PRE-COMMERCIALIZATION STUDIES OF THE AGRILIFE RESEARCH FLUIDIZED BED GASIFICATION SYSTEMS USING COTTON GIN TRASH

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Abstract

Texas A&M AgriLife Research spent a considerable amount of time and research dollars to develop a new mobile fluidized bed gasification (FBG) system. The unit generates combustible synthesis gas that is combusted in an internal combustion engine to generate electrical power. AgriLife tested the unit for numerous biomass wastes (high biomass sorghum, miscanthus, energy cane, switchgrass, etc.) and several companies have licensed the technology. One company (SDL Citadel Global, LLC, Dallas, TX) has built a 1-MW commercial-sized system to convert municipal solid wastes (MSW) into electrical power. Another company (Arriba Energy, Inc., LLC, Houston, TX) plans to convert municipal sewage sludge (also called biosolids) into electrical power and high quality biochar for soil amendment.

This paper discusses the progress behind the completed fabrication and demonstration of a new 4 ton per day, 200-400 kW pilot fluidized bed gasification facility assembled on top of a trailer, ready for field demonstration purposes. The unit was tested using cotton gin trash (CGT).

Introduction

The accumulation of cotton gin trash in all cotton gins in the US is still an environmental disposal issue. There is yet no widespread use of cotton gin trash. Previous studies made use of CGT for animal feed, a composting material, briquettes, a mulching material and simple incorporation in agricultural land. However, most of these applications will not significantly reduce the amount of CGT that accumulates in cotton gins every season. Thermal conversion is one of the options that will significantly reduce the volume of this material and convert this into valuable products. The United States banned the incineration of CGT wastes many years ago. Gasification or thermal conversion using incomplete amounts of oxidant will convert high-energy content biomass into a combustible gas called synthesis gas. Internal combustion engine may use the synthesis after proper tar removal to generate electrical power.

Lummus Corporation (Savannah, GA), the world's leading full-line supplier of machinery and replacement parts for the cotton ginning industry had interest in developing this technology for utilization in many cotton gins in the US and the world. For several years, they have provided funding to Texas A&M AgriLife Researcher personnel to implement pre-commercialization studies for potential adoption in many cotton gins. Cotton gins primarily need electrical power to run all the ginning machines and heat for drying seed cotton. Currently, gins rely on the grid for the electrical power and natural gas for drying. Simple calculations showed that a cotton gin would generate enough cotton gin trash with the energy that may be enough to generate the required power during the ginning season while using excess heat energy to dry the wet seed cotton. Hence, Lummus Corporation implemented pre-commercialization studies to demonstrate this feasibility in an actual cotton gin in Texas in the near future.

Materials and Methods

The TAMU Mobile Gasification System

The photo below (Figure 1) shows the mobile gasification system being developed at Texas A&M University. The development of this technology has progressed significantly since its initial work in the 1980's. The unit is fully mobile and there is no need for external power supply during start up. Table 1 shows typical performance of the system using cotton gin trash, manure and wood shavings.

Figure 1. The TAMU Mobile Gasification System.

Pre-Commercialization Studies

The Texas A&M AgriLife Research's mobile gasification system was used to evaluate the conversion of cotton gin trash into heat and electrical power. The studies involved redesigning the following major component parts to be suitable for cotton gin trash.

a. Feeding mechanism

b. Gas clean-up system

c. Bio-char handling system

d. The power generation system

Raw cotton gin trash is quite difficult to introduce in the reactor due to the presence of dirt and rocks if the material is not properly stored in a cotton gin. Hence, there are proper handling issues that a cotton gin operators must address if they plan to convert their CGT into heat and electrical power.

Other related Activities and Deliverables

The other deliverables for the project included the following:

a. Updated drawings of a mobile 250 kW gasifier design

b. Full-scale demonstration of the system using cotton gin trash

c. Design of an indirectly heated workable drying system utilizing recoverable heat from the system

d. Development of new pre-feasibility studies for heat and power and with or without the sale of biochar co-product

Results and Discussion

Cotton gin managers in the US should start planning for the eventual use of cotton gin trash and eliminate the problem of disposal and storage of CGT wastes. This material is a valuable energy resource with a high-energy content. This section illustrates the simple energy and mass balances calculations in a typical small cotton gin and how excess energy is available in a cotton gin each year. These valuable materials are just left to rot in the yard losing opportunity to offset the heat and power needs of a cotton gin.

Electrical Power Needs of a 20 BPH Facility

A recent survey of active cotton gins in Texas shows that an average cotton gin would use electrical power at a rate of about 50 kWh/bale. Hence, a 20 bale per hour (BPH) gin will easily consume one (1) MW of electrical power as shown in the calculation below.

$$Power(MW) = \frac{50kWh}{bale} \times \frac{20bales}{hr} \times \frac{MW}{1000kW} = 1MW$$

Depending on the location of the cotton gin, a 20 BPH cotton gin facility operating 24-hrs per day and 30 days per month would spend about $72,000 in electricity cost if paying at an average rate of $0.10/kWh. Below shows the calculation.

$$Electricity\ Bill = \frac{1MW \times 24hrs}{day} \times \frac{1{,}000kW}{MW} \times \frac{\$0.10}{kWh} \times \frac{30days}{month} = \$72{,}000/month$$

The cotton gin manager could avoid paying for electrical utilities if they make use of CGT for power production. At 1,000 hrs operation per season, the total savings could be over $100,000.

Cotton Gin Trash Heating Value and Trash and Power Production

The heating value of cotton gin trash is quite high. Typical energy content is about 7,000 Btu/lb [16.25 MJ/kg]. A 20 bale per hour cotton gin facility using stripped cotton with an average trash content of 500 lbs per bale would generate an average of 8,000 lbs per hour of trash as shown below.

$$Trash\left(\frac{lbs}{hr}\right) = \frac{20\ bales}{hr} \times \frac{0.8}{} \times \frac{500\ lb - trash}{bale} = 8{,}000\ \frac{lbs}{hr}$$

At an energy content of 7,000 Btu/lb about 56 Million Btu/hr of energy is available in the cotton gin trash. Hence, if one were to convert this into electrical power at a conversion efficiency of only 10%, one would produce about 1.6 MW of electrical power as shown in the calculation below.

$$Power\ (MW) = \frac{8{,}000lbs}{hr} \times \frac{7000Btu}{lb} \times \frac{1055J}{Btu} \times \frac{W - s}{J} \times \frac{hr}{3600s} \times \frac{MW}{1 \times 10^6 W} \times 0.10 = 1.6MW$$

Clearly, there is more than enough energy in the CGT to satisfy 100% of the electrical power in a cotton gin even if the conversion efficiency is as low 10%. Gasification efficiency ranges from 15% to 20%. Note that if one uses 10% of the energy value of the CGT for power, the remaining 90% of the energy is wasted heat. One should be able to recover this energy and utilize this for drying of seed cotton. This was another component of the deliverables for this project and reported on in a separate technical session.

Potential Market for Biochar

Additionally, there is a potential market for another major co-product of gasification, the biochar. On the average, one would generate 20% of the CGT input as biochar co-product. Hence, for a 20 bale per hour rated cotton facility and ginning at a nominal rate of 16 bales per hour with a trash generation of 500 lbs per bale will generate 0.8 tons per hour biochar. On an average day, this is close to 20 tons of biochar per day. If the cotton gin operates 1000 hours per season, the gin would produce about 800 tons of biochar. If valued at a nominal cost of $100/ton, the gin could have additional revenue of $80,000 greater than their monthly utilities cost.

$$Hourly\ Biochar\ Production\ \left(\frac{tons}{hr}\right) = \frac{16bales}{hr} \times \frac{500lbs}{bale} \times \frac{ton}{2{,}000lbs} \times 0.2 = 0.8\frac{tons}{hr}$$

$$Daily\ Biochar\ Production\left(\frac{tons}{day}\right) = 0.8\frac{tons}{day} \times 24\frac{1day}{24hrs} = 19.2\frac{tons}{day}$$

$$Seasonal\ Biochar\ Production\left(\frac{tons}{season}\right) = 0.8\frac{tons}{hr} \times \frac{1{,}000hrs}{season} = 800\frac{tons}{season}$$

$$Biochar\ Revenue\left(\frac{\$}{season}\right) = 800\frac{tons}{season} \times \frac{\$100}{ton} = \$80{,}000/season$$

Clearly, there is potential if the cotton gin is able to find a market for the biochar. Biochar is now a marketable commodity. The International Biochar Initiatives (IBI) has developed several standards for biochar. One could formulate this material according to the standards outlined by IBI and get a higher value to as much as $300/ton.

Performance of the TAMU Gasification Systems

Table 1 (metric Units and Table 2 English) shows a classic data set when CGT, animal manure and wood shavings are gasified. Note that CGT syngas has a heating value of about 114 Btu/f^3, or 1/10th of natural gas. Numerous natural gas generator sets are now able to combust low quality natural gas and generate electrical power. The goal of this project is to demonstrate that possibility. The heat energy cost of a gin facility is around $0.4 MCF/bale. At $5/MCF, each gin facility would spend about $2/bale for this type of energy. This energy needs may also come from the syngas for a potential $32,000 savings per season.

Table 1. Comparison of average gas composition and gasifier operating conditions (Metric Units).

Gasifier	Cotton Gin Trash	Animal Manure	Wood Shavings
Bed Temperature (ºC)	762	762	756
Air flow (m^3/min)	0.40	0.42	0.39
Fuel Feed Rate (g/min)	306	339	300
Fuel-to-air ratio (kg/kg)	0.625	0.651	0.625
Carbon Efficiency (%)	65.74	51.35	56.10
Cold Gas Efficiency (%)	45.61	28.74	46.29
Carbon Saturation Ratio	0.376	0.401	0.357
H/C Ratio	1.217	1.011	1.056
Carbon in Ash (%)	20.3	6.1	12.2
Low Calorific Value (LCV) Gas	Dry Mole Percent		
Hydrogen (H_2)	9.765	3.999	4.377
Methane (CH_4)	2.492	1.643	3.549
Ethylene (C_2H_4)	0.791	0.239	1.116
Ethane (C_2H_6)	0.200	0.031	0.246
Propane (C_3H_8)	0.180	0.292	0.279
Propylene (C_3H_6)	0.016	0.007	0.012
Carbon Monoxide (CO)	11.203	5.744	12.098
Carbon Dioxide (CO_2)	12.548	8.494	9.797
Nitrogen (N_2)	56.629	71.786	60.348
Oxygen (O_2)	6.536	7.771	8.188
Production Rate (m^3/min)	0.56	0.47	0.51
Heating Value (MJ/m^3)	4.25	2.22	4.41

Table 2. Comparison of average gas composition and gasifier operating conditions (English Units).

Gasifier			
Bed Temperature (°F)	1404	1404	1393
Air flow (ft^3/min)	14	15	14
Fuel Feed Rate (lbs/min)	0.6732	0.7458	0.6600
Fuel-to-air ratio (lb/lb)	0.625	0.651	0.625
Carbon Efficiency (%)	65.74	51.35	56.10
Cold Gas Efficiency (%)	45.61	28.74	46.29
Carbon Saturation Ratio	0.376	0.401	0.357
H/C Ratio	1.217	1.011	1.056
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Carbon Dioxide (CO_2)	12.548	8.494	9.797
Nitrogen (N_2)	56.629	71.786	60.348
Oxygen (O_2)	6.536	7.771	8.188
Production Rate (ft^3/min)	20	17	18
Heating Value (Btu/ft^3)	114	60	118

Summary

Cotton gin operators must start planning for the eventual use of cotton gin trash so that it will not become a nuisance in their yard. We have presented one option in this paper for heat and electrical production. We have shown that there is enough cotton gin trash produced in most cotton gins in the US to offset their heat and power requirements while generating extra revenue from biochar, a by-product of the gasification system.

We have shown that for a very small 20 BHP gin, the savings could amount to approximately $32,000 in natural gas for drying and $100,000 for electrical power per season. Additional revenue of up to $80,000 could come from the sale of biochar by-product. If the gin invested these savings on a new gasification system, the cotton gin may be sustainable in their electrical power and natural gas needs in the future while generating additional revenue from the biochar.

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