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CANE TRASH BURNER: A NOVEL WAY OF UTILISING THE ENERGY INHERENT IN SUGARCANE TRASH

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Abstract

The dry leaves (trash) adhering to ripe sugarcane are a significant source of renewable energy. At present, most of this energy is wasted in South Africa, since approximately 90% of the cane crushed is burnt in the fields prior to harvesting. Apart from wasting valuable energy, this practice causes substantial environmental pollution. The cane trash burner is a patented machine that burns the cane leaves off the stalks in a sugar mill prior to shredding. Tops are left in the field while the cane, with adhering trash, is harvested and transported to the factory. The energy captured in the burner can be utilised for electricity through generating steam in a normal sugar mill boiler. The paper describes the construction of the pilot scale version of the burner, and gives details of initial burning trials, including the potential energy recoverable from the process. It deals with the main advantages and disadvantages of using the burner and lists some of the important economic factors affecting its incorporation into a standard raw sugar factory.

Keywords: sugarcane, trash, leaves, renewable energy, cane trash burner, cane trash for energy

Introduction

Burning sugarcane in the field prior to harvest is common practice in South Africa for a number of reasons:

- It is a quick method of removing the trash from the cane. Trash (the dry leaves on cane stalks) has a much lower sucrose content than the stalks (de Beer *et al.*, 1989) and it is desirable to remove this before extracting sucrose from the cane in order to maximise sucrose extraction and minimise sucrose losses. Manual removal of trash (called 'trashing') is more labour-intensive than burning and hence more costly.
- Burnt cane has a higher bulk density than cane that is harvested with the trash adhering. Thus the payloads (in terms of sucrose mass) for a given volumetric capacity of the transporting vehicle for burnt cane is higher than for cane that is harvested green without removal of trash in the field (de Beer *et al.*, 1989), and the transport costs associated with moving the cane from the field to the raw sugar factory are less for burnt cane than for unburnt cane. Even when trash is manually stripped from the cane stalks in the fields

prior to transporting it to the factory, trashed cane normally brings more extraneous matter (with lower sucrose content than cane stalks) into the factory than burnt cane.

However, burning of cane in the field prior to harvest also has some undesirable effects:

1. While burning of cane is normally done in a controlled manner with few run-away fires occurring, the air pollution caused by the smoke and smuts during the burning process is a nuisance, particularly in areas that are close to highly populated regions. Increasing resistance from the general public to this practice is being experienced.
2. Trash has a significant energy content which can be harnessed and could thus increase the profitability of cane farming. In other words, burning of cane prior to harvesting can be considered a significant waste of energy. This energy (because it comes from a renewable source) could reduce the dependence on coal for energy in regions that have large areas under cane, and thus contribute in a small way to a reduction in global warming.
3. The deterioration of cane caused by in-field burning, and its effect on sugar quality and recovery losses as a result of deterioration products generated (such as dextran) when there are delays in bringing the burnt cane to the factory, are well documented.

This paper presents a way of combining the positive effects of cane burning on sugar processing with minimising, to a large extent, the negative impacts while simultaneously utilising the significant amount of energy inherent in the trash.

Concept of the cane trash burner (CTB)

The CTB is a piece of equipment with the purpose of performing the same function in the factory as in-field burning of cane. Cane is harvested with the adhering trash, topped and then transported ‘as is’ to the factory. At the factory the cane is then put into the CTB where the trash is burnt off the stalks in a controlled manner. Straight from the CTB the burnt (cleaned) stalks are fed to the shredder and sucrose is extracted in the normal way. The purpose of the CTB is three-fold:

1. to achieve the same cleaning of extraneous matter as is obtained during in-field burning of cane prior to harvesting
2. to provide a means of utilising the energy that can be obtained from cane trash
3. to eliminate the air pollution that is generated by burning cane in the field.

Key to the successful introduction of the CTB in sugar extraction is the requirement that the cane moves through the CTB in a controlled manner so that the sucrose in the cane stalks deteriorates no less than during in-field burning. This means that the residence time of the cane in the CTB must be controlled and that the cane stays in the burner no longer than is necessary to burn off the cane trash. This necessitates that cane flows through the burner in plug-flow, and that it is not possible for portions of the cane to be held up in the CTB. This itself poses design challenges.

An additional benefit of the CTB is that it provides an opportunity for sand or soil that comes in with the cane to be removed in the CTB. In this way it can benefit the sugar extraction process in reducing the wear and tear on shredding, diffuser or extraction mills and de-watering mills caused normally by soil that moves through the factory. This should result in substantial savings in maintenance costs associated with such wear and tear (Wienese and Reid, 1997).

Since for the same mass of sucrose transported to the factory using burnt cane, the cane with adhering trash has a larger volume (and lower bulk density) than cane that has been burnt prior to harvesting, and the transport costs for cane will be higher when the CTB is being incorporated into the process. A very preliminary economic assessment revealed that the increased transport costs are more than off-set by the overall economic benefits of this modified way of extracting sugar from cane. Using cane prices and transport costs prevailing in 2006, and relative data quoted in the literature of that period, it was found that (excluding capital cost implications involved in the installation of the CTB) a saving of R14.47 could be achieved per ton of cane thus processed. Details of this analysis are given in Appendix 1.

While this preliminary economic analysis yielded encouraging answers, key to the success of this proposed technology was the guarantee that the CTB does not damage the sucrose in cane more than what is done during in-field burning of trash off the cane stalks. In order to get some measure of assurance on this, it was felt necessary to build a pilot plant which simulates the flow of burning cane through a large-scale CTB. With research funds provided by the University of KwaZulu-Natal, a pilot plant cane trash burner was built, details of which are given in the next section.

Apparatus

The pilot plant was designed and constructed in the engineering workshop of the School of Chemical Engineering, University of KwaZulu-Natal. The essential parts are described below. Figure 1 shows the front view of the CTB, which consists of the following component parts.

1. Perforated plate on inside of burner along which cane, ash, leaves and soil are swept from the feed point to the exit.
2. Feed point at which cane is fed into the burner.
3. A gas burner array to ignite the incoming cane trash.
4. A chimney through which flue gas exits the burner.

The unit was constructed from steel angle iron enclosed in stainless steel sheet metal. A static perforated-plate plenum below the feed point, inside the unit, was secured at an angle such that cane could move down to the exit at the rear of the unit. In order to encourage the cane to move along the plenum a series of horizontal metal scouring bars moved along the upper face of the plenum. The bars were connected to a moving chain driven by an electric motor. In this way cane could be moved from the feed point to the exit. A gas burner array, located immediately to the rear of the feed point, was installed to ignite the cane trash. Automatic shut-off and interlocks were provided for safety reasons. A master shut-off valve allowed the gas supply to be terminated as soon as the cane trash burning became self-sustaining. A variable speed motor and gearbox allowed the speed of the scouring bars to be controlled according to the flame front velocity in the burning cane/trash. An exit slot for cane that had the trash burned off was provided at the rear of the unit. Perforations in the plenum allowed ash and soil to fall into a collection region at the base of the apparatus. A flue allowed hot combustion gases to be ducted out of the top of the unit. A portable infrared thermometer was used to measure the surface temperature of the CTB panels and of the cane.

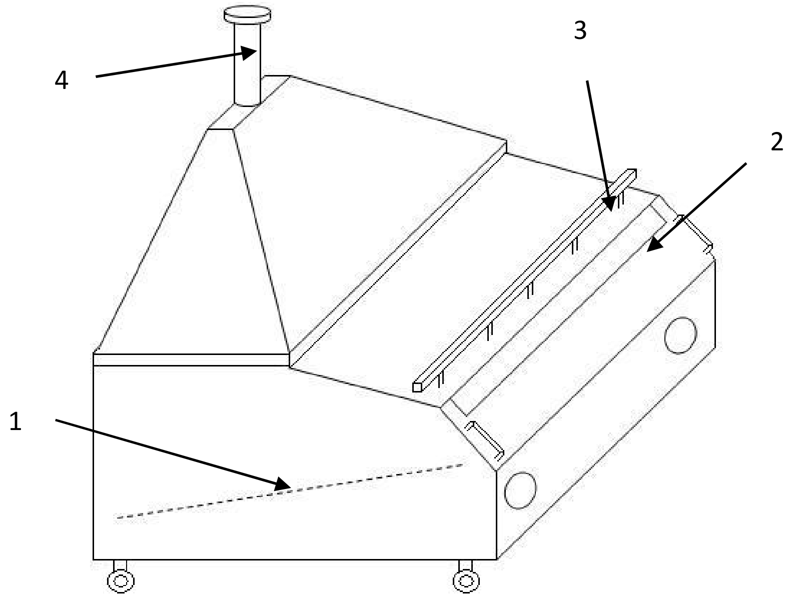

Figure 1. Cane trash burner, front/side view.

Experimental Procedure

The cane was separated into two bundles, one being dry cane which had been cut over a month before the test, and the other being fresh cane which had been cut on the day of the test. The dry cane was then weighed and split further into three smaller, approximately evenly sized bundles each weighing approximately 35 kg. The fresh cane was split into four bundles, also weighing approximately 35 kg.

The CTB was moved outdoors to a well ventilated area. The cane stalks were aligned parallel to the feed point of the CTB, so as to make feeding easier and safer.

The weight of the liquefied petroleum gas (LPG) cylinder before the testing phase was recorded. The gas cylinder was then connected to the CTB and the valves and connectors were checked to ensure there were no leaks.

The motor and flue gas temperature monitor were switched on. The equipment was tested to ensure the motor, sensors, monitors, etc. were in working order. Ambient temperature was recorded.

A favourable motor speed was selected, such that the cane spent enough time within the CTB to allow for efficient burning of the trash. The gas cylinder valve was then opened and the burners were lit.

Feeding of the dry cane was begun. Between three and five cane stalks were fed to the burner every five seconds.

De-trashed cane was continuously removed from the back of the CTB throughout the run.

The flue temperature and the temperature of the panels making up the burner were recorded at an intermediate time during the process.

As soon as trash burning stabilised the gas cylinder valve was closed.

During the run the temperature of the burnt cane was recorded as it exited the burner.

The burnt cane was separated from the ash and weighed.

The ash (including some soil) was collected and weighed.

The LPG cylinder was disconnected and re-weighed to get the mass of gas used during the run.

The procedure was then repeated for the fresh cane.

Results

Results for first run (dry cane)
The speed of the scourer bars was set at 23 mm/s, giving a residence time of 61 s. During the run a total of 0.39 kg of LPG was consumed over 726 s in burning 11.4 kg of trash on 104.83 kg of cane fed to the device, and 1.76 kg of ash was recovered. The total run time was 900 s. Ambient temperature was 24 °C and the maximum surface temperature of exiting cane was 50 °C.

Results for second run (fresh cane)
The speed of the scourer bars was varied between 2.3 and 23 mm/s, giving a residence time of between 610 and 61 s. During the run a total of 0.18 kg of LPG was consumed over 876 s in burning 10.91 kg of trash on 126.38 kg of cane fed to the device, and 1.75 kg of ash was recovered. The total run time was 1200 s. Ambient temperature was 24 °C and the maximum surface temperature of exiting cane was 50 °C.

Figure 2 shows the dry cane and the resultant de-trashed cane; Figure 3 shows accumulated cane from run1; Figure 4 gives a front view of the cane trash burner and Figure 5 shows the cane trash burner in operation.

Discussion of results

In both runs, on dry and wet cane, the trash burned off the cane relatively well, with little or no trash exiting the rear of the burner along with the unburnt cane. The device worked well, with a small amount of blue smoke exiting the flue. Generally there was no smoke. There were a few smuts in the flue gases from time to time. There was no evidence of thermal damage to the cane that exited the CTB. Given that the feeding of cane to the burner was not as uniform as it could have been, there were probably undesirable fluctuations in the feed rate which were assumed to have given rise to disturbances on the plenum inside the unit. Such disturbance could have led to release of smuts to the flue. Indeed, the feed to the unit, being manual, gave rise to inconsistent combustion characteristics. This meant that the residence time was changed to suit the varying feed.

Figure 2. Dry cane and the resultant de-trashed cane. Figure 3. Accumulated cane from run 1.

Figure 4. Front view of pilot cane trash burner. Figure 5. Pilot cane trash burner in operation.

The mechanical arrangement inside the unit proved to be entirely satisfactory.

The gas burners at the entrance to the unit gave intermittent problems. The primary difficulty was the safety system which occasionally cut off the gas supply inadvertently. As it transpired, when the feed rate and the residence time were adjusted correctly, the trash burn was self-sustaining.

Ash fell through the holes in the plenum, to be collected manually after the run. The ash contained soil that was adhering to the cane feed. Some ash exited the rear of the unit along with the de-trashed cane, but was left behind when the cane was recovered manually.

The almost complete separation of (i) cane, (ii) hot flue gases, (iii) smuts, ash and soil into three process streams was observed throughout the runs. This is considered to be a major advantage of this novel system.

No analytical tests were performed on the cane other than temperature measurement.

Energy value of trash

The energy value of trash depends on the variety of cane (relative mass of trash in relation to cane stalk), the moisture of the trash and the amount of sand brought into the factory with the cane. Typical values for mass % trash at 20% moisture content are 150 kg trash per ton of topped cane . The recoverable energy (lower calorific value, or LCV) obtainable from trash is calculated from the formula (Purchase *et al*., 2008):

$$\text{LCV (kJ/kg)} = 18260 - 31.14 * \text{Bx\%trash} - 207.01 * \text{moisture\%trash} - 182.6 * \text{ash\%trash}$$

Using ash % trash of 1.5 and Bx % trash of 6.5, the LCV of trash is 13.6 MJ/kg. The LCV of coal has a value of 27.5 MJ/kg. At a coal price of R600/ton, the coal equivalent energy value of trash is R45/ton cane.

Conclusions from pilot plant tests

- The pilot cane trash burner concept has been shown to work.
- There was no visible thermal damage to the cane that had been burnt in the cane trash burner.
- Cane, flue gases and ash/soil/smuts exited the unit separately.
- Hot flue gases exited via the chimney.
- Cane exited through the purpose-built exit slot.
- Ash, soil and smuts exited through the plenum and through the cane exit slot.
- The burn was self-sustaining.
- The cane surface temperature at the exit of the burner was 50 °C or less.
- Mechanically, the system worked well.

Advantages and disadvantages of the CTB

The advantages of incorporating the CTB into the sugar extraction process are:

- No pollution from in-field burning
- Utilisation of renewable energy
- Reduction of greenhouse gas emissions (saving of coal)
- Reduced wear and tear in factory
- Reduced cane deterioration prior to shredding (fresher cane)
- Possibility of earning carbon credits
- Simplified harvesting (no in-field burning, trashing).

The disadvantages are:

- Reduced cane truck payloads (increased transport costs)
- Different harvesting procedure
- Different cane payment/testing.

Future work

The pilot plant runs were not of sufficient length to allow the unit to reach steady-state. This was due to the throughput of cane being about 2t/h, which required storage space not available at the venue. Thus it would be desirable to relocate the unit to a sugar mill or other facility where ample cane would be available to perform longer runs. Only when steady-state has been achieved can the true thermal performance of the cane trash burner be evaluated. Such longer runs would also provide realistic cane samples to evaluate cane quality before and after treatment.

Further research would enable students to register for higher degrees based on performance studies.

It is envisaged that the maximum amount of information from these studies could best be obtained through a consortium of appropriate higher education institutions, statutory and private research bodies, private enterprise and statutory research funding bodies.

Clearly, the pilot plant studies would be limited in scope. To determine the long-term financial viability of the concept a demonstration plant would have to be built. This is necessary because the effects of the energy transformation processes, such as steam generation from the heat of the flue gases, on the overall economics, would need to be proven.

On a full scale plant there would be a range of alternatives to convert the flue gas heat into a useful form. Heating process water, providing heat for drying refined sugar, raising steam for factory use or for electricity generation are all possible. Paper studies on these alternatives would be a guide to the ultimate use.

The full-scale unit would need significant work to be done to design a properly functioning feeding device. This is seen as one of the major challenges of the cane trash burner.

A detailed economic study is necessary to give an accurate indication of the economic benefit of introducing the cane trash burner into the normal sugar extraction process. A rough estimate of the capital expenditure required to incorporate a cane trash burner equipped with steam generating equipment that can generate electricity (i.e. including turbo-alternators) into a factory processing 300 tons of cane per hour came up with a figure of R250 million.

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APPENDIX 1
Economic advantage assessment

The assessment is calculated on the basis of 1 ton cane as delivered to the factory. The data presented below represents values relative to 2006.

1. Increased transport costs of cane. de Beer *et al.* (1998) calculated that the total cost of harvesting, loading and delivering topped, unburnt cane to the mill compared to that for burnt, topped cane increases by the ratio 10.63/9.15 (i.e. a factor of 1.162). This figure includes the reduction of payload. Using an average distance of 12 km and transport cost R2.50/ton/km, the marginal increase in cost per ton of clean cane delivered would be 0.162 x R2.50 x 12 = **R4.86.** This will represent a negative benefit, i.e. **-R4.86** per ton of normal cane.
2. Savings in coal replacement energy. The trash adhering to one ton of clean cane (excluding the tops, which are left in the field) has the energy value of 75 kg of coal. At price of coal of R225 per ton, this represents a saving of (75/1000) x R225 = **R16.88** per ton of normal cane.
3. Savings as a result of reduced wear and tear of sugar processing equipment due to reduced soil content. Wienese and Reid (1997) state that the average soil content of mechanically loaded cane in 1996-97 was 1.2-1.6%. The estimated wear and tear cost per 1% soil in cane was stated at R2.50 per ton cane, which has probably increased since then. If one assumes that the cane trash burner can reduce the soil content in the cane by 70%, then the estimated wear and tear savings per ton cane would be 0.7 x 1.4 x R2.50 = **R2.45** per ton clean cane.
4. Benefit due to delivering fresher cane. While correlations have been established between cane staleness and sugar loss, an economic value of potential benefit accruing to fresher cane delivered as a result of the elimination of field burning has not been included here.

Summarising the above figures, the net economic benefit of bringing in the adhering trash into the factory and burning it off in the cane trash burner (excluding the capital and operating cost component of the burner) is estimated at:

-R4.86 + R16.88 + R2.45 = **R14.47** per ton clean cane.