

## CONSTRUCTION OF A DOWNDRAFT BIOMASS GASIFIER

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### INTRODUCTION

Gasification is a thermal process of converting dry biomass feedstock into a mixture of gases that can be burnt in internal combustion engines and gas turbines. The use of producer gas to run internal combustion engine was first tried in around 1881. It was referred to as 'suction gas', because the gas was sucked by the engine from the gasifier. It was also known as 'town gas' or 'coal gas'<sup>1</sup>. A variation of this gas (using steam or hydrogen instead of oxygen or air) is also known as 'synthesis gas' because a variety of chemical compounds can be made from it. The essential chemical species in all these gases are CO (Carbon monoxide) and H<sub>2</sub> (Hydrogen), both of which burn to release heat. Town gas was predominantly used for street lighting in early European cities like London. It lost out to natural gas because it is highly poisonous due to the presence of carbon monoxide. Gradually the use of producer gas as a domestic fuel was taken over by cheaply available natural gas. The advent of petroleum further accelerated a decline in the need for producer gas.

Gasification is the generic term to describe the technology of conversion of solid fuels into gaseous ones. Thus there can be coal gasification or biomass gasification. Although both coal and biomass can be burnt directly to get heat energy, gasification of these fuels has certain advantages which cannot be achieved by direct burning. The main advantage of biomass gasification is that the resultant gaseous fuel can be used in an engine directly. Since gas engines are readily available, through biomass gasification one can produce electricity. It is certainly possible to get electricity from directly burning biomass, but that would require, first, a boiler for making steam and then a steam turbine.

Environmentally, Biomass Gasification is a clean technology free of CO<sub>2</sub> emissions, if well designed. Utilization of renewable energy sources makes it a sustainable energy system. Biomass Gasification has been receiving attention because of the following reasons:

- Reduction of wood consumption up to 50%
- Environmentally sound technology
- Decentralized electricity generation
- Good use of domestic resources
- Savings in foreign currency in importing energy
- Boost to agriculture
- Easy to operate and maintain
- Local employment
- Replacing the fossil fuels.

The disadvantages can successfully be mitigated both by "good practices" and engineering measures.

In developed countries, there is not much interest in small-scale decentralized electricity generation because of its high cost. However, co-firing, i.e. using biomass along

with other fuels to reduce fossil fuel consumption is becoming very popular and this practice is responsible for the consumption of vast quantity of biomass. Developed countries like Brazil are more interested in liquid bio-fuels, bio-ethanol and bio-diesel. India is becoming a leading user of the small-scale version of this technology and many new designs are being innovated. Thailand is also experimenting with it.

Bangladesh is an agrarian country and there is easy availability of agriculture-based mass, which can be used to generate energy. Burning this biomass directly is the oldest and also the least efficient method of generating energy. On the other hand, gasification of this mass is technologically viable and at the same time has the potential to replace the consumption of fossil fuel to some extent.

In this study, the goal is to construct a downdraft biomass gasifier at laboratory scale and to check whether the required composition of producer gas can be achieved successfully. The construction of the gasifier is based on the design proposed by Bhattacharya et al.<sup>2</sup>.

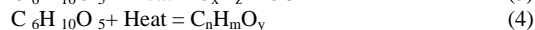
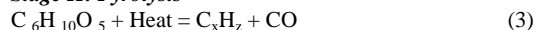
### THEORY OF GASIFICATION

Air biomass gasification can be expressed in three stages as follows<sup>3-6</sup>:

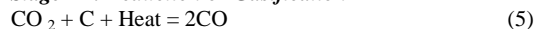
#### Stage I: Oxidation



#### Stage II: Pyrolysis



#### Stage III: Reduction or Gasification



Oxidation reactions (1) and (2) are exothermic and release heat. Carbon and Hydrogen oxidized in this phase are from the organic molecules of the solid fuel (biomass). They are transformed into carbon dioxide and water vapor, respectively. Ash is also produced during combustion. The products from this stage enter the last stage where, through reactions (5) and (6) a reduction process is encountered. As a result, Carbon monoxide and Hydrogen are formed which are the final products of the gasification process and are still combustible. In parallel, there is another phase occurring at high temperature (the energy for this process can be obtained from oxidation) to crack the heavier biomass molecules into lighter organic molecules and carbon monoxide through reactions (4) and (5). In this phase, other than the products found from the chemical reactions, tar and char are also produced. Tar is mainly gasified in stage III while char, depending upon the technology used, can be significantly "burned" through reactions (5) and (6), reducing the concentration of particulates in the product.

The net product of air gasification can be found by summing up the partial reactions, as follows:



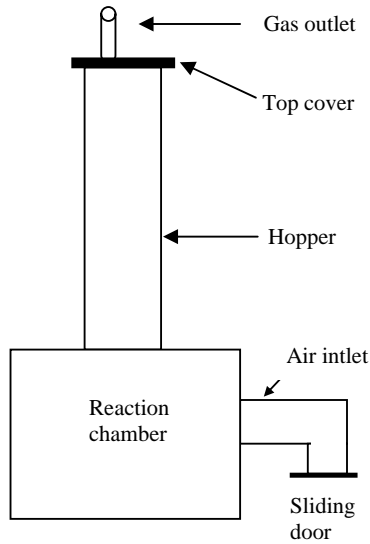


Figure 1: Schematic Diagram of the Complete Gasifier.

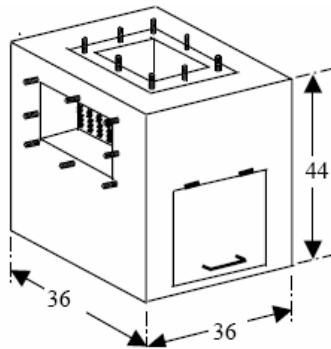


Figure 2: Schematic Diagram of Reaction Chamber. Dimensions are in cm.

**EXPERIMENTAL SET-UP AND PROCEDURE**

Reaction chamber, fuel chamber, air inlet, and gas outlet are the main components of the downdraft gasifier shown in Fig. 1.

**Reaction chamber:** Reaction chamber is the heart of the gasifier. The outside wall of the reaction chamber was made of 2mm thick (14 gauge) mild steel sheet and outside dimension of the reactor was 36 x 36 x 44 cm as shown in Fig. 2. The inside wall was made of bricks cemented together by castable refractory. The inside dimension was 16 x 16 x 22 cm.

The reaction chamber was supported by four legs and had a grate at a height of 22 cm from the top. Above the reaction chamber was the fuel chamber from where the fuel flowed down by gravity. The grate was made by parallel steel bars of diameter 6 mm with 2 cm spacing in between. Ash from the reaction chamber could fall down freely through the grate and accumulate in an ash collector. A mild steel door (18 x 18 cm) was provided at one side of the chamber for removing the accumulated ash. The door, made of 2mm thickness mild steel sheet is fixed to the reaction chamber body using two hinges. The ash accumulated below the grate is periodically removed by opening this door. The door is also used to ignite the

Gasifier by introducing a flame torch. Some images of the reaction chamber are shown in Fig. 3.

**Air inlet:** The inverted 'L' shaped air inlet made of 2 mm thick mild steel sheet was attached to one side of the reaction chamber. A sliding piece of mild steel sheet was provided to control the amount of primary air supply for regulating the heat output. Perforated mild steel sheet of 2 mm thickness were used at primary air inlet and exit areas to hold the fuel

**Fuel hopper:** It was made of mild steel sheet and was located above the reaction chamber. The fuel storage hopper had a height of 70 cm and a square cross-section (17 x 17 cm). The upper end of the hopper was covered by a lid, which was designed for ease of loading of the fuel.

**Gas outlet:** The producer gas formed in the reaction chamber passed out through a gas outlet made of 1/2 inch diameter mild steel tube set at the top of the fuel chamber.



Figure 3: Photograph of the Reaction Chamber. Top: without bricks; Upper middle: with bricks; Lower middle: plastered with refractory cement; Bottom: ash removal door.



Figure 4: The complete Gasifier



Figure 5: The producer gas is being ignited

**Feed stock preparation:** Gasifiers are very sensitive to the moisture content of feedstock. A gasifier cannot handle too much wet feed. In the present study, wood chips of 1-3 inches were naturally dried for two days and were used as feedstock for the gasifier.

**Operational procedure:** A photograph of the complete Gasifier is shown in Fig. 4. It was started after loading the fuel chamber with feedstock and igniting it by a flame torch as shown in Fig. 5. It usually took about 7-10 minutes for starting up. The sliding gate was fully open during the start-up. After 7-8 minutes of starting, combustible gases (producer gas) in the form of thick yellowish white smoke evolved, which was ignited using the flame of a candle to check for the combustibility.

**RESULTS & DISCUSSION**

Table 1 shows the composition of the producer gas. From the Table, it is evident that the obtained gas composition, particularly the hydrogen content is close to but less than the desired composition. The composition data also show that the produced gas contained a large amount of CO<sub>2</sub>. Besides, excessive tar formation occurred during operation. All of these referred to poor partial oxidation. This was due to poor control of airflow rate and lack of strong suction at gas outlet as well inadequate drying of feedstock. These constraints can be overcome

conveniently by introducing a valve system instead of the sliding door to ensure better control of airflow rate. Lower moisture content of the feedstock is necessary for efficient operation of the gasifier. Thus the feed needs to be adequately dried for several days. Total cost of construction of the gasifier at BUET was approximately 4000 Taka. The cost so far looks reasonable although further treatment such as filtration of the producer gas is needed before the gas can be used as engine fuel.

**Table 1: Composition of the Producer gas**

Gases	Composition (mol%)	
	Typical	Experimental
CH <sub>4</sub>	2-3	1.3
CO <sub>2</sub>	9-11	30
CO	20-22	7.32
N <sub>2</sub>	50-54	43.33
H <sub>2</sub>	12-15	8.08
CH <sub>4</sub>	2-3	1.3

**CONCLUSION**

A downdraft gasifier was successfully constructed and operated using wood as feedstock. Though the composition of the producer gas was not up to the desired level, it is expected that a few minor modifications will provide better result.

**ACKNOWLEDGMENT**

The contents of the following websites were found useful during the course of this work.

- <http://www.wisbiorefine.org/proc/biomassgas.pdf>
- [http://www.decisioneering.com/articles/download/biomass\\_to\\_hydrogen.pdf](http://www.decisioneering.com/articles/download/biomass_to_hydrogen.pdf)
- <http://www.urjagen.com>
- <http://www.gengas.nu/byggbes>
- <http://www.energy.se/goran/hig/ses/01/biomass>

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