PERFORMANCE OF THE PILOT MODEL UPDRAFT GASIFIER

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ABSTRACT

The gas from biomass gasifier contains quantities of particulates, tars, and other constituents that may exceed the specified limits which may hinder their safe usage in applications where tar free clean gas is required such as in automobile engines. To determine performance of pilot model updraft gasifier with use of wood chips, coconut husk, coconut shell and pressed sugar cane biomass solid fuels at used weight of 1.25 Kg. To calculate the mechanical efficiency and thermal efficiency of the gasifier. Two main factors affecting the thermal efficiency of the gasification process are the amounts of methane formed in the gasifier and the kind of coal used. Thermal efficiencies are calculated for the various coal gasification processes having potential for commercialization.

Keywords: Performance characteristics, Pilot model updraft gasifier

Objective: The main objective of the work is to modify the setup so that it is suitable for performing experiments. This objective is met by solving the following.

- To design of pilot model updraft gasifier optimum design condition.
- To use constant weight 1.25 kg of biomasses are wood chips, coconut husk, coconut shell and pressed sugar can to take the time taken calculate the discharge.
- To take the temperature difference in between combustion chamber to fuel feed area on working time.
- To calculate Mechanical efficiency and thermal efficiency and draw the graph.

INTRODUCTION

The basic characteristic of updraft fixed-bed gasification equipment used for biomass gasification is studied in order to gain in depth knowledge of the processes taking place in the reactor. These processes are used to explain the characteristics of gases produced by examining the combustion temperatures attained in the flare. Also explained is the amount of air necessary to gasify wood. The updraft equipment settings for air flow should be within this range in order to produce gas with the reactor. The suitability of the experimental wood chips used in the experiments conducted are also studied (Jefferson, 2006).

Another way of comparing different processes, the results show that higher amounts of methane formed by direct methanation in the gasifier will result in higher thermal efficiency of the process. Efficiency of Lurgi Process decreases considerably when higher ranking coals are used. The available work efficiency can be used not only for comparison but also to pinpoint inefficiencies inherent in certain process steps (K.Sivakumar, 2010).

Figure 1. Gasifier Process

Increased measurement accuracy is required for the air pollutants that cause acid rain such as sulfur dioxide, nitrogen oxides and photochemical oxidants, in order to achieve international consistency and global evaluations of concentration. As fluctuations in the flow rate have a significant effect on measurement accuracy when air is sampled, in particular, measurement accuracy has recently been improved through use of electric flow controllers such as mass flow meters as well as the existing float flow meter. Thus, general points to note when planning and carrying out sampling
are described as follows (Sarah, 2009). A one-dimensional unsteady state mathematical model for the simulation of a small scale fixed-bed updraft gasifier is presented. The model is based on a set of differential equations which couples heat and mass transport in the solid and gas phases with sewage sludge drying and devolatilization, char gasification and combustion of both char and gaseous species. The model was used to simulate the behavior of sewage sludge with 20% moisture in an updraft fixed-bed gasifier (2 m height, 0.165 m inner diameter) of a pilot-scale plant operating at atmospheric pressure. Good agreement was achieved between predictions and experimental measurements for the dynamic axial temperature profiles and the steady state composition of the producer gas (J.J. Hernandez, 2012). Biomass gasification is a process of converting solid biomass fuel into a gaseous combustible gas (called producer gas) through a sequence of thermo-chemical reactions.

In this paper the updraft type biomass gasifier constructed and operated with three biomass fuels- wood chips, sugarcane wastes, and coconut shell and to check whether the required composition of the producer gas can be achieved successfully and when the gasifier operated at the constant air velocity the composition of these fuels were found with the help of gas analyzer. In this work, a typical updraft biomass gasifier successfully constructed. The results of the composition of the produced Producer gas for three different biomass fuels were not up to the desirable level but it is expected that a few modifications with this gasifier provides better results (Jeng-Chvan, 2006). This report is one in a series of emergency technology assessments sponsored by the Federal Emergency Management Agency (FEMA). The purpose of this report is to develop detailed, illustrated instructions for the fabrication, installation, and operation of a biomass gasifier unit (i.e., a 'producer gas' generator, also called a "wood gas generator) that is capable of providing emergency fuel for vehicles, such as tractors and trucks, in the event that normal petroleum sources were severely disrupted for an extended period of time. These instructions have been prepared as a manual for use by any mechanic who is reasonably proficient in metal fabrication or engine repair. This report attempts to preserve the knowledge about wood gasification that was put into practical use during World War II. Detailed, step-by-step fabrication procedures are presented for a simplified version of the World War II, Embowered wood gas generator. This simple, stratified, downdraft gasifier unit can be constructed from materials that would be widely available in the United States in a prolonged petroleum crisis. For example, the body of the unit consists of a galvanized metal garbage can atop a small metal drum; common plumbing fittings throughout; and a large, stainless steel mixing bowl for the grate. The entire compact unit was mounted onto the front of a farm tractor and successfully field tested, using wood chips as the only fuel. Photographic documentation of the actual assembly of the unit as well as its operation is included (Jeng-Chvan, 2006).

**Current Setup:** The setup consists of a pilot model updraft gasifier, partial oxidizer to remove tar and a flare. In the gasifier, wood chips, coconut husk, coconut shell and pressed sugar cane with an average size of less than 2 inches are broken down by the use of heat in an oxygen-deficient environment to produce a combustible gas. This gasifier is auto thermal in that heat for gasification is generated through combustion of part of the feed material on hand use.

Since air is used as a gasification agent, the system in the produces a low calorific value gas and tars. Tars are a complex mixture of organic compounds with molecular weights greater than that of benzene. They are formed during thermal degradation of biomass. The tars can be partially oxidized in a partial oxidator to reduce the tar content in the gas to acceptable levels. After tar partial oxidation, the combustible gases are flared in a flame tube and exhausted to the atmosphere. The flare safely incinerates the gaseous combustible products from the gasifier primarily to carbon dioxide and water vapor that can be discharged into the atmosphere in an environmentally acceptable manner.

The arrows indicate the gas flow direction. The partial oxidizer is not used in the experiments carried out in this work. For most of the applications the efficient and economic removal of tar still presents the main technical barrier to overcome.

However, this is not the focus of this project. The setup in the laboratory was built for experimental purposes but is presently not functioning as well as it should. The aim of the project is to identify the problems with the system and then solve them so that the system is operational. With the system working, tests will then be performed on the system to determine how the gas produced varies by varying gasification air flow and hence equivalence ratio. The essence of these tests is to determine the gasification air flow rate at which the gasifier produces combustible gases in a controlled release manner. The effect of air flow on producer gas is followed by observing the fluctuations in combustion temperatures of the flare. The biomass reactor in the laboratory is a batch operated cylindrical reactor.
made of steel, which is heat resistant. The cylinder has an internal diameter of 170 mm and the thickness of the steel material used in the construction is 8 mm. The height of the reactor is 480 mm and can accommodate a maximum of 1.25 kg of fuel when fully loaded. Feeding is from the top of the reactor through an open cone way the gasifier after loading operations.

![Figure 2. Updraft Gasifier Zones](image1)

![Figure 3. Experimental Setup](image2)

Initial ignition of the gasifier is situated at the bottom of the gasifier. An ash container with a height of 100 mm is located at the bottom of the reactor. Perforated steel plate of 35% porosity holds the wood chips above the ash container and serves to disperse the air for gasification uniformly over the bed. Gasification air enters the gasifier through four inlet holes that terminate into the combustion chamber. The reactor is pressure controlled with a maximum operating pressure of 0.7 bars above atmospheric pressure. For measuring temperature, K-type thermocouples, which are located longitudinally on the reactor walls at various positions, are used. The complete experimental setup of the apparatus along with the air blower is shown in figure 3.

**EXPERIMENTAL PROCESS**

The particles of biomass, for instance wood chips are fed at the top of the reactor and slowly move to the bottom where the residual ash is withdrawn. The combustion and gasification agents normally air is injected through the distributor at the bottom. In their downward movement, the biomass particles undergo the following main processes drying, devolatilization, gasification, and combustion.

During the conversion in a gasifier, there is no sharp delimitation between these regions. For instance, a descending particle may be going through de volatilization in its outer layers while inner 10 layers are drying. A simplified sequence of events occurring in the updraft gasifier is described as follows starting from the top of the fuel bed.

**Drying:** During this event, the temperature of the wood chips is increased and the moisture in the wood is evaporated by heat exchange between the wood and the hot gas stream that is coming from the combustion zone.

**Devolatilization:** The temperature of the dry wood chips is increased further and the volatile products are released from the wood chips thereby leaving char. For all biomass, volatiles represent a significant portion of the fuel and in gasifiers, devolatilization provides part of the produced gases. The release of volatiles is driven by increase of temperature. As the wood chips slowly descend, the hot gases produced in the gasification and combustion zones exchange energy with the colder solid. Three main fractions are produced during pyrolysis of biomass:

- Light gases, among them H₂, CO, CO₂, H₂O, and CH₄.
- Tar, composed of relatively heavy organic and inorganic molecules that escape the solid matrix as gases and liquid in the form of vapor.
- Char, the remaining solid residue.

This can be represented as, Biomass → Char + Volatiles (gases + tar)

**Gasification (reduction):** After drying and devolatilization, the char enters the gasification zone where carbon reacts with steam, carbon dioxide, and hydrogen. Endothermic reactions in this section produce carbon monoxide and hydrogen. The slightly exothermic reaction of hydrogen with carbon produces methane.
The carbon monoxide produced also reacts with water to produce hydrogen and carbon dioxide in the water gas shift reaction. Differentiation between the gasification zone and combustion zone is based on the presence or absence of oxygen. The reactions that take place in this region of the gasifier can be represented by:

\[ C + CO_2 \rightarrow 2CO \quad \Delta H = 164.9 \text{ MJ/kmol} \]
\[ C + H_2O \rightarrow H_2 + CO \quad \Delta H = 131 \text{ MJ/kmol} \]
\[ C + 2H_2 \leftrightarrow CH_4 \quad \Delta H = -75 \text{ MJ/kmol} \]
\[ CO + H_2O \leftrightarrow CO_2 + H_2 \quad \Delta H = -42 \text{ MJ/kmol} \]

**Combustion:** The remaining char is burned, using oxygen from air in the feed gas and leaving an ash residue according to,
\[ 2C + O_2 \rightarrow 2CO \quad \Delta H = -221 \text{ MJ/kmol} \]
\[ 2CO + O_2 \rightarrow 2CO_2 \quad \Delta H = -283.0 \text{ MJ/kmol} \]

From the point of view of energy generation and consumption, if taken as irreversible, the combination of exothermic reactions 2.6 and 2.7 involves an energy input of 394 MJ/kmol of carbon (calculated at 298 K) and is mainly responsible for the energy requirements of the process.

This energy is used to promote and sustain the gasification and pyrolysis reactions, which are mostly endothermic. In typical updraft gasifiers the following processes take place at temperatures indicated in Table 1.

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**Factors affecting gasification:** Studies have shown that there are several factors influencing the gasification of wood. These include the following:

**Energy content of Fuel:** Fuel with high energy content provides easier combustion to sustain the endothermic gasification reactions because they can burn at higher temperatures. Beech wood chips have an energy content of approximately 20 MJ/kg. This is typical for most biomass sources and has been proved to be easy to gasify.

Fuel moisture content: Since moisture is in effect water, a non-burnable component in the biomass, it is important that the water content be kept to a minimum. All water in the feed stock must be vaporized in the drying phase before combustion otherwise there will be difficulty in sustaining combustion because the heat released will be used to evaporate moisture. Wood with low moisture content can therefore be more readily gasified than that with high moisture. Wood with high moisture content should be dried first before it can be used as fuel for the gasifier. The beech wood chips used in the experiments have been factory dried to a moisture content of 10% prior to packaging. This makes it suitable as a fuel for the gasifier. Updraft gasifier are also capable of operating with fuels that have moisture contents of up to 50%.

**Size Distribution of the Fuel:** Fuel should be of a form that will not lead to bridging within the reactor. Bridging occurs when unscreened fuels do not flow freely axially downwards in the gasifier. Therefore particle size is an important parameter in biomass gasification because it determines the bed porosity and thus the fluid-dynamic characteristics of the bed. On the other hand, fine grained fuels lead to substantial pressure drops in fixed bed reactors. The experimental 13 wood chips are approximately 10 x 10 x 2 mm and regular in shape. This size is not fine grained when compared to the micron scale and thus no substantial pressure drops occur in the reactor. Temperature of the Reactor: There is a need to properly insulate the reactor so that heat losses are reduced. If heat losses are higher than the heat requirement of the endothermic reactions, the gasification reactions will not occur. The reactor in the laboratory has been insulated with 50 mm of alkaline earth silicate to keep heat losses minimal.

**Primary air necessary for combustion of product gas:** The product gas leaves the gasifier hot, dirty (with tar) and moist and does not undergo cleaning, cooling and drying before combustion in the flare. The primary air for stoichiometric combustion is estimated based on the stoichiometric requirements of the individual components. The stoichiometric equations for combustion of these gases are given by:

\[ H_2 + O_2 + 3.76N_2 \rightarrow 2H_2O + 3.76N_2 \quad (3.2) \]
\[ 2CO + O_2 + 3.76N_2 \rightarrow 2CO_2 + 3.76N_2 \quad (3.3) \]
\[ CH_4 + 2(O_2 + 3.76N_2) \rightarrow CO_2 + 2 H_2O + 7.52N_2 \quad (3.4) \]

The air fuel ratios for complete combustion of these gases are determined and shown in the following table.
Component | Air-fuel Ratio
---|---
H₂ | 4.76: 1
CO | 2.38:1
CH₄ | 9.52:1

The product gas flow rate can be used to determine the amount of primary air necessary for combustion from the above ratios.

RESULTS AND DISCUSSIONS

Fig. 4. shows the variation of discharge with respect to time for the fuel wood chip.

Fig. 5. shows the variation of discharge with respect to time for the fuel coconut husk.

Fig. 6. Shows the variation of discharge with respect to time for the fuel pressed sugarcane.

Fig. 7. shows the variation of discharge with respect to time for the fuel coconut shell.

Fig. 8. shows the variation of discharge with respect to efficiencies for the fuel wood chips.

Fig. 9. shows the variation of discharge with respect to efficiencies for the fuel coconut husk.
Fig. 10. Shows the variation of discharge with respect to efficiencies for the fuel coconut shell.

Fig. 11. shows the variation of discharge with respect to efficiencies for the fuel pressed sugarcane.

CONCLUSION

- Major factors that affect efficiency of gasifier performance are dry flue gas, moisture in fuel, latent heat, unburned fuel, radiation depending on the fuel properties.
- The factors that mainly affect the gasifier performance can be rectified to improve the efficiency.

REFERENCE


