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PERFORMANCE OF A PORTABLE DOWNDRAFT GASIFIER

Jacob Joseph Powell
Froilan Aquino
Sergio Capareda
Department of Biological and Agricultural Engineering
College Station, TX

Abstract

Gasification uses heat and an oxidant, such as O_2 or H_2O vapor, to break down solid carbohydrate materials into basic building block chemicals (CO, H_2, CO_2, H_2O, CH_4) (Frontline Bioenergy, 2006). Many feedstocks can be used during gasification, including coal and agricultural byproducts, such as, manure and cotton gin trash. Gasifiers produce combustible gases that can be obtained for use as SynGas or producer gas, or can be used to generate heat energy or electricity. There are several types of gasifier concepts available, including fluid-bed, entrained flow, and downdraft gasifiers. The purpose of this article is to describe a plan to develop a portable downdraft gasifier suitable for research and demonstration using biomass, specifically cotton gin trash, as a fuel.

Introduction

Gasification is the production of combustible gases from solid, organic material by the application of heat with limited air (Mayer, 1988). Gasification uses heat and an oxidant to break down solid carbohydrate materials into basic building block chemicals, such as CO, H_2, CO_2, H_2O, and CH_4 (Frontline Bioenergy, 2006). The formula below represents the process of gasification:

$$Fuel + Heat + Air^{*} \rightarrow Combustible\ Gas + H_2O + Carbon / Ash + Liquids$$

Where,

Fuel consists of solid carbohydrate materials;
Air is at a level below the stoichiometric ratio of air needed for combustion; and
Liquids produced include methanol, acetic acid, acetone, and tar (Capareda, 2006).

When air is introduced into the system is at stoichiometric ratio, combustion occurs; limiting, but not completely eliminating, air that enters the system allows gasification to occur. Gasification is more preferable than combustion of solid biomass because of slagging and fouling that can occur during combustion. Combustion systems are also sensitive to fuels with high ash content, such as cotton gin trash (Capareda, 2006). According to Priyadarsan et al. (2004), gas produced from gasification is more usable than solid biomass fuel and can be used to generate process heat and power. These gases can be utilized in the production of electricity, burned directly for heat, or captured and used to fuel engines.

Gasifiers can be classified into several categories, including fluidized-bed, entrained-flow, and moving-bed types. A broad range of operating conditions can be obtained in a fluidized-bed gasifier, and the fluidized state of the inert particles in the bed result in a near-isothermal zone and the ability to accurately control reaction temperatures (LePori and Soltes, 1985). Fluidized-bed gasifiers are able to handle a wide range of biomass with a high throughput (Capareda, 2006). Entrained-flow gasifiers are designed for high throughput coal applications. Pulverized coal and an oxidizing gas flow concurrently, into a turbulent, high pressure, high temperature environment (CCSD, 2002).

Moving-bed gasifiers allow free, uniform passage of air through the fuel bed. Fuels used in moving-bed gasifiers should be relatively uniform in particle size in order to prevent the formation of channels in the fuel bed (LePori and Soltes, 1985). Updraft and downdraft gasifiers are two types of moving-bed gasifiers. The type of moving-bed gasifier is designated based on the direction of air flow through the gasification bed. Updraft gasifiers are the simplest air gasifier, with the sensible heat of the gas used to dry and pre-heat biomass. Air is fed from the bottom of the reactor, and uncracked gas (the gas contains tar) is collected from the top of the reactor (Capareda, 2006). Fig. 1 shows a schematic of an updraft gasifier.

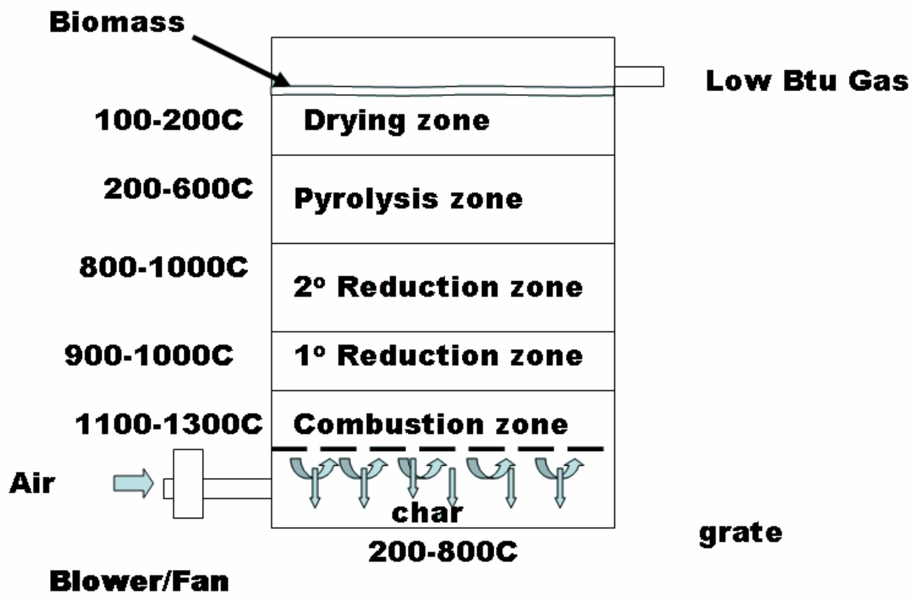

Figure 1. Schematic of an updraft gasifier (Capareda, 2006).

With a downdraft gasifier, air is introduced into a downward-flowing bed of fuel. Gas is collected from the bottom of the gasifier, and tarry oils are cracked and reduced to non-condensable gaseous products, unlike the updraft gasifier (Capareda, 2006). Downdraft gasifiers produce an enhanced quality gas, with an energy content of about 200 Btu/ft^3. This energy content is much higher than the low quality gas (110 Btu/ft^3) produced by fluidized-bed gasification. This high energy content allows the gas produced from a downdraft gasifier to be used as fuel in an internal combustion engine (S. Capareda, personal communication, 11 January 2007). The schematic below shows the process of downdraft gasification.

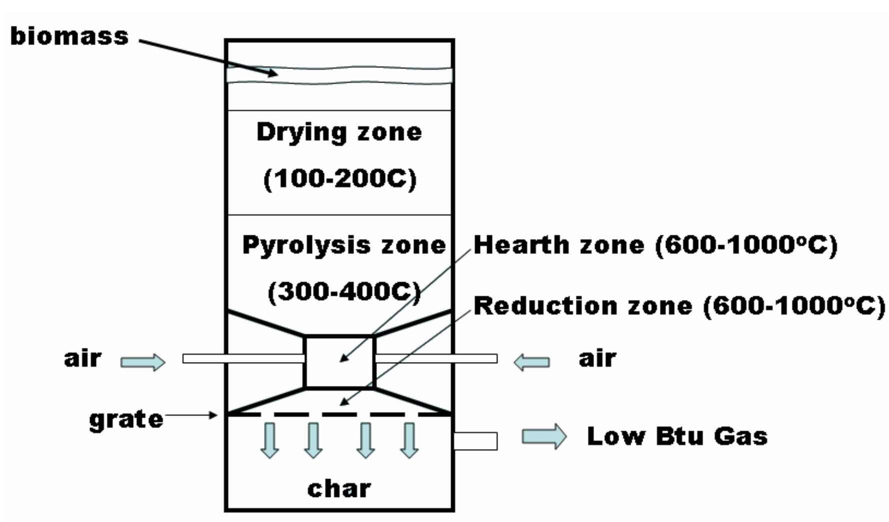

Figure 2. Schematic of a downdraft gasifier (Capareda, 2006).

In the process of downdraft gasification, fuel is brought into the system from the top of the unit. Air is sent into the system and pulled downward. Partial combustion at the bottom of the unit is used to initiate the process. Once gasification begins to occur, the combustion is ceased, and gasification continues. Char that falls through the grate is removed, either mechanically or manually, from the system.

Moving-bed gasifiers can handle most types of solid biomass, including cotton gin trash (CGT). Cotton gin trash is a byproduct of the cotton ginning process, and is composed of sticks, burs, leaves, and other foreign materials. According to Baker et al. (1994), the ginning of one bale of stripper cotton produces 700 pounds of trash, while the ginning of one bale of picker cotton produces about 100 pounds of trash. The energy content of CGT is 16.3 MJ/kg, or about 7000 Btu/lb (Oursbourn et al., 1978). Utilization of agricultural byproducts, such as CGT, is beneficial for the environment, and can be profitable for the agricultural industry. Cotton gin trash is a plentiful byproduct that can be utilized for energy production.

The objective of this research is to design and build a portable downdraft gasifier suitable for using cotton gin trash as a fuel. This gasifier will be used for gasification research, for demonstration purpose, and as a tool for future research.

Methods

The Bio-Energy Testing and Analysis (BETA) Laboratory at Texas A&M University (Department of Biological and Agricultural Engineering), currently has several types of biomass-to-energy conversion systems, including an updraft gasifier, a fluidized-bed gasifier, and a pyrolyzer. These systems have been and are still being used for biomass conversion research. The BETA Lab does not, however, have a downdraft gasification system. There are currently plans to build a portable downdraft gasification system. The figure below shows the basic design of the downdraft gasifier.

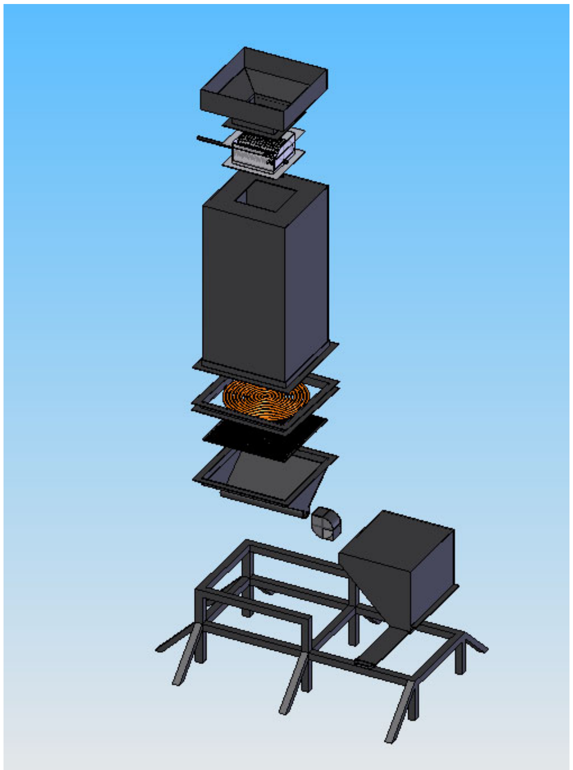

Figure 3. Downdraft gasifier (Capareda, 2006).

Upon completion, the gasifier will stand about six feet tall, with a base approximately three feet wide and six feet long. The gasifier will be mounted on a 16 foot bumper-pull trailer. The portable downdraft gasifier will be used for gasification testing, for demonstration, and as a tool for further research.

Gasification Tests

There are various types of tests that can be run using the gasifier. First, the effectiveness and efficiency of this particular gasifier can be tested. Factors that may be varied for tests include fuel feeding rate and air input rate. The efficiency of the system is generally based on energy balance, or how much energy is produced versus how much potential energy is put into the system.

Another type of testing deals with feedstock effectiveness. These tests include comparing the gas production from feedstocks that are different in type, packaging, or mixture. An example of comparing types would be to compare the gas produced from gasifying CGT versus that produced from gasifying wood chips. Packaging differences to compare could be pelletized CGT versus unprepared CGT. Comparisons of feedstock mixtures could also be made, such as pelletized CGT mixed with manure versus pelletized CGT mixed with wood chips.

The final type of testing deals with analyzing gases that are produced from the gasifier. This analysis includes, but is not limited to, measuring the total volume of gas produced. The gas produced can be analyzed to identify the constituents of the gas produced. The equipment to be used for constituent identification is a gas chromatograph, which can be seen in fig. 4 below.

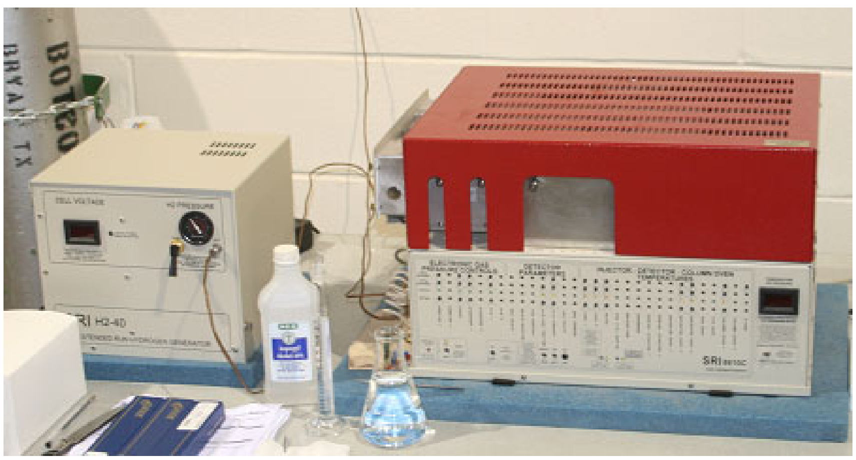

Figure 4. Gas chromatograph.

Demonstration

Since the gasification system will be mobile, it can easily be used as a demonstration tool. The gasifier can be pulled to cotton gins or cooperatives in order to demonstrate the gasification process to the public and to industry representatives. Cotton gin trash will be converted to an effective, storable fuel on-site. These demonstrations will aid in showing producers and ginners that agricultural byproducts, specifically CGT, can be utilized to produce electricity and heat that is available for use by the producers and ginners. Utilizing these byproducts can help those in the agricultural industry to become more self-sufficient, and, therefore, more profitable.

Fuel Production for Other Research

As mentioned previously, the gas produced from a downdraft gasifier has relatively high energy content. This allows the gas to be used as a fuel for internal combustion engines. This will be the most common application of the portable downdraft gasifier. Many irrigation engines are currently fueled by natural gas; the gas produced using a downdraft gasifier can be a supplement to natural gas. The BETA Lab has a system in place to run engine power tests using a dynamometer test system. Engines that are fueled by producer gas can be tested with this system. Power tests include the development of engine performance curves for a particular engine and a particular fuel.

Brake specific fuel consumption, which is a good indicator of fuel efficiency, can also be determined. These abilities allow for further comparison of gas produced from gasifying CGT, as well as other feedstocks.

Another capability of the BETA Lab is emissions analysis. Exhaust emissions from engines fueled with producer gas can be analyzed for pollutant concentrations. The primary elements of interest that are found in engine exhaust include NO_x, SO_2, CO, CO_2, and total hydrocarbons (THC). Other elements of interest include volatile organic compounds (VOCs) and polycyclic aromatic hydrocarbons (PAHs), which can be measured and identified with a gas chromatograph. Maintaining awareness of emissions is becoming ever more important thanks to increasingly strict environmental regulations.

Summary

The Bio-Energy Testing and Analysis Laboratory at Texas A&M University has plans to develop a portable downdraft gasification system. This system will enable the BETA Lab to perform tests on the gasification of cotton gin trash and other feedstocks using a downdraft style gasifier. The system will be used to demonstrate to the agriculture industry that gasification can be beneficial to the environment as well as practical and profitable for the producer. The system will also be used to produce a storable gaseous fuel that can be used in other research areas, such as comparing the performance and emissions of an engine using producer gas from two different feedstocks. The ability to perform these tests and demonstrations will aid in the promotion of downdraft gasification as a means of biomass conversion to energy.

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