AN UPDATE ON THE BIO-ENEGY CONVERSION PROCESSES UTILIZING COTTON GIN TRASH

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Abstract

Various conversion processes utilizing cotton gin trash are continually being investigated at Texas A&M University (TAMU). The current available technologies for conversion include the following: a mobile fluidized bed gasifier (FBG) for heat and power purposes and a mobile fast pyrolysis system for bio-oil and bio-char conversion. There are also other new processes being investigated to produce transport fuels. Each conversion process will be discussed in this paper including their level of maturity and commercialization potential. The gasification of cotton gin trash has already been technically demonstrated in previous years. The remaining issue would be on the utilization of the products and by-products of the process and the identification of commercial economical applications. Drying wet cotton bales is the easiest and most practical application and would not require any further research. Electrical power production is also feasible if an appropriate scheme for the sale of electricity is identified, particularly taking advantage of the peak power demand in some areas. Bio-oil production via fast pyrolysis is gaining popularity for the production of refinery grade crude oil. High energy density bio-crude oil can be produced from cotton gin trash. The chemical composition is very different from refinery grade crude oil and would require further upgrade. The product is highly oxygenated, with some moisture and having low pH. Once moisture is removed, the bio-oil has very high energy content of approximately 11,000 Btu/lb and may be mixed with fuel oil #2 or may be used in boilers for heating purposes. Production of liquid transport fuel such as gasoline, diesel, ethanol and JP-8 may be realized in the future via other liquefaction processes.

Introduction

The heating value of cotton gin trash (CGT) is approximately 7,000 Btu/lb, typical of most biomass such as corn stover, straw and high tonnage sorghum. One ton of CGT would contain 14 million Btu of energy equivalent to 120 gallons of gasoline. Converting this biomass resource into valuable energy or non-energy products would provide additional revenue to the cotton industry.

During the ginning of baled cotton approximately 150 lbs of CGT are produced per bale of picked cotton or 400 lbs per bale of stripped cotton. The energy contained in cotton gin trash per bale of picked and stripped cotton is approximately 1.05 and 2.8 million Btu, respectively. The energy used to process a bale of cotton is approximately 170,600 Btu. Clearly, there is enough energy in the CGT to be used to process a bale of cotton even with 10% conversion efficiency. The recent government programs concerned with achieving energy independence will bring about new affordable technologies to convert these biomass resources into valuable liquid fuels or valuable by-products. These new developments will provide additional incentive to cotton ginners in improving their revenue during the ginning season.

Objectives

The main goal of this report is to present an update on the work being conducted at Texas A&M University on bio-energy conversion processes utilizing cotton gin trash. The specific objectives are as follows:

(a) Discuss the available thermal conversion technologies and their status.
(b) Discuss the advantages and disadvantages of each conversion process including recent developments.
(c) Present future directions for advanced CGT conversion processes.
(d) Identify usable products that may be of importance.

Materials and Methods

A number of conversion technologies have been investigated at TAMU since the initial energy crisis in the 1970's and the 1980's. This report focuses primarily on the two most important thermal conversion technologies, particularly gasification and pyrolysis.

Development of Thermal Conversion Technologies

Pyrolysis is a thermal conversion process in complete absence of oxygen. Biomass resources are normally heated in an enclosed, completely oxidant-free reactor. There are three products produced: solid char, liquid bio-oil and synthesis gas. Each of these products has valuable use. The gasification process produces a similar product range except that the process is endothermic, that is, no external heat is required for the process to be operated on a continuous basis.

Pyrolysis Technologies

Texas A&M University has developed a continuous pyrolysis process to convert CGT or any biomass into high energy content char, moderate energy bio-oil and medium energy density synthesis gas. A mobile pyrolysis system has likewise been fabricated and developed. The TAMU continuous pyrolyzer can handle biomass at rates of between 300-600 g/min (18-36 kg/hr). The unit is scalable and may be able to handle several tons of biomass each day. The technology is ready for commercialization. A market has to be developed for the primary product and other by-products. The advantages of pyrolysis processes are as follows:

(a) Higher value products are produced.
(b) Mobile portable systems are available.
(c) Various other biomass products may be processed.

The primary disadvantage of using a pyrolyzer is the fact that external heat is required to make the process sustainable. Combustion of the co-produced synthesis gases may provide the external heat. Thus, in effect, the primary products are the high energy density bio-oil and a high energy content char.

Gasification Technologies

Texas A&M University had a patent for a fluidized bed gasifier in the late 1980's (LePori and Parnell, 1989) and has recently applied for a new and improved patent. Aside from CGT, other biomass resources namely, wood chips, sorghum biomass, switch grass, poultry litter, and dairy manure have been tested for gasification. A new computer control system for the gasifier has been developed and a new unit has been fabricated and placed on top of a commercial trailer. Complete technical drawings have been made for this new system. The 1-foot diameter unit can handle between 2-4 tons per day of biomass to as high as 50 tons per day of biomass for mobile applications. The advantages of a fluidized bed gasification system are as follows:

(a) High throughput.
(b) Can handle various other fuels.
(c) Mobile systems are available.

The only disadvantage of the mobile gasification system is the pre-heating requirement during start-up and the required power to run the blowers and feed motors. The gasification system developed at Texas A&M University is ready for commercialization as well.

Results and Discussion

Use Commercialization of the TAMU Gasifier

The TAMU fluidized bed gasifier is available for commercialization with the following applications:

(a) Production of synthesis gas for subsequent combustion into power,
(b) Production of char, and
(c) Production of bio-oil from the condensation of synthesis.

TAMU Mobile Gasifier/Pyrolyzer

The TAMU pilot fluidized bed gasifier (1 ft diameter) can handle between 2-4 tons/day of biomass per day and has the potential to generate between 100-200 gallons of bio-oil. Between 0.6 to 1.2 tons of char may be produced as well. This char has high energy content similar to low grade coal and may be used as co-firing fuel for coal power plants. The char may be further upgraded into activated carbon adsorbent material. Commercial activated carbon sells for more than $2,000/ton (Calgon Carbon, 2009).

Current Biomass Conversion Activities

Synthesis Gas Separations into Pure H_2 and CH_4

Synthesis gas is primarily composed of CO and H_2 with approximately 15% and 10% by volume, respectively. Methane (CH_4) is approximately 5% by volume. The energy content of the low calorific value (LCV) synthesis gas is about 150 Btu/ft^3. There are several uses for the synthesis gas as follows: (a) as fuel for electrical power production, (b) separate into pure hydrogen or methane (c) condense into high energy content bio-oil.

Current research on the use of synthesis gas includes pyrolysis optimization of the synthesis gas, particularly hydrogen and methane and further separating them into pure hydrogen and methane. Results showed that as much as 5 gallons of hydrogen or 3 gallons of methane may be produced per lb of biomass input. Initial separation studies showed that carbon monoxide (CO) may be separated from the synthesis gas streams at 97% efficiency. A zeolite-metal catalyst was used for the adsorption and separation study. A similar catalyst was used to separate methane from the synthesis gas streams.

Bio-oil Upgrade to Refinery-Grade Crude Oil

The synthesis gas may be passed through a condenser to quench the gas and generate liquid bio-oil by-product. Physically, bio-oil is similar to crude oil but is very different chemically. In order for the bio-oil from biomass to be converted into refinery grade crude oil, there are three criteria to be satisfied as follows: (a) water content must be minimal, (b) total acid number must be very low, and (c) the material must be free of bound oxygen. Thus, current research efforts are directed into satisfying the above criteria. Once those criteria are satisfied, the resulting product may be sold to commercial refineries for fractionation into gasoline, diesel fuel or even aviation fuel (JP-8). This refining process may lead to generating other by-products such as wax and lubricating oils.

Several other options are available for the bio-oil. The liquid water may be easily separated to raise the heating value of the resulting organic portion to as high as 11,130 Btu/lb. This high energy content combustible product may be used directly in fuel-oil fired burners or as co-firing fuel with diesel engines. Some suitable additives (between 5-10% mixtures) may be necessary if the bio-oil is to be mixed with diesel fuel. Several tests have been made to identify the proper solvent to use including the proper amount in diesel mixtures.

Char Upgrade into Activated Carbon

The char generated from either the fluidized bed gasifier or the mobile pyrolyzer may be re-applied directly into agricultural soil as soil amendment or as fertilizer. However, at higher gasification temperatures, the nutrients may not be readily available and would require simple acidulation (use of mild acid) before the nutrients may be available for plant uptake. The char has high energy value of as high as 22 MJ/kg and very similar to heating value of low grade coal (LePori and Soltes, 1985). Thus, the char material is an ideal co-firing fuel for coal power plants.

Further, the char may be upgraded into activated carbon, a highly valuable commercial adsorbent. The char collected by the cyclones of the fluidized bed gasifier or the pyrolyzer has mild adsorptive properties with an iodine number of about 300. Commercial activated carbons have iodine numbers of as high as 1200 (Capareda, 1990). Upgrading the char into commercial grade activated carbon may require some pre-treatment such as chemical impregnation using $ZnCl_2$ or by simple steam activation.

Clearly, there are numerous products and by-products from thermal conversion of CGT or many other biomass feedstock. Thermal conversion technologies, particularly the fluidized bed gasifier and a pyrolyzer have already been developed. Further issues include finding the right application that would provide the best economic return.

Conclusions

Gasification and pyrolysis conversion systems are currently available for the production of power, liquid fuels and other valuable by-products. TAMU has been improving the design of the fluidized bed gasifier since initiating research in the early 1980's. A new patent application has been filed for an improved gasifier system with computer control system. A mobile pyrolyzer has also been recently developed.

Applications of these thermal conversion systems are diverse and summarized as follows:

Synthesis gas

(a) The synthesis gas may be directly combusted to generate electrical power;
(b) may be passed through a condenser to generate bio-oil; and
(c) may be separated into pure hydrogen or methane.

Bio-oil

(a) The water in the bio-oil may be separated by simple decantation to provide a high energy organic component (11,130 Btu/lb) that may be used directly as boiler fuel.
(b) The bio-oil may be blended with diesel fuel using appropriate solvents; and
(c) may be upgraded into commercial-grade crude oil and sold to oil refineries for further separation into gasoline, diesel or aviation fuel.

Char

(a) The char may be sold as soil amendment;
(b) used as co-firing fuel for coal power plants; and
(c) further upgraded into activated carbon and sold as adsorbents.

Clearly, several critical refinements are needed to generate marketable products from thermal conversion of cotton gin trash or other biomass resource.

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