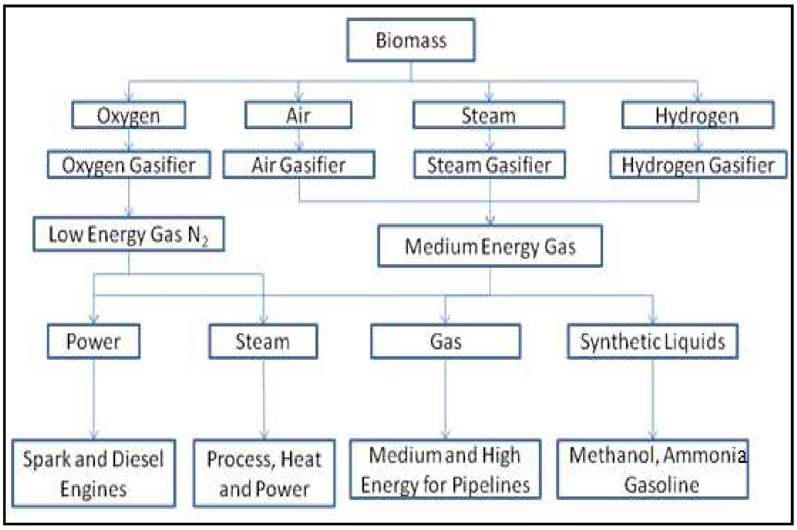


**Figure 2: Gasification Process and their Products.**

The objectives of the study are to:

- Production of producer gas from waste biomass using chemicals.
- To enrich the quality of producer gas using different chemicals.
- To reduce the production of $CO_2$, $CH_4$ of the producer gas,
- Analyzing the composition of producer gas and also determining its gas calorific value, the flow rate and efficiency of gasifier.

**Types of Biomass as Gasifier Fuel**

There are various fuels that can be used in a gasifier such as charcoal, saw dust, wood, peat, agriculture wastes (eg. coconut shell) etc.

**Sawdust**

Most of the downdraft gasifiers are not suitable for unpelletized sawdust. While using saw dust, many problems occurs such as excessive tar production, pressure drop etc. But in most of the downdraft gasifiers, sawdust is used as a filter and includes wide range of porous materials where minute particles gets trapped and allows only gas to pass through it as shown in Fig. 3.

**Figure 3: Sawdust.**

**Wood**

Most of the wood species have ash contents less than 2%; hence it is one of the suitable fuel for a gasifier. The high volatile content in wood produces the gas with large amount of tar content in gasifier system that is suitable for direct burning. In the gasifier, either wood or wood coated with chemicals is used as a fuel, as shown in Fig. 4. This gas can be used in the engines, but cleaning is required, which is difficult and labour intensive. Most of the downdraft gasifier systems are designed to deliver a product gas contain low tar and this is can be possible by using wood chips having low moisture content [5].

**Figure 4: Wood Pieces of 5-10 cms in Size.**

**Charcoal**

High quality charocal contains negligible amount of tar. This charcoal is loaded at the bootom of gasifier reactor as shown in the Fig. 5. Thare are several disadvantages of using charcoal such as relatively high cost of charcoal, energy loss during charcoal manufacture etc.


**Figure 5: Charcaol Loaded in the Gasifier.**

**Agriculture Residues**

The agriculture residue that is produced in most of the countries is widely used for gasification. The agriculture waste includes coconut shells, maize cobs etc. In the bridging section coconut husk create bridging problems, which can be prevented by mixing specific amount of wood. The cereal straws generally contains above 10% of ash, which causes slagging problems in down draft gasifiers. Rice husk contains ash of 20% and above and this is may be the most difficult fuel available [6].

**The Gasifier**

Initially the flame at the chimney will not be burning continuously. This happens when the temperature of charcoal in the reduction zone reaches about 600 $^{\circ}$C. At this temperature, quenching of the flame does not occur, but the flame may blow off due to high gas velocities. The downdraft gasifier is a nonportable gasifier, having two inputs to admit air into the burner.

## METHODOLOGY

The methodology adopted in this experiment is as shown in Fig. 3.1.

- Literature survey of research papers related to gasification is used, different techniques to absorb $CO_2$ was determined.
- Exploring the percentage absorption of $CO_2$ by using different chemicals, based on the latest literature survey.
- Proximate analysis of the sample was carried out.
- After each trial, different quantity of the same chemical was used to determine the maximum absorbance percentage of $CO_2$.
- Chemicals were introduced or mixed at different zones, such as orifice of gasifier, water tank, filters.
- Results were compared to determine the zone that gives maximum absorbance.
- After conducting all experiments, results were compared to determine the catalyst that gives higher absorbance of $CO_2$.
- Gas Chromatography was used to analyze the percentage of CO, $CO_2$, $CH_4$, $H_2$ and $N_2$ of producer gas.
- The flow rate of the produced producer gas was found out using Bubble flow meter.
- Efficiency of gasifier was found out.

## EXPERIMENTAL PROCEDURE

Since the design of the gasifier, flow of biomass in the gasifier cannot be altered, chemicals such as Dolomite, Olevin sand, $CaCO_3$, Manganese, Diethanolamine were used to absorb $CO_2$. There are also other chemicals such as monoethanolamine, sodium azide, potassium carbonate, sodium hydroxide that can be used to absorb $CO_2$.

The steps involved in the waste biomass gasification are as follows

The wood pieces were dried at 100 $^{\circ}$C for 2 days in the hot air oven as shown in Fig. 6.

**Figure 6: Hot Air Oven.**

The wood pieces of about 5 cms as shown in Fig. 7 a, were loaded into the gasifier drum as shown in Fig. 7 b.

**Figure 7: a. Wood Pieces of Approximate 5-10 cms in Size b. Gasifier Drum.**

Initially the synthesis gas is passed through the cyclone seperator as shown in Fig. 8 a, where the denser particles get seperated, consequently passed through the saw-dust filter as shown in Fig. 8 b, where minute paticles gets seperated. For further purification, this gas is made to pass through the cloth filter as shown in Fig. 8 c. The producer gas evolving through this filter contains no impurities [].

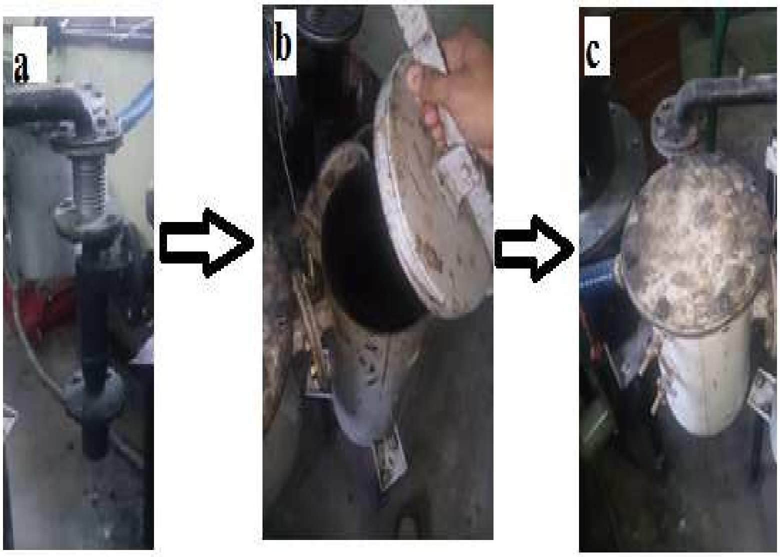

**Figure 8: Filters a. Cyclone Filter b. Saw-Dust Filter c. Cloth Filter.**

The evolved syngas was analyzed through Gas Chromatography as shown in Fig. 9 a and hence the percentage of CO, $CO_2$, $H_2$, $CH_4$, $N_2$ were determined as shown in Fig. 9 b.

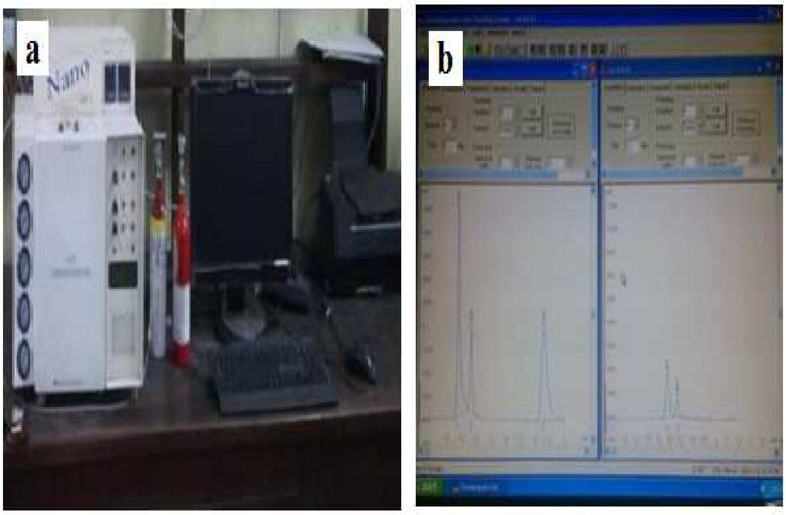


**Figure 9: Analysis of the Gas by a. Gas Chromatography b. GC Spectrum.**

The flow rate of producer gas is important in finding efficiency and was found using Bubble-flow meter as shown in Fig. 10.

**Figure 10: Bubble-Flow Meter.**

Treatment 1: The wood chips coated with chemicals such as $CaCO_3$, dolomite etc, as shown in Fig. 11 was oven dried at temperature of 80 $^{\circ}$C and loaded into the gasifier

**Figure 11: Wood Coated with Dolomite.**

Treatment 2: Chemicals such as Dolomite, Olevin sand, Calcium-carbonate etc were introduced at orifice, where the temperature is about 300 °C as shown in Fig. 12.


**Figure 12: Gasifier.**

Treatment 3: Chemicals such as Dolomite, Olevin sand etc. were introduced in the reduction zone, where the temperature is approximately 600 °C as shown in Fig. 13.

**Figure 13: Reduction Zone of the Gasifier.**

Treatment 4: Chemical solution such as Diethanolamine was introduced in the tank, where the temperture is about to 60 °C, as shown in Fig. 14.

**Figure 14: Recycling Water Tank.**

**Calculations**

Wet weight or initial weight = 100 g

Dry weight or final weight = 87 g

Hence, moisture content by using equation (2.8)

(100-88)/88 = 13.63 %

In the control run following readings were noted

**Observed Data**

Initial Weight 1.50 kg

Final Weight 0.76 kg

Wood Burnt 0.74 kg

Initial Temp 570 $^{\circ}$C

Final Temp 850 $^{\circ}$C

Total Time 2400 sec

Feed rate = (3600 x 0.74) / 2400 = 1.1 kg/hr

Hence, Feed Rate = 1.1 kg/hr.

Gas flow rate = ($10^{-4}$ x 3600) / 2.1 = 0.17

Hence, Gas Flow Rate = 0.17 $m^3$/hr.

Gas evolved = feed rate/gas flow rate = 0.17/1.1 = 0.155

Hence, Gas Evolved = 0.155 $m^3$/kg

The standard heating value of the producer gas is given by different industries such as NREL, Verenum, TU-Wien, Carbona etc. In this experiment to determine the heating value, standards given by NREL method were used

Heating Value = 10.788A + 12.622B + 35.814C,

Where, A is the quantity of $H_2$, B is the quantity of CO and C is the quantity of $CH_4$.

HV or Calorific Value = (10.788 x 2.87 + 12.622 x 11.826 + 35.814 x 2.64)/100

Hence, Calorific Value = 2.74 MJ/$Nm^3$.

Efficiency of the Gasifier is calculated by,

□□= Heating Value of producer gas x Volumetric flow rate of producer gas

Mass of wood chips loaded in the gasifier x calorific value of wood chips

$\square_{mech} = \frac{2.68 \times 10^6 \times 10^{-4}/2.1}{4745 \times 0.85/2400 \times 2.1}$

= 75.8 %

In this experiment, each chemical exhibiting the maximum value of either absorbance of $CO_2$ or enrichment of CO or heating value etc was observed as shown in the Table 5.28 and Fig. 5.28.

**Table 1: Effect of Chemicals on the Production of the Producer Gas**

| S. No. | Quantity of Sample | CO | $CO_2$ | $H_2$ | HV | $CO/CO_2$ |
|---|---|---|---|---|---|---|
| a | Control run | 9.8 | 11.8 | 5.5 | 2.3 | 0.9 |
| b | Wood with coal as a filter | 10.6 | 11.8 | 6.6 | 2.4 | 0.9 |
| c | When 500 g Dolomit introduced at the reduction zone | 12.4 | 10.3 | 8.1 | 3.1 | 1.2 |
| d | Wood sample mixed with 500 g of olevin sand | 11.7 | 10.8 | 5.2 | 3.0 | 1.1 |
| e | When 25 g of olevin sand, 25 g uncalcinated and 25 g calcinated dolomite was introduced at orifice | 12.3 | 11.6 | 5.1 | 3.4 | 1.1 |
| f | When 500 ml (0.5 %) of diethanol amine was introduced in the tank | 13.1 | 8.4 | 5.0 | 3.0 | 1.6 |
| g | When 1 kg of $CaCO_3$ was introduced in the tank | 12.4 | 11.6 | 3.7 | 2.9 | 1.1 |
| h | When 500 g of $CaCO_3$ introduced at the reduction zone | 14.0 | 9.3 | 6.7 | 2.9 | 1.5 |
| i | When mixture of 250 g doomite and 250 g $CaCO_3$ was introduced at the reduction zone | 12.6 | 9.9 | 5.9 | 2.8 | 1.2 |
| j | When 15 g of calcinated manganese into orifice | 9.7 | 13.4 | 4.7 | 2.5 | 0.7 |

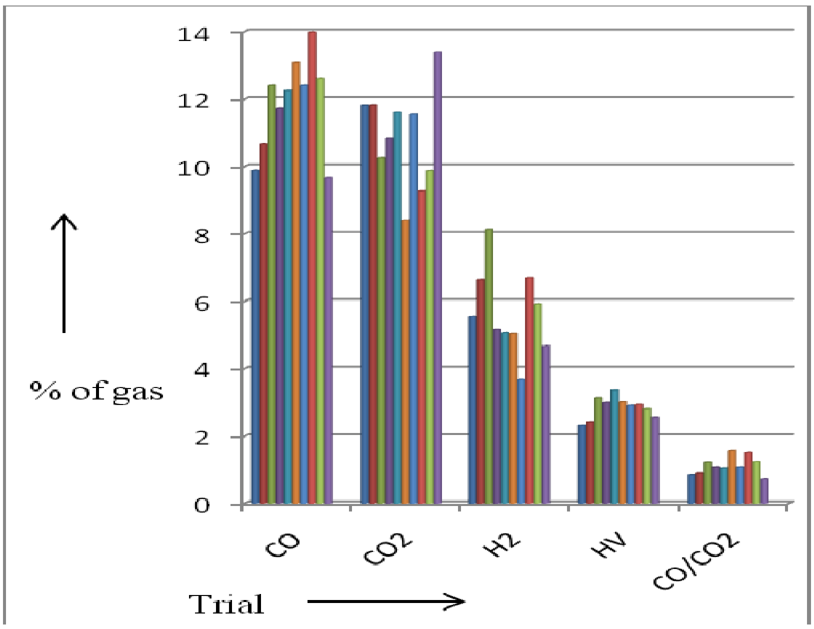


**Figure 15: Effect of Chemicals on the Production of the Producer Gas.**

## CONCLUSIONS

The experimental studies carried out on gasification by using various chemicals of different quantities, following conclusions were drawn

There were no considerable changes when Olevin sand was introduced into the gasifier.

Maximum amount of CO was produced when 500 g of $CaCO_3$ introduced at the reduction zone (41.1%).

The production of $CO_2$ was minimum (28.82%) when 500 ml of diethanolamine was introduced in the tank and maximum (13.3%) when 15 g of calcinated manganese was introduced at the orifice of gasifier.

The production of $H_2$ was found maximum

- When 500 g of dolomite was introduced in the reduction (47%).
- When 500 g of $CaCO_3$ introduced at the reduction zone (21%).

The Calorific value was highest

- When mixture of 25 g of olevin sand, 25 g uncalcinated and 25 g calcinated dolomite was introduced at orifice (45.5%).
- When 500 g Dolomit introduced at the reduction zone (35.4%).
- The ratio of CO to $CO_2$ was found highest
- When 500 ml (0.5 %) of diethanol amine was introduced in the tank (1.56).
- When 500 g of CaCO3 introduced at the reduction zone (1.5).

Thus, it was observed that $CaCO_3$ is the suitable chemical that can be used in the gasification. It was observed that by introducing 500 g of $CaCO_3$ in the reduction zone of gasifier, maximum amount of CO (41.1%), nearly maximum amount of $H_2$ (21%) and reduction in $CO_2$ (reduced to 21.5%) with highest $CO/CO_2$ (76.5%) and almost maximum amount of heating value (27.4%) was produced.

## FUTURE SCOPE

The technological progress in the increase of the production of CO and reducing the emissions of $CO_2$ either by alternating the design of the gasifier or by using other chemicals such as Monoethanolamine, Sodium azide, Sodium hydroxide etc. The bottom ash produced during gasification can be used in building sectors, roads, agriculture etc. Efforts can be made to design new solvent systems that will have lower energy consumption. In addition to this CFD studies can be studied on gasification kinetics and gasifer operation.

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