Sugarcane Bagasse as A Alternative Non-Conventional Boiler Fuel

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***Abstract*—The primary goal was to replace PNG (Piped Natural Gas) in a boiler which led to the invention of Sugarcane-Peanut Bagasse made from agro-waste resulted from ice-cream manufacturing. The newly developed bagasse performs way better than the conventional PNG as far as environment is concerned. By using such bagasse as a combustible fuel leads to considerable cost saving as well as reduction in SO_2 NO_X emissions. Moreover, the ash remains after the combustion of bagasse can be used as a replacement of cement in concrete electronic document is a "live" template and already defines the components of your paper [title, text, heads, etc.] in its style sheet.**

Keywords--Bagasse, Sugarcane, Peanut, Moisture, Agro-waste.

I. INTRODUCTION

The fibrous matter remaining after the sorghum stalks or agro-waste's crushing is simply called as a bagasse. Bagasse is an efficient bio-fuel. It is similar to the bagasse made from agave plant. When produced in sufficient quantities, it can be used in sugar mills as a fuel due to the production of sufficient energy by its combustion. Secondary use includes cogeneration (to provide both the heat energy and electricity) which can also be commercialized to sell as grid energy. The amazing fact is that, it balances the amount of carbon dioxide, i.e. it emits the same amount of CO_2, which it absorbed during the phase of its being a plant! How environment friendly this fuel is! There are many places in the world where this green power is used. For example, Florida Crystals Corp Hawaiian Electric Industries. Inspired by the same, we decided to make eco-friendly bagasse from the waste products in Havmor Ice-creams LTD, Gujarat, India.

II. PRODUCTION, STORAGE & COMPOSITION

The ratio of bagasse production and the source from which it is produces is nearly 0.3. It can be said that the country which produces more sugarcane can also produce more bagasse. A common characteristic of a bagasse is that it contains high moisture content, say 45-50% which is detrimental to its use as a fuel. We have somehow reduced this hazard by introducing peanut remains in the bagasse. As peanut has an oily base, it helps in faster combustion of the bagasse resulting in higher efficiency! In addition to this, the way of its raw storage also helps in drying the bagasse. It is stored under moist conditions due to which a mild exothermic reaction takes place between its residues. It is stored in wet condition for paper and pulp production, but in our case we would store it in a way mentioned above. Our bagasse analysis results in following proportion of different elements. Cellulose is 47-57%, Hemi cellulose is 18-23%, Lignin is 20-26%, Ash is 1-4% and waxes are approximately less than 0.8%. The resulted bagasse is very in-homogeneous material comprising around 27-38% of pith fibre which is derived from its raw plant.[1]

III FUEL PROPERTIES

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This matted cellulose fibre when processed in mill produces energy. Previously when there were not scares of conventional energy resources, such remains were treated as waste only and were dumped in the dumping zone. However, since last 3 to 4 decades we are facing crisis in terms of availability of conventional fuels as well as pollution resulted from them. In such a situation, bagasse has come up as an alternate resource and can save a considerable amount of conventional resources when treated mindfully. [3]

III. BAGASSE COMBUSTION PROCESS DISCRIPTION

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Figure 1: Bagasse: As a row material

Basically there are two stages of bagasse combustion. 1. Primary Combustion 2. Secondary Combustion

1. Primary Combustion: It refers to the physical and chemical changes occurring on the fuel bed. It comprises of the drying de-volatilization ignition and burning of the bagasse.
2. Secondary Combustion: It refers to the oxidation of the bagasse and particulate matter released in the primary combustion phase. It is aided by high temperature, sufficient air and turbulence in gas stream. The turbulence must be intense and last longing to ensure adequate mixing at elevated temperature. Time, Temperature and Turbulence air (TTT) require delicate balance for complete combustion of the bagasse. The disturbance in one or more of these variables can result in measurable increase in emission of CO (Carbon Monoxide) and other organic compounds. Such CO compounds are counted as volatile organic compounds or total organic compounds.

Feeding Techniques: Boiler most common among older plants, bagasse used to be gravity fed through chutes and piles up on a refractory hearth.

From the 8 to 15 feet long sugarcane plant, only stalk contains necessary characteristics to be turned into a bagasse. All other parts of the sugarcane (i.e., leaves, top growth, and roots)are termed "trash". Minimum trash/extraneous material is the main objective of harvesting the crop. The cane is normally burned in the field to remove a major portion of the trash and to control insects and rodents. The three most common methods of harvesting are: 1.handcutting 2.machine cutting and 3.mechanical raking. The cane that is delivered to a particular sugar mill will vary in trash and dirt content depending on the harvesting method and weather conditions. Inside the mill, cane preparation for extraction usually involves washing the cane to remove trash and dirt, chopping, and then crushing. Juice is extracted in the milling portion of the plant by passing the chopped and crushed cane through a series of grooved rolls. The cane remaining after milling is bagasse.

IV BOILER OPERATING PROCEDURES

Boiler operating procedures can influence uncontrolled emissions from bagasse-fired boilers. First, like other waste-fired boilers, bagasse boilers may use auxiliary fuels for start-up. In our case, the PNG is usually the start-up fuel, the initial sulfur dioxide (SO_2) and nitrogen oxides (NO_x) emissions are higher than when bagasse alone is fired. The duration of startup typically for a normal bagasse boiler isupto8hours. On the other hand, the bagasse made by us contains peanut trash which makes it a little oily. This leads to the reduction in lead time by 3 hours. During the waiting period, particulate matter (PM) emissions may increase due to poor combustion conditions in the boiler while it is cold. In most are as, bagasse boilers are started up once at the start of the harvest season and are not shut down until the end of the season, unless it is absolutely necessary. In Hawaii, the boilers are operated differently in that they are shut down on weekends unless they are cogenerating electricity. For economic reasons, cogeneration boilers typically operate continuously nearly year round. Also, bagasse-fired boilers in Hawaii are generally more efficient than in other are as due to lower fuel moisture contents, larger boiler sizes, and the placement of the stoker feed system higher above the grate to increase suspension burning. Second, most bagasse boilers may require an auxiliary fuel (normally fuel oil or natural gas) at times to produce the total energy needed for the facility to sustain good combustion with wet bagasse. As is the case during start up, combined oil and bagasse firing will increase SO_2 and NO_x emissions. Auxiliary fuel is used when ever additional heat input is required. If the supply of bagasse to the boiler is interrupted, auxiliary fuel will be used to provide up to 100 percent of the heat input of the boiler. During these periods, SO_2 and NO_x emissions will increase.

TYPICAL BAGASSE COMPOSITION

Proximate Analysis	%
Moisture	44.9
Ash	0.8
Volatile Matter	49.6
Fixed Carbon	4.7
Ultimate Analysis	
Carbon	19.2
Hydrogen	2.6
Sulfur	<0.1
Ash	0.8
Nitrogen	0.15
Oxygen (By Difference)	77

V FIRING METHODS

Fuel cells, horse shoe boilers, and spreader stoker boilers are used to burn bagasse. Horse shoe boilers and fuel cells differ in the shapes of their furnace area but in other respects are similar in design and operation. In these boilers (most common among older plants), bagasse is gravity-fed through chutes and piles on to are factory hearth. Primary and over fire combustion air flows through ports in the furnace walls burning begins on the surface pile. Many of these units have dumping hearths that permit ash removal while the unit is operating. [4]

In more recently built mills, bagasse is burned in spreader stoker boilers. Bagasse fed to these boilers enters the furnace through a fuel chute and is spread pneumatically or mechanically across the furnace, where part of the fuel burns while in suspension. Simultaneously, large pieces of fuel are spread in a thin, even bed on a stationary or moving grate. The flame over the grater adiates heat back to the fuel to aid combustion. The combustion area of the furnace is lined with heat exchange tubes (water walls).

VI. POLLUTANT EMISSIONS

The most significant pollutant emitted by bagasse-fired boilers is particulate matter caused by the turbulent movement of combustion gases with respect to the burning bagasse and resultant ash. Emissions of sulfur dioxide (SO_2) and nitrogen oxides (NO_x) are lower than conventional fossil fuels due to the characteristically low levels of sulfur and nitrogen associated with bagasse. Auxiliary fuels (typically fuel oil or natural gas) may be used during startup of the boiler or when the moisture content of the bagasse is too high to support combustion; if fuel oil is used during these periods, SO_2 and NO_x emissions will increase. Soil characteristics such as particle size can affect the magnitude of particulate matter (PM) emissions from the boiler. Cane that is improperly washed or in correctly prepared canal so influence the bagasse ash content. Upsets in combustion conditions can cause increase demissions of carbon monoxide (CO) and unburned organics, typically measured as volatile organic compounds (VOCs) and total organic compounds (TOCs).

VII. CONTROL

Mechanical collect or sand wets crubbers are commonly used to control particulate emissions from bagasse-fired boilers. Mechanical collectors may be installed in single cyclone, double cyclone, or multiple cyclone (i.e., multiclone) arrangements. The reported PM collection efficiency for mechanical collectors is 22 to 62 percent. Due to the abrasive nature of bagasse flyash, mechanical collector performance may deteriorate overtime due to erosion if the system is not well maintained. The most widely used wet scrubbers for bagasse-fired boilers are impingement and venturi scrubbers. Impingement scrubbers normally operate at gas-side pressure drops of 5 to 15 inches of water; typical pressure drops for venture scrubbers are over 15 inches ofwater.[5] Impingement scrubbers are in greater use due to their lower energy requirements and fewer operating and maintenance problems. Reported PM collection efficiencies for both scrubber types are 90 percent or greater. Fabric filters and electro static precipitators have not been used to a significant extent for controlling PM from bagasse-fired boilers because both are relatively costly compared to other control options. Fabric filters also pose a potential fire hazard. Fugitive dust may be generated by truck traffic and cane handling operations at the sugar mill. PM emissions from these sources may be estimated.

VIII. OPERATING EXPERIENCE FOR BAGASSE AS A FUEL

Data obtained in two investigations of bagasse as a boiler fuel are interpreted to obtain information on the properties and combustion of bagasse. Bagasse has a uniform heating higher value near 8300 British Thermal Unit/Pound (19,300 kJ /kg), an ash content range from 0.8 to 18 percent, and an intrinsic ash content of about 1.5 percent. It is shown that the common sulfated ash determination overestimates the actual ash content by about 50 percent. Data on furnace draft and tramp air are used to show that the cells of pile-burning furnaces operate at about 60 percent excess air[6]. Data is presented which shows that proper utilization of bagasse in spreader-stoker furnaces has been obtained, but both inadequate turbulence and improper fuel distribution can deteriorate their performance. Bagasse is the fibrous and pithy material remaining after the sugar containing juice has been crushed and squeezed from the sugarcane. In our case, it also includes peanut trash and other crop trash. Raw sugar is obtained from this juice in a process involving clarification, concentration and crystallization, and each of these steps requires energy, usually in the form of low pressure steam. The whole process requires approximately 6 kg of steam/kg of raw material. About 0.3 kg of bagasse/kg of raw material is available for waste fuel. Bagasse is similar in many respects both physically and chemically to other cellulosic waste fuels. The average chip size is between 2 mm and 1 cm, moisture content is usually near 45 percent (on an as-fired basis).
Proximate analysis indicates approximately 49.6 percent volatiles and 4.7 percent fixed carbons while ultimate analysis indicates 23.9 percent carbon, 2.6 percent hydrogen, and 77 percent oxygen.

Approximately a third of the initial mass of raw material becomes bagasse, so there is a very large waste stream to contend with during grinding. The practice of burning bagasse in boiler furnaces has been viewed in the past partially as a simple incineration of this waste while energy recovery has been secondary. With current energy prices, assured future escalation and potentially limited supply, optimum bagasse energy utilization is a high priority goal for this industry.

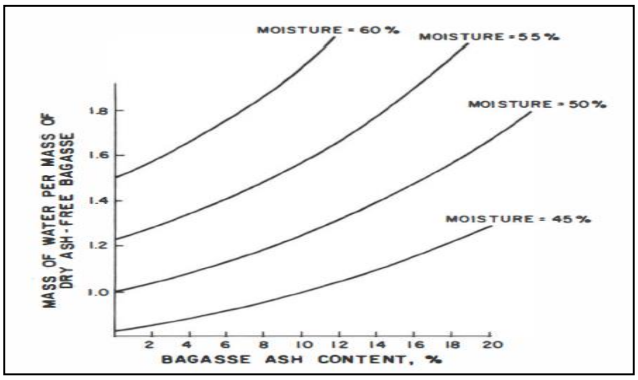

Figure 2: The graph of water content per mass of Dry Ash free bagasse VS %Ash content [3]

IX. CELL BURNING OF BAGASSE

A typical pile burning bagasse boiler consists of a modestly rated boiler section on top or just to the side of a furnace which is divided in to two sections. The top section of the furnace is open, is usually refractory lined rather than water wall, and contains openings for supplemental fuel firing and feed chutes for dropping bagasse in to the cells in the lower section. The lower section is broken into cells which are typically 7 feet (2 m) in average diameter, round or oblong, and approximately 7 ft (2 m) high. Most installations employ two or four cells although three cell arrangements have been used. The cells are refractory lined with refractory floors. Air is introduced through tuyeres in the cell walls generally at two levels; within 8 in. (20 cm) of the floor, and near the top of the cell.

Relatively low pressure forced draft air is used with plenum pressures of approximately 500 Pascal. The bagasse pile is conical with a 60 deg. slope. The base of the pile extends to the perimeter of the cell when fully charged.

Burning of the bagasse occurs in three overlapping zones; the drying zone near the top of the pile, the volatilization zone near the mid-level of the pile and the char burnout zone around the base of the pile. Traditionally, most of the forced draft air has been directed at the char burning zone. Energy is radiated from the luminous char to the surrounding refractory and a portion of this is reradiated to the pile to promote drying and volatilization. Refractory arrangement is obviously important, although little design effort has been directed towards this aspect of bagasse burning. The volatiles mix with air and burn in the cell above the pile or in the upper section of the furnace. Radiation from the burning volatiles, or the hot combustion products, could contribute to the energy radiated to the drying and volatilization zones. However, lack of a large luminous flame probably indicates limited radiation from this source.

X. STROKER FIRING OF BAGASSE

Bagasse is fired in spreader-stoker furnaces in a manner similar to other waste and fossil fuels. The usual problems associated with feeding this waste material, distributing it evenly on the grates, and proportioning the air between under grate and over fire occur with bagasse as with the other fuels. However, proper operation can be achieved. This is indicated by K wok's data for two identical spreader stokers at one factory. Excess air for these units ranges from 25 to 100 percent but for the most part remained within the range of 40 to 70 percent.[7] Figure 4 is a plot of the percent of energy lost in the flue gas combustible, Fc, for data from both boilers. The solid line in these plots is eye-ball brackets of the observed data. The parabolic shape is typical for spreader-stoker firing. The pronounced low excess air wing indicates a lack of available oxygen for combustion under mixing conditions which can be achieved in these large units.

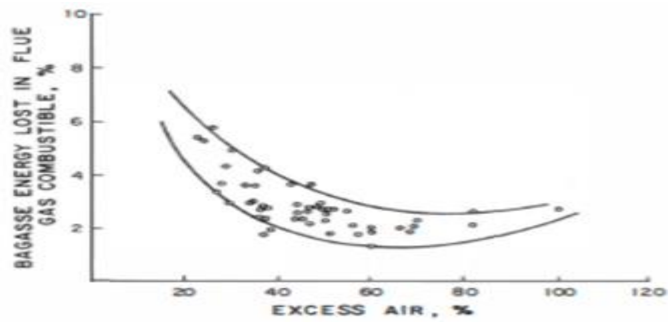

Figure 2: Energy Loss VS Excess Air % [2]

XI. SUGGESTION OF A NEW BOILER, RUNNING WITH SUGARCANE BAGASSE.

We have consulted with Praj sales and service about the new boiler which would work on both the bagasse and PNG. The specifications provided by them are as follows. Our motto was to have a boiler working on the bagasse. But it is also important that in case of emergency when the available quantity of bagasse is not enough to fulfill the fuel requirements, it is necessary that a secondary provision be provided. For that, we consulted Praj sales and services, which deals with commercial boilers. The specific details along with the dimensions of particular components are given in the tables below.

Customer : M/s. Havmor Ice Cream Ltd, Ahmedabad		
Offer Reference. Env/BF/Pun/AMS/364058/Rev 0		
		BF 1
	Units	Online Bagfilter for 2 TPH Boiler
Inputprocessdataforeachfilter		
Quantity of filters	no	1
Application		Boiler
Firing Type		Manual
Type of Fuel		100% Imported Coal 100% Kutch Lignite 100% Rice Husk 100% Biomass Briquette (Briquette contains : GN Shell, Saw dust as binding material)
Bag filter is not designed for fouling fuels like Mustard stalk, Mustard husk, 100% Ground Nut shell, 100% Wood, Coconut Shell, Soya briquette fired in boiler, Incase these fuels fired in boiler bagfilter shall be bypassed.		
Bag filter is designed for Biomass fuels in briquette form only, if these fuels are fired in loose form in boiler, additionally spark arrester need to be provided which is in customer scope		
Dust to be handled		Flyash
Gas flow rate	Am3/hr	6000
Bagfilter is designed on ID fan volume basis		
Gas temperature (Minimum)	°C	180
Gas temperature (Maximum)	°C	210
We recommend to use Bagfilter 20°C above acid dew point temperature to avoid corrosion with Bagfilter.		
Bag filter will be bypassed for temperature above 240 deg C.		
Gas pressure at BF inlet	mmwc	-175
Inlet dust load	gm/Nm3	8
Oxygen Content in flue gas	%	5
SO2 Content in flue gas	%	0.01
Moisture in gas	%	7
Type of dust (Main Characteristic)		Fine
Dust Min bulk density for RAV sizing	Kg/m3	> 210
Dust Max bulk density for power	Kg/m3	800
Dust size distribution		100% > 5 •

Table 1: Specification

Customer : M/s. Havmor Ice Cream Ltd, Ahmedabad		
Offer Reference. Env/BF/Pun/AMS/364058/Rev 0		
		BF
	Units	Online Bagfilter for 2 TPH Boiler
Technical datasheets for each filter		
Type of filter		Pulse jet
Filter mounting		Structure
Filter cleaning		Online
Gas entry		Casing
Design pressure (incl wind load)	mmwc	± 500
Operating Δ P across filter	mmwc	150
Max. Δ P across filter	mmwc	200
Δ P across ICBD	mmwc	25
Total Δ P	mmwc	225
Maximum outlet dust emission	mg/Nm3	100
Outlet emission committed at the outlet of bagfilter before ID fan.		
Offered bag height	m	3.6
Offered filtration area (Gross)	m2	167.808
Offered air-to-cloth ratio (Gross)	m3/min/m2	0.60
Selected filter		AJC-108(96)-
Number of bags offered (Gross)	no	96
External painting of filter- Primer		Red Oxide
External painting filter- Finish		Not in TL
External surface preparation of filter		Manual wire
External paint spec of filter- Primer		2 coats, 20 • each
External paint spec of filter- Finish		NA
Internal painting of filter		Red Oxide
Internal surface preparation of filter		Manual wire
Internal paint spec of filter		2 coats, 20 • each
Insulation & cladding scope		Not Provided by
Insulation & cladding requirement		Required
Mineral wool insulation spec		LRB,100
Mineral wool insulation thk	mm	75
Aluminum cladding spec		22 SWG
Filter casing		
MOC		IS 1079 Gr
Thickness	mm	3
Condition of supply		Assembled
Filter Tube sheet		
MOC		IS 2062 Gr

Table 2: Specification

Procedure for the data regarding consumption of PNG per day in SCM, we have prepared the tables as follows. The initial reading is taken at 7 am daily and the final reading is taken at 7 pm daily. It is important to note that the readings have been taken from reliable company equipment's.

The consumption of PNG gas per day is given here as per our observation:

Date	Initial Reading	Final reading(kg)	Consumption (kg)
02/08/2014	568579.433	569049.133	469.00
09/08/2014	571299.187	571624.715	325.428
16/08/2014	573148.106	574142.365	708.863
23/08/2014	576713.258	577270.148	458.614
28/08/2014	578229.681	578842.951	613.109
06/09/2014	581070.357	581608.258	583.698
19/09/2014	601538.789	602008.315	481.581

Table 3: Cost Evaluation

Bagasse Ash Waste: The ash can be used as a soil fertilizer.

Figure 3: Bagasse Ash [9]

Other Uses:
Partial cement replacement in concrete.

Concrete:
4 main ingredients:

- Water,
- Cement,
- Coarse,
- Aggregate

Fine Aggregate: Aggregates act as fillers while the cement and water are the binders that hold everything together.

Figure 4: Concrete powder [10]

XII. CONCRETE POWDER

Concrete:
Portland cement: A finely-ground material that is mainly composed of lime, silica, alumina, and iron. Manufacturing of Portland cement accounts for 5% of the world's carbon emissions. To reduce environmental impact, pozzolanic materials can be used as a partial cement replacement

XIII. PROPERTIES OF BAGASSE ASH

High silica content: 87%, Cement's silica content: 22%, Low specific gravity: 1.80, Cement's specific gravity: 3.15Percent passing 45 micro meter: 95%, Cement percent passing 45 micro meter: 82% Bagasse ash can increase the overall strength of the concrete when used up to a 20% cement replacement level. Bagasse ash is a valuable pozzolanic material and it can potentially be sold at a price similar to that of slag and fly ash. Currently, bagasse ash is not sold as a pozzolanic material. However, other similar materials sell for these amounts.

Material	Cost
Portland Cement	Rs. 6400/ton
Fly Ash (Coal By-Product)	Rs. 3100/ton
Slag (Steel By-Product)	Rs. 2387/ton

Table 4: Relative costs of materials used in concrete

XIV. CONCLUSION

Following conclusions have been made from thee experimental study carried out for the switch over of a boiler:
A potential alternate fuel source has been identified. By using the suggested fuel, the company can save a considerable amount of money as well as can play their role in nurturing the environment. The use of bagasse ash can also help in increasing the concrete strength and reducing the overall cost. In future we will try to make a bagasse which would emit even less PM. We will also try to increase the efficiency of the boiler. We believe that by adopting the change suggested, they can maximize their profit and environment can also be preserved!

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