THE USE OF BIG/GT TECHNOLOGY IN SUGAR MILLS

By

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Abstract

The approval in Brazil of environmental laws phasing out cane burning prior to harvest led to an increasing interest in studying alternatives for utilisation of sugar cane trash. The use of sugar cane trash as fuel to generate power and heat is one of these alternatives. Biomass Integrated Gasification with a Gas Turbine (BIG/GT) is an advanced technology that will provide much more power per tonne of milled sugar cane than the Condensing Extraction Steam Turbine (CEST). The objective of this work is to introduce a general overview of the gasification technologies that exist at different levels of development and to present a realistic example of the integration of one of the BIG/GT technologies with a typical Brazilian sugar mill, considering the export power capacity, investment cost, availability of trash and bagasse.

Introduction

Gasification of solid fuels has been used for many years in different applications. The interest of considering this technology for power generation derived from the possibility of using low quality and cheap fuels, such as coal with high sulfur and ash contents and agricultural residues, in conjunction with high efficiency combined cycles. With this alternative an overall thermal efficiency, from fuel to electric power, above 40% (based on the higher heating value of the fuel) can be achieved in a combined cycle thermal power plant.

For more than 10 years, the gasification associated with gas turbines has been evaluated as an alternative for cogeneration of power and heat in sugar mills. This concept is known as Biomass Integrated Gasification/Gas Turbine or simply BIG/GT. The main advantage of this technology is that larger levels of electricity generation per tonne of cane (kWh/t cane) are possible (Table I), but the process steam consumption has to be brought to levels below 30% on cane (300 kg steam/t cane) to maximise electricity cogeneration.

In sequence, an overview of the various gasification technologies will be presented and a quantitative example of the integration of one of the most promising alternatives with a typical Brazilian mill will be suggested. This integration study is part of a project being developed by Centro de Tecnologia Copersucar (CTC) and funded both by Copersucar and Global Environment Facility (GEF).

Gasification technologies

There are several gasification technologies that can be used for biomass. The selection of the process has to be based on the type and characteristics of fuel, final use of the product gas, size of the plant and other specific conditions. These technologies can be grouped in the following way to facilitate selection by a potential user:

Gasification agent

- Air blown: air as the gasifying agent is the simplest and cheapest solution but it results in a low calorific value product gas (4–6 MJ/Nm³ LHV) due to the high concentration of nitrogen.
- Oxygen blown: the calorific value of the gas can be increased to values around 14 MJ/Nm³ (LHV) when oxygen is used as the gasifying agent; however, this option is hard to justify economically when the product gas is intended to be used for power generation.
- Steam blown: steam can be used as the gasifying agent, in combination with air or oxygen, to control the bed temperature and/or to increase the calorific values of the gas; in the case of indirect heating, it can be the only agent

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Power generation</th>
<th>Process steam (kg/t cane)</th>
<th>Excess power (kWh/t cane)</th>
</tr>
</thead>
<tbody>
<tr>
<td>22 bar/300°C boiler Backpressure turbine</td>
<td>SEASON</td>
<td>500</td>
<td>0–10</td>
</tr>
<tr>
<td>45 bar/480°C boiler Backpressure turbine</td>
<td>SEASON</td>
<td>500</td>
<td>15–30</td>
</tr>
<tr>
<td>82 bar/480°C boiler Backpressure turbine</td>
<td>SEASON</td>
<td>500</td>
<td>20–40</td>
</tr>
<tr>
<td>82 bar/480°C boiler Extracting/Condensing turbine</td>
<td>YEAR ROUND (1)</td>
<td>340</td>
<td>80–100</td>
</tr>
<tr>
<td>BIG/GT</td>
<td>YEAR ROUND (1, 2)</td>
<td>&lt;300</td>
<td>150–300</td>
</tr>
</tbody>
</table>

(1) Supplementary fuel required.
(2) Technology not commercial yet.

KEYWORDS: Bagasse, Cane Trash, Biomass Gasification, BIG/GT, Cogeneration, Electricity.
Gasifier pressure
- Low pressure: gasification takes place at, or slightly above, atmospheric pressure; the advantages of this alternative is to simplify the fuel feeding operation and the gas clean up system.
- High pressure: the gasifier operates at pressure from 10 bar to 35 bar, depending on the gas turbine compression ratio. Higher thermal efficiencies can be achieved at the cost of much more complicated fuel feed and gas clean up systems. The gasifier is physically smaller which may be another important advantage due to lower investment costs.

Reactor type
- Fixed bed: the fuel is fed to the gasifier and forms a solid layer, and the various steps of the gasification process occur in well defined areas of the vessel (combustion, reduction, pyrolysis and drying). This alternative is normally used for small gasifiers and it is not suitable for fine-grained fuels like sugar cane bagasse, rice hulls and shredded sugar cane trash.
- Fluidised bed: in this type of gasifier the fuel in the form of small particles and an inert fine-grained solid (such as sand, alumina or dolomite) are maintained in suspension by the gasifying agent. It is the option preferred for large scale gasifiers and it is very flexible with respect to fuel type. Fluidised bed can be either of the bubbling bed type or of the circulating bed type.
- Entrained flow: it requires the fuel to be finely pulverised and to be fed to the gasifier together with the gasifying agent. The fuel fineness requirements make this alternative unattractive for biomass.

Heating process
- Direct heating: most gasifiers in use or in the development stage use the heat generated by the partial combustion of the fuel in the same vessel where the gasification takes place, to maintain the process. This is called direct heating gasification.
- Indirect heating: in this type of gasification the thermal energy required to drive the gasification process comes from combustion of residual chars, or part of the fuel, in a different vessel from the one where the gasification process is taking place. The thermal energy is transferred from one vessel to the other using flowing sand, or other types of pulverised solid, as carrier. The gasifying agent is normally steam and, since there is practically no nitrogen to dilute the product gas, this produces a calorific value close to 20 MJ/Nm³ (lower heating value) which is high enough to be used in commercial gas turbines without modification.

For application in sugar mills, considering loose bagasse/trash as fuel and sizes from 10 to 150 MWₑ, the preferences are pointing to air blown direct heating circulating fluidised bed gasification. However, the RENUGAS process from the Institute of Gas Technology (IGT), USA, that uses bubbling bed and the FERCO/Battelle process, that uses indirect heating, have the potential to become attractive options for sugar mill installations.

Figures 1 and 2 show, in a simplified way, the flow diagrams of the circulating fluidised bed, atmospheric and pressurised, respectively.

Integration of a BIG/GT plant with a typical Brazilian mill
The integration of the BIG/GT plant with a typical mill, selected as reference for the project, is an important step in the technical economic evaluation of the electric power generation in sugar/alcohol factories using sugar cane residues, bagasse and trash, as fuel. The study is being developed by CTC (Centro de Tecnologia Copersucar) with the assistance of TPS (Termiska Processer AB), who is responsible for the basic and process engineering of the BIG/GT plant. This project is cofunded by the Global Environment Facility (GEF) and Copersucar.

TPS has already performed several tests (laboratory, bench scale and pilot plant) with bagasse and trash samples provided by CTC. From these tests TPS prepared a preliminary energy balance for the BIG/GT module based on the GE LM 2500 gas turbine. In cogeneration mode the BIG/GT unit will operate totally integrated with the mill, receiving bagasse and trash and delivering steam and electric power required for the mill operation. The cogeneration mode, is being developed by CTC with TPS assistance as an interactive process. With the preliminary performance data provided by TPS for the BIG/GT unit, CTC developed several alternatives for the energy system operating with different conditions of steam (pressure, temperature), process steam consumption levels and partial substitution of electric motor drives for existing steam turbine drives. The energy balances for these alternatives are the main tools for the cogeneration system optimisation.
systems definition and energy balances

Basic assumptions

The cogeneration schemes have been developed based on a typical factory as illustrated in Figure 3 and on the following assumptions:

**Typical mill (reference plant)**
- Annual cane processing: 1,300,000 t;
- Daily milling capacity: 7,000 t;
- Milling season: 4,457 h;
- Offseason operation: 3,164 h;
- Annual bagasse availability: 345,800 t (50% moisture);
- Annual trash availability: 103,000 t (15% moisture);
- Bagasse/trash moisture content at gasifier inlet: 10%;
- Process steam consumption: 530 kg/t cane;

**BIG/GT plant**
- Net power generation: 16.8 MW
- Heat recovery steam generator (HRSG) output: 56.4 t/h at 82 bar/480°C; 72.4 t/h at 22 bar/300°C; 83.2 t/h at 2.5 bar saturated

**Main equipment existing in the mill**
- Boilers: 1×100 t/h and 1×54 t/h (22 bar/300°C)
- Turbo-alternators: 3,300 kW

Alternatives evaluated for BIG/GT—mill integration

The several alternatives of mill energy balances were matched with the BIG/GT plant and resulted in the alternatives shown in Table 2.

In all cases it was attempted to keep the same power export capacity during all year (season and off season). Each alternative had different trash requirement.

This alternative analysis generated the information required for a preliminary investment cost evaluation and export power levels estimates (gross power generated minus BIG/GT and mill internal power consumption).

The summary of these alternatives is shown in Table 3.

Conclusions from the study

Based on a preliminary economic evaluation and considering the impacts on the existing installation of the typical mill and the estimated maximum trash availability, the alternative 20T340 has been selected for detailed basic and process engineering and design to provide the data required for final economic evaluation of electric power costs.

This alternative (20T340) has been selected based on the following considerations:
- Maximum use of existing equipment (minimum investment cost).
- Trash requirement compatible with recoverable trash quantity.
Crushing rate per day 7 000 t/day
Crushing rate per hour 292 t/h
Process steam cons 7 009 kJ/kg
Low heating value 26% Bagase cane
Bagasse % cane 81.4 t/h
Total bagasse 13.9 t/h
Bagasse consumption 3 106 kW
E E Consumption 330 kW
E E Exported 0 kW
E E Imported

Boiler 1
Cap. 54 t/h
75% Production 54 t/h
20 kg/cm² 300°C
3 023 kg/kg
427 kg/kg

Boiler 2
Cap. 100 t/h
75% Production 100 t/h

2567 kW
47.0 t/h
mill 1 - 6
46%

930 kW
21.2 t/h
Auxiliaries
37%

3436 kW
41.3 t/h
Turbo-alternator 70%

Dessuper-water 105°C
To sugar factory/distillery
6.0 t/h
130°C 154.6 t/h

To deaerator
5.5 t/h

Assumptions:
Inlet deaerator water temperature 85°C
Outlet deaerator water temperature 105°C

Fig. 3—Mass and energy balance—typical sugar mill.

Table 2—Alternatives evaluated for BtG/GT-mill integration.

<table>
<thead>
<tr>
<th>Alternative</th>
<th>HRSG steam conditions bar/°C</th>
<th>Mill steam condition bar/°C</th>
<th>Process steam consumption kg/t cane</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>20T340</td>
<td>22/300</td>
<td>22/300</td>
<td>340</td>
<td>1</td>
</tr>
<tr>
<td>20M280</td>
<td>22/300</td>
<td>22/300</td>
<td>280</td>
<td>1</td>
</tr>
<tr>
<td>81M280-2B</td>
<td>82/480</td>
<td>22/300</td>
<td>280</td>
<td>2</td>
</tr>
<tr>
<td>81T340</td>
<td>82/480</td>
<td>22/300</td>
<td>340</td>
<td>1</td>
</tr>
<tr>
<td>81M280</td>
<td>82/480</td>
<td>22/300</td>
<td>280</td>
<td>1</td>
</tr>
<tr>
<td>C81T340</td>
<td>82/480</td>
<td>82/480</td>
<td>340</td>
<td>1/3</td>
</tr>
<tr>
<td>C81M280</td>
<td>82/480</td>
<td>82/480</td>
<td>280</td>
<td>1/3</td>
</tr>
</tbody>
</table>

Notes: 1—HRSG steam supplemented by mill boilers to supply process demand.
2—HRSG producing all steam required by process.
3—Existing 22 bar mill boilers replaced by 82 bar new boilers.

Table 3—Summary of the alternatives evaluated for BtG/GT-mill integration.

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Exported power (MW)</th>
<th>Trash requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Season</td>
<td>Off season</td>
</tr>
<tr>
<td>20T340</td>
<td>27.9</td>
<td>27.9</td>
</tr>
<tr>
<td>20M280</td>
<td>27.9</td>
<td>27.9</td>
</tr>
<tr>
<td>81M280-2B</td>
<td>43.3</td>
<td>58.5</td>
</tr>
<tr>
<td>81T340</td>
<td>28.1</td>
<td>29.3</td>
</tr>
<tr>
<td>81M280</td>
<td>27.5</td>
<td>29.2</td>
</tr>
<tr>
<td>C81T340</td>
<td>29.3</td>
<td>29.3</td>
</tr>
<tr>
<td>C81M280</td>
<td>29.3</td>
<td>29.3</td>
</tr>
</tbody>
</table>
The average conditions in the State of São Paulo allows about 60% of cane to be harvested green; assuming 80% trash recovery efficiency and 140 kg of trash (dry basis) per tonne of cane results in a trash availability of 103,000 tonnes, with 15% moisture content, for the typical mill. This restriction resulted in the elimination of alternative 81M280-2B with was considered the best technical option.

The BIG/GT system is to be assembled inside the mill's industrial area, receiving fuel (bagasse and trash) and condensate water from the mill and supplying steam and electric power to the mill. Figure 4 shows steam flows, fuel and condensate and Table 4 shows the final figures for this integration.

Concluding comments

This paper has outlined the results of a current study in Brazil into the use of gasification in the sugar mill environment to increase electricity output considerably and to use some of the cane trash which cannot now be burned prior to harvest. The BIG/GT process results in a major increase in the amount of electricity exported to the grid (from about 3 MW to about 30 MW in the example here with an even larger increase in total power exported). In the end, it is the income derived from this extra power export that has to justify the capital investment in the BIG/GT facility.

The gasification process, therefore, gives sugar mills a potential major increase in income from cogeneration of electricity. Compared to cogeneration using just the conventional steam cycle, a doubling of the amount of electricity exported is possible. At the same time, the need to change factory steam economy to maximise electricity output gives the sugar mill the economic opportunity to upgrade equipment as part of that increase in energy efficiency. (This opportunity exists whether the conventional steam cycle or the BIG/GT cycle is used as the basis for increased cogeneration.) In practice, the fact that such cogeneration projects are an addition to an existing sugar factory puts economic constraints on what can or cannot be done. In this paper, it was pointed out that the reasons for choosing the particular BIG/GT configuration for more detailed analysis included the need to maximise the use of existing equipment. The same economic constraint will apply when considering changes within the sugar mill itself to improve energy efficiency.

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**Table 4—Exported power and fuel consumption.**

<table>
<thead>
<tr>
<th></th>
<th>20T340 Integration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bagasse Consumption (50% moisture) (tonnes/year)</td>
<td>147,500</td>
</tr>
<tr>
<td>Sugar cane trash consumption (15% moisture) (tonnes/year)</td>
<td>100,900</td>
</tr>
<tr>
<td>Net Power to Grid (GWh/year)</td>
<td>197.7</td>
</tr>
<tr>
<td></td>
<td>27.9</td>
</tr>
</tbody>
</table>

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**Fig. 4—Mass and energy balance—BIG/GT mill integration—20T340 alternative.**
Another aspect of gasification that should be mentioned and which is likely to have increasing relevance is the greenhouse gas effect and global warming. Electricity generated from bagasse and trash is electricity generated from a renewable energy source. BIG/GT technology gives the opportunity to maximise energy generated from a renewable energy source that releases carbon dioxide when the bagasse/trash is burned but reabsorbs it when the cane crop grows to provide the energy for the following year.

BIG/GT technology, therefore, has many positive aspects that are encouraging R&D efforts in many countries. However, as yet, the technology is not fully proven and commercial. We all await with some eagerness the successful outcomes of this R&D and can anticipate the day when BIG/GT technology will enable sugar factories to make an even greater contribution to the financial health of each sugar cane growing country.

GAZÉFICATION DE LA BIOMASSE ET LA TECHNOLOGIE DES TURBINES A GAZ EN SUCRERIE DE CANNE.

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Résumé

La législation au Brésil demande la récolte de cannes vertes. On a donc décidé d’étudier des méthodes pour utiliser la paille. Un des possibilités bien connue est de se servir de la paille pour générer de l’énergie. Le BIOMASS INTEGRATED GASIFICATION avec turbines a gaz (BIG-GT) est une technologie nouvelle qui donne plus d’énergie par tonne de canne que les technologies établies.


Mots clefs: bagasse, paille, gazéification, cogeneration, électricité.

EL USO DE GASIFICACION DE BIOMASA INTEGRADO CON TECHNOLOGIA DE GAS TURBINA EN FABRICAS DE AZUCAR

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Resumen

La aprobacion en Brazil de leyes ambientales quitando la quemadura de la cana antes de cosechar ha creado mas interes en estudiando alternativos para el uso de el residuo de la cana de azucar.

El uso de el residuo de la cana de azucar a combustible para producir energia y calor es una de las alternativas. Biomasa Integracion Gasificacion con una Gas Turbina (BIG-GT) es una tecnologia avanzada que dispone mucha mas energia por tonelada de cana molida que el turbogenerador de condensacion por extraccion (Condensing Extraction Steam Turbine (CEST)).

El objectivo de este trabajo es de introducir una vista general de las tecnologias de gasificacion que existen en fondos diferentes de progreso y presentar un ejemplo realistic0 de la integracion de una de las BIG/GT tecnologias con una fabrica de Cana en Brazil caracteristico, en consideracion a la capacidad para exportar energia, el gasto de inversion, y el residuo y el bagazo disponible.

Palabra claves: bagazo, residuo de cana, biomasa gasificacion, BIG/GT, cogenegacion, electricidad.