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RATIONALE FOR INTEGRATING A HEAT AND POWER GENERATING UNIT IN A COTTON GIN FUELED BY COTTON GIN TRASH

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Abstract

Pelleted cotton gin trash, processed at the USDA-ARS Cotton Production and Processing Research Unit (Gin Lab) in Lubbock, Texas has been successfully gasified in preliminary testing using an advanced BioMax® downdraft gasification unit developed by Community Power Corporation, Littleton, Colorado. The BioMax® is an automated, skid mounted, semi-continuously fed, downdraft gasifier system which has been integrated with an engine/generator set that produces grid quality electricity from producer gas while recovering waste heat for drying or space heating.

The goal of the proposed study is to evaluate the feasibility of integrating a heat and power generation system with a cotton gin to save on cost of fuel for drying modules and electricity during the ginning season. Preliminary estimates of the cotton-gin trash available and the energy consumption during the ginning season suggest that excess dense cotton-gin-trash pellets could be stored for off-season use or shipped off site to other users needing heat and power. The whole process is expected to clean up all the remaining gin trash generated during the ginning season, thereby also cutting on transport and disposal costs for the trash. Using the results of the study, an energy and mass balance analysis will be made for different-sized gins to come up with different heat and power production scenarios including the preliminary economics and the number of modular units needed per facility.

Introduction

Electricity and fuel energy comprised about 15% of the cost of ginning cotton in modern gins (Anthony and Mayfield, 1994). The electricity consumption per bale has remained relatively constant over the years. The gin operating cost survey (TCGA, 2005) for the 2004/2005 season showed that each cotton gin uses an average of about 50 kWh per bale and pays an average of $0.07/kWh for electricity. On the average, the heat energy usage in the form of natural gas was about 0.25 Mcf/bale at an average cost of $7/Mcf. In some areas in the country, the natural gas cost is more than this average value. The amount of energy in the cotton-gin trash generated per bale for a picker or stripper gin is more than the combined electricity and heat energy needed during cotton ginning. Several studies have been conducted in the past to prove such claim. To date no commercial gasifier has been installed and in operation in any of the gins in the US to take advantage of the energy from the waste stream. Cotton ginners continue to pay for electricity and heat energy cost, both of which are on the rise with the aftermath of the hurricane season, as well as, pay for disposal cost of the cotton-gin trash. The main goal of this work is to demonstrate that it is technically feasible and economically sound to convert the waste stream into electricity and heat thereby minimizing the cost of purchasing grid electricity and natural gas for drying purposes.

Objectives

a. To evaluate the performance of a pelleted cotton gin trash in an advanced downdraft gasification technology, and
b. To perform feasibility analysis on the conversion of pelleted gin trash to power and heat for a cotton gin.

Methodology

Gin trash waste was pelleted by the USDA-ARS Processing Laboratory in Lubbock, Texas. The pellet mill used to pellet the material is shown in Figure 1. The pelleting process will ensure that materials will flow freely through the gasifier and the material will have more energy per unit volume. Figure 2 shows the raw cotton gin trash (right) and the pelleted fuel (left).

The general pelleting process included (a) loading the raw material on a bulk feed bin, (b) mixing of a binder which is usually 10% starch, (c) extruding the material (although not a necessary step) if needed, (d) drying in hot air at 135^{o}C, (e) adjusting the moisture content to between 15-20%, (f) pelleting using the CPM 7000 unit, (g) cooling of the material and (h) bagging into an 18 kg bag. These outlined steps may not be followed in many instances. The basic process is simply to mix the binder with the cotton gin trash and perform pelleting of the resulting mixture.

The pelleted material was sent to the Community Power Corporation (CPC) research facility in Littleton, Colorado for gasification tests. The study made use of a Biomax® 15 system to evaluate performance. The BioMax® is an automated, skid mounted, semi-continuously fed, downdraft gasifier system which has been integrated with an engine/generator set that produces grid-quality electricity from producer gas, while recovering waste heat for drying or space heating.

The unit is shown in Figure 3. The advanced gasification unit comprised of an automatic drier/feeder module, a gas production module and a power generation module. The pellet feed rate on the BioMax® 15 was about 18 kg/hr. Gas analysis was made and the power generation performance was evaluated and compared with natural gas. Gases produced were fed to the BioMax® 15's GM Vortec engine that is coupled with a generator to produce grid-quality electricity.

Results and Discussions

Loose cotton gin trash needs to be densified in order to achieve uniform flow in the gasifier. In addition, this makes the input material have a much higher density. Table 1 shows the characteristics of the pelleted fuel. The table shows the ultimate analysis of the pelleted material that includes percentage of carbon (C), hydrogen (H), oxygen (O), nitrogen (N), and sulfur (S). The moisture content, volatile combustible matter, fixed carbon, bulk density, calorific value, ash, sodium and the percentage of fines were also reported. The approximate maximum length of the material is about 3.81 cm.

The heating value of the pelleted fuel was reported at 18.29 MJ/kg (or 7880 Btu/lb). Compared with bituminous coal having a heating value of about 27.4 MJ/kg (11,800 Btu/lb), the pelleted fuel has a heating value of close to 70% of that of coal. By weight, one would need an extra 50% gin trash pellet to equal the heating value of bituminous coal.

Figure 1. The California Pellet Mill Model 7000 (CPM 7000) used to pellet cotton gin trash.

Figure 2. Shown is the raw gin trash (left) and the pelleted form used in this study.

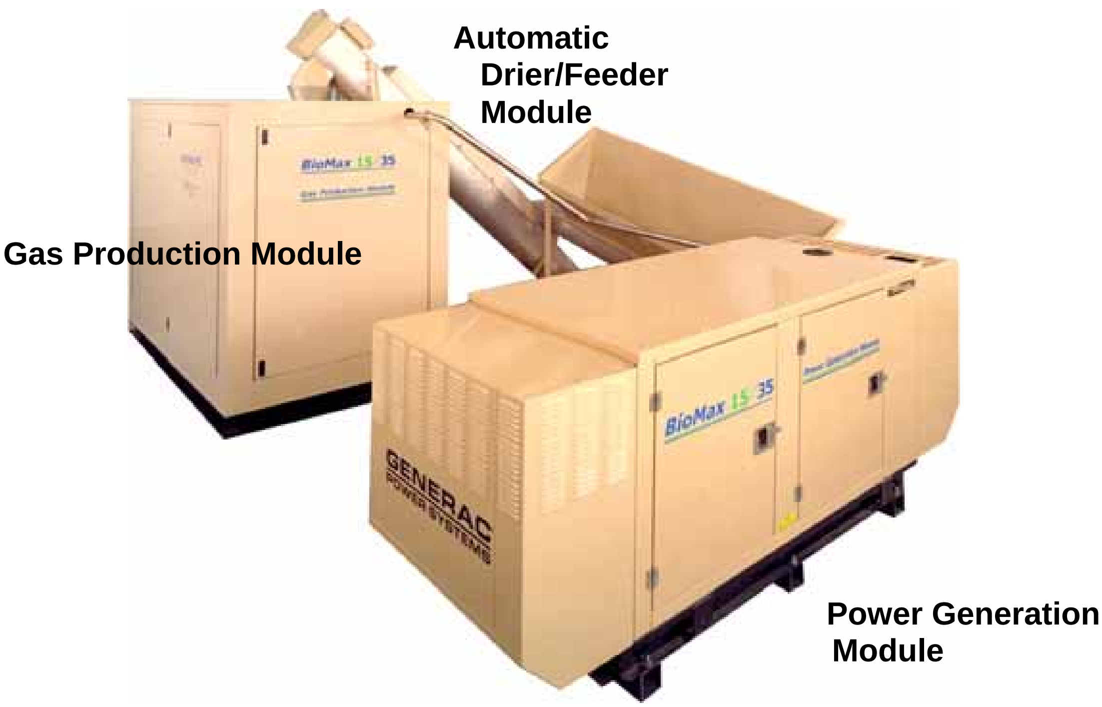

Figure 3. The Community Power Corporation (CPC) BioMax® 15 System used in this study.

Table 1. Cotton gin waste fuel pellet analysis.

Treatment	Bulk Density (kg/m3)	Calorific Value (MJ/kg)	Ash (%)	Total Sulfur (%)	Water Soluble Sodium (ppm)	Maximum Pellet Length (cm)	Fines (%)
Lbk-2	676.8	18.29	5.22	0.165	116	3.81	1

Treatment	Gas Composition and Test method						
	Carbon (D5373) (%)	Hydrogen (D5373) (%)	D5373 Nitrogen (%)	Difference Oxygen (%)	D5142 Moisture (%)	D5142 Volatile (%)	D5142 FC (%)
Lbk-2	48.16	5.51	1.22	39.97	8.25	47	48.05

Producer Gas Analysis

Shown in Figure 4 is the percent composition of gases (dry basis) generated during the preliminary runs. The gas analysis showed that the low heating value (LHV) of gas composition showed an average of 7.93 $\pm$ 0.93 MJ/Nm^3 (213 $\pm$ 27 Btu/ft^3). The graph of gas analyses may seem to show the composition of the producer gas to vary considerably (LHV standard deviation = 9% after steady-state). This could be interpreted as making the control of the combustion difficult. However, on the contrary, the calculated amount of air required for stoichiometric combustion is relatively constant for a given heat load (volume of air per MJ std. dev. = 1.5% after steady state). This is shown in Figure 5. This figure shows that the variations in the composition of the producer gas do not affect the required amount of combustion air very much. The percentage of standard deviations (coefficients of variation) of the stoichiometric combustion air is about a tenth of those for the composition. The gas engine performed well with the producer gas derived from pelleted cotton gin waste.

Table 2 shows the average composition through all the sampling episodes. The percentage of important gases such as hydrogen, carbon monoxide and methane is about 20%, 23% and 8% respectively.

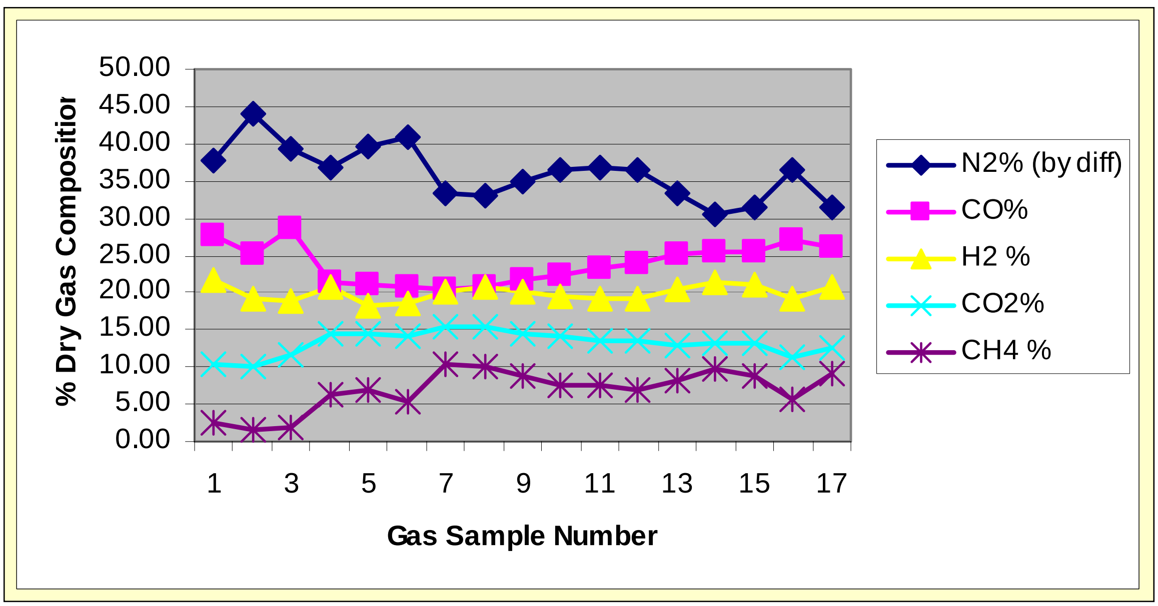

Figure 4. Gas composition data generated from gasification of pelleted gin waste.

Table 2. Average composition of combustible gas from gasification of pelleted gin waste.

	Gas Composition (%)				
Excluding air	CO	CO_2	CH_4	H_2	N_2 (by diff)
Average	23.24	13.75	7.94	19.95	35.11
Std. Dev.	2.63	1.58	2.76	1.06	3.60

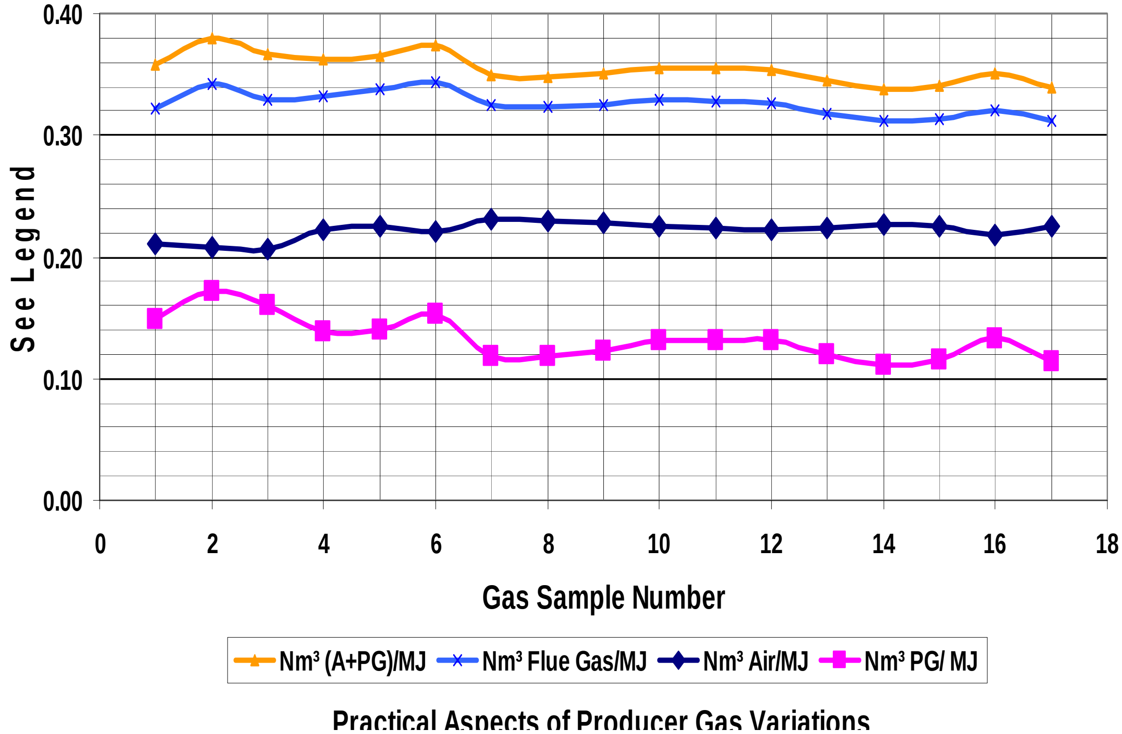

Figure 5. Plots of calculated air requirement of producer gas for stoichiometric combustion showing relatively constant air levels.

Comparing Producer Gas with Natural Gas

The lower heating value of natural gas is about 36.11 MJ/Nm^3 (970 Btu/ft^3) while for the producer gas derived from gasification of pelleted gin waste was about 7.93 MJ/Nm^3 (213 Btu/ft^3). For the same amount of heat released, the following illustrate the comparison between natural gas and producer gas generated from this study:

- Four and a half times more volume of producer gas needed to equal the heating value of natural gas;
- Air for producer gas is 85% less than that of natural gas for stoichiometric combustion;
- Volume of producer gas and air-to-fuel mixture is only 1.2 times that of natural gas and air; and
- Flue gas volume from producer gas combustion is only 1.1 times those from natural gas;

These observations suggest that the design of combustion equipment to burn producer gas is very similar to that for natural gas except for the producer gas flow rate.

Conclusions

Given that the cost of energy from natural gas and other fossil fuels is generally rising, the economic utilization of the energy contained in waste biomass streams is becoming more viable. This economic utilization of waste material has the potential local economic impact equivalent to a new miniature natural-gas well.

It was shown that it is technically feasible to continuously produce grid quality electrical energy and thermal energy from gasification of pelleted cotton gin trash. The pelleting process allowed for easy feeding of the raw material into the advanced downdraft gasifier.

Future Work

Research work will continue to establish the relationship between densification level and performance of the gasifier to minimize the cost of material processing. The cost of feedstock is proportional to the level of pre-processing to be made on the biomass resource. Further, more tests is needed to establish the economic indicators to prepare this modular gasification unit for commercialization. In addition, barriers to its adoption by numerous dedicated cotton gins will have to be thoroughly evaluated such as cost of electricity produced, demand or standby charge among others

It would be potentially valuable in the gasification tests to evaluate density as a variable, from pelleted to compacted to undensified. In the future, test range of samples at various compaction levels will be made to develop a correlation between compaction and performance. The information would be potentially useful for a range of other Texas agricultural residues.

Acknowledgement

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