Improve the Efficiency of Boiler by Reduce the Moisture in Bagasse

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***Abstract*: The aim of project is remove the biogases moisture and improve the boiler efficiency. Bagasse is a by-product of sugar milling and improvement fuel resource for that industry. It is a fibrous, low density material with very a very wide range of particle sizes and high moisture content. Its chemical properties are similar to those of hardwood fiber. It is difficult to characterize the physical properties of bagasse particles in the usual ways (i.e. by particle density, size, drag co-efficient, etc.).These properties are necessary to apply normal design procedures. For example, pneumatic conveying, fluidization, drying, combustion, etc. Normally gravimetric method is used for moisture content determination. Generally the moisture level up to 50% after the milling process. Because of moisture content its calorific value are affected. So burning of bagasse at suitable level of moisture is essential from the viewpoint of furnace performance. Here the moisture is removed by direct and indirect methods. The method of influencing conduction, convection and radiation process. By the utilization of exhaust flue gas as a source for moisture removal of bagasse.**

Keywords: Boiler, Bagasse, Calorific Value, Moisture content, Dryer, Heat transfer, Fuel.

I.INTRODUCTION

Bagasse is a by-product of cane which can be obtains after the extraction of sugar juice from the cane. Moisture is directly influence with its calorific value. By remove/reduce moisture the performance of furnce is improved in boiler. Here the moisture is removed by the conduction, convection and radiation process. Generally drying is refers to the removal of moisture from a solid by evaporation. Based on the mode of heat transfer, Bagasse dryers can be classified into two types

1. Indirect or non contact dryers. 2. Direct or contact dryers.

Indian standards IS 6997- 1973[1]. Test code for sugarcane crusers. pressure and temperature are taken as reference from steam tables[2] (S.I.UNITS R.S.KHURMI).

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II. BAGASSE PREPARATION AND STABILIZATION

INDIRECT DRYERS:

They are also called as non-adiabatic units, where the heat transfer medium is separated from the product to be dried by a metal wall. In the case of drying of bagasse, the heat transfer is only through conduction and forced convection. Irradiative heat transfer taken place because of lower temperature levels of operation. The indirect drying method can be tried for bagasse with low pressure steam (3atm or less) by adopting large tube bundles, inside a large bin. Typically the bagasse moisture can be reduced from 50% to 45%. A dryer handling 90TPH through put of wet bagasse at 50% initial moisture can be dried to around 86TPH of bagasse at 45% outlet moisture with around 4.0 TPH of evaporated moisture. The dryer would consume around 6.3 tons of low pressure steam. Even after discounting for the energy of steam used and the electrical power required for the drive of dryer motor, this can be significant energy economy because of increased boiler efficiency and increased boiler steam output. The increase in boiler efficiency and the increase in steam to bagasse ratio because of lower moisture content in bagasse.

A typical indirect dryer for bagasse application can be a bin dryer. The large bin is kept vertical with large diameter (100 or150mm) pipes passing along the vertical axis at a pitch of 450 to 600mm and bin circumference is also lined with vertical steam pipes. The pipes are fed at the top with low pressure steam with radial outlets from a common feed header, reaching to individual pipes. The pipes are again connected together at the bottom end and the condensate removed out of the system. The bagasse is charged to the dryer at the top from belt conveyors. The bagasse descends vertically down to the bottom where it is extracted by bagasse extractor. During its travel down the container bin, the bagasse gets dried by physical contact with the steam pipes and the liberated water vapour travels up and out of the container bin. As on date there are no non-contact type bagasse drier functioning any where successfully. The above description is of a drier with promising feature that can be given a trial.

DIRECT DRYERS:

Direct dryers or adiabatic or contact type dryer, transfer heat contact of the product with the hot gases. The gas transfer sensible heat to provide the heat to provide the heat of vaporization of the moisture present in the solid. It is possible to obtain some non luminous radiation heat transfer benefit also in this case, since the moisture content in bagasse is quite high. Direct heating is preferred wherever feasible, for the following reasons.

1 .Rate of heat transfer is high due to direct contact between the flue gas and the raw material.

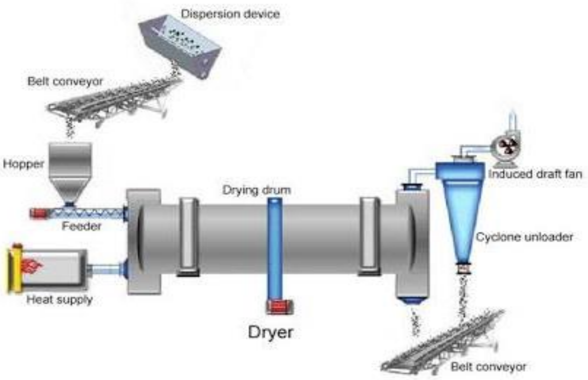
2. Short residence time.

3. Uniform drying.

Drum type rotary can be selected for direct drying bagasse. The waste flue gases at boiler outlet or other suitable temperature level waste gas can be used for this purpose. Generally rotary dryers operate in concurrent mode to avoid possibility of ignition. However, since bagasse contains very high moisture and the waste gases contain significantly low quantities (less than 10% by weight) of oxygen, a counter current dryer can be advantageously adopted to save on cost and space for dryer installation. Never the less, contact type dryers will have suitable provision for firefighting because of possibilities of leakages air ingress.The main component of this dryer is a steel set up on rollers by means of bandages (hoops) located in the shell. The cylindrical is usually inclined with a slope to the horizontal so that the solids slowly progress through the dryer under gravity, but the characteristic action of the dryer is provided by the longitudinal lifting baffles known as flight, which collect the material and subsequently shower it through the flue gas stream as the barrel rotates. These lifters are fastened to the inner surface of the drum.The additional requirement for direct (contact type) dryers, is that it becomes necessary to separate the waste gases (with dried out moisture) from the fine dust bagasse that would be carried along. This concept therefore requires additional investments.

There were some contact type direct dryer tried for bagasse dryer in a certain location in India. The dryer was later dismantled since there were operational problem that had to be addressed to, before making it suitable for continuous operation. Bagasse drying is a concept which deserves additional attention and developmental efforts. Since the ultimate aim is to achieve energy economy in the combustion of bagasse, it is necessary that the energy balance is always kept in mind while various concepts are developed.Here we select the direct method because the indirect drier method having more conflicts in its operation. In India most of the industries are removed the indirect drier method for more time consuming and low moisture removal rate.Its moisture removal rate up to 5% but the direct drier methods moisture removal rate 8-10% from the natural moisture of bagasse.

III. EXPERIMENTAL SET UP



CAPACITY OF DIRECT DRIER:

i) To dry the wet bagasse from the initial 50% to 40% of moisture

ii) Capacity up to 100 tons per hour or 2250 tons per day, based on input. This drier can use chimney temperature of as low as 1500°c

iii) The same drier can also dry wet bagasse from 50% moisture to 25-30% of moisture, provided the flue gas temperature in the chimney is up to 2000°c.

REASON FOR DRYING BAGASSE:

A) INCREMENTAL CALORIFIC VALUE:

When any fuel is burnt its heat generating capacity is indicated by a term calorific value which means the quantity of heat generated by burning a unit weight of the fuel. The total heat generated by burning a unit of weight of fuel is known as gross calorific value (GCV). If the latent heat of water vapour in the combustion of gases is not recovered, it is lost in the flue gases along with the sensible heat of water formed by combustion. The balance quantity of heat is known as Net calorific value (NCV). Water has no calorific value, but on the other hand it absorbs heat in getting vaporized, and as such this process reduces the calorific value of wet bagasse.All the constituents of mill wet bagasse with the exception of moisture are combustion. But the presence of water in bagasse reduces its fuel value, as a part of the heat value of bagasse is used for the evaporation of moisture content of bagasse, before bagasse can catch fire. Thus heat is wasted.

High calorific value,

HCV = (19605-19605(moisture % sample)-19605(ash % sample) -3114(brix % sample)

= (19605-(19605*50)-(19605*5)-(3114*2))

= 8760.0 kj/kg (or) 2091.88 kcal/kg.

B) HEAT RECOVERY:

Bagasse driers offer a great advantage of permitting the flue gas temperature
to be brought down to the lowest level. Bagasse drying gainfully uses the flue gasses.

C) REDUCED AIR POLUTION:

Bagasse drying is considered as a method to solve air pollution problems in the co-generation plant.

D) BAGASSE SAVING:

A 2500 TCD sugar mill generates 750 tons of bagasse per day with 50% moisture. When the same is dried to 30% moisture, the increased calorific value even after taking into account the weight loss is 20-22%. This implies that by drying bagasse up to 30% moisture, sugar factories can save 150 tons of bagasse per day with 50% moisture, which will be a saving of 24000 tons on 160 days of working the saved bagasse, can be sold to the nearby paper mills after depithing & subsequent drying.

COMBUSTION:

Combustion is an exothermic oxidizing reaction .Its mechanism is not fully understood, but for practical purposes the products of combustion of a fuel such as bagasse can be determined from its ultimate analysis as shown in table 3.1. In a furnace the oxidizing agent is air and the main products of combustion are nitrogen, carbon dioxide, water vapour and oxygen. Secondary products are the Oxides of trace elements such as sulphur, phosphorous and vanadium.The simplest way of measuring combustion efficiency is to determine the percentage by volume of carbon dioxide, oxygen and carbon monoxide in the flue gases. A trace of carbon monoxide indicates incomplete combustion whilst the carbon dioxide or oxygen figures indicate incomplete the quantity of excess air present.

The heat released when oxidizing carbon to carbon to carbon dioxide is 14,590 B.T.U/1b while only 10,210 B.T.Uj1b are available if carbon is oxidized to only carbon monoxide. In practice unfortunately, to ensure complete combustion a small amount of excess air is needed.

E) ENERGY BALANCE ON DRYING OF BAGASSE:

1) Generation of equivalent units of electricity from 200 kgs of saved bagasse.

2) Net saving of bagasse.

3) Monetary value of electricity generated from saved bagasse.

Depending on the type of fuel and furnace design, this varies from 10Wo 50%, over and above that required for theoretical combustion. The products of combustion are thus diluted and the efficiency of heat recovery is reduced. The reduction in efficiency, however, due to incomplete combustion far outweighs the loss due to the small amount of excess air required to complete combustion. Fig. 3.1 shows the relationship between “excess air” and percentage carbon dioxide for a number of different fuels.

STEAM CONDITION IN A CANE SUGAR FACTORY:
PROPERTIES OF SUGARCANE BAGASSE:

CHEMICAL PROPERTIES	DESCRIPTION
Proximate analysis "as fired"	
Carbon C%	11.5
Volatile%	37
Water%	50
Ash%	1.5
Total	100
Ultimate analysis "as fired"	
Carbon C%	22.5
Hydrogen H%	3
Sulphur%	Trace
Nitrogen%	_
Oxygen%	23
Phosphorus%	_
Moisture%	50
Ash%	1.5
Total	100

COMBUSTION EQUIPMENT:

Combustion equipment must be robust, easy to maintain, consume a minimum of power, and enable the fuel to be burnt as completely as possible in the furnace without using too much excess air. Different fuels require different types of combustion equipment to meet these conditions.

BAGASSE:

These two fuels, because of their high moisture and volatile contents are essentially gaseous in character. The most efficient way of firing them therefore is to introduce them into the furnace in a similar manner to a gas, i.e. with a proportion of the combustion air illustrate typical furnaces. Due to their relative bulkiness and the fact that neither bagasse nor hogged timer can be stored successfully in a diverging bunker, a furnace having large storage and thermal inertia characteristics can be installed. Fig. 9.2B illustrates a typical example of this type of unit. Should the bagasse supply fail, continuous steaming can be maintained for a period of some 10 to 20 minutes thus providing a reasonable time for bagasse to be reclaimed from store to maintain load, or in the event of a bagasse carrier failure to enable auxiliary power equipment to be brought on line.

Whilst most of the ash produced in this type of unit is disposed of while the boiler is on range through collectors in the boiler itself, the furnace must be shut down at weekly factory shutdown. The furnace is extremely simple, has no moving parts and possesses self feeding characteristics which simplify auto- control. The state of the bed is quiescent in relation to suspension firing which reduces grit carryover and smut emission considerably. Grit collectors can be dispensed with whereas they are considered essential with suspension firing.

IV. BOILER AND TURBINE USED IN KOTHARI SUGAR MILL

BOILER:

In the boiler drum and tubes, water circulates due to difference between the density of water in the lower temperature sections of the boiler. Wet steam from the drum is further heated up in the superheated for being supplied to the prime mover. (i.e., water converted in to steam)

TYPE OF BOILER:

BI-DRUM WATER TUBE BOILER.

Use	Equipment	Steam conditions	Remarks
Electrical Power generation	Turbo alternator of: Back pressure, pass Out/condensing or Condensing design	200-900 p.s.i.g. 600-850°F	Power is generated by expanding H.P. Steam down to process conditions,i.e., 30-40 psi sat. Where condensing facilities are included,thus cater for balancing electrical and steam loads and/or meeting off crop power demands
Mill Drives	a)Electrical	_	Power obtained from main turbo-alternator station
	b)Steam turbine	300-450 p.s.i.g. 650-750°F	Small horse powers produce higher steam conditions. Due to high efficiencies,pressure reducing and desuperheating plant required to balance factory load
	c)Reciprocating steam engine	100-250 p.s.i.g. sat-550°F	High capital cost of plant and foundations and oil entrainment in steam have tended to make this type of prime mover obsolete
Process	Evaporators,juiceheaters,pans,etc.,	Up to 40 p.s.i.a.sat	Since the heat transfer coefficient of saturated steam is about 10 times higher than superheated steam, superheated conditions should be avoided.

SPECIFICATION

Heat transfer area 2503 m² each
Pressure 66 kg/cm²
Temperature 485 °C
Steam generation 40 TPH each

Water line:

Economizer inlet temp 105°C
Economizer outlet temp 250°C

Air line:

Air pre-heater inlet temp 32°C
Air pre-heater outlet temp 180°C
Flue gas line**:**
Economizer inlet temp 385°C
Economizer outlet temp 210°C
Air pre-heater inlet temp 210°C
Air pre-heater outlet temp 140°C

TURBINE:

Turbines are the hydraulic machines which converts steam energy in to mechanical energy.The mechanical energy is used in running an electric generator which is directly coupled to the shaft of the turbine. Thus the mechanical energy converted in to mechanical energy.

TYPES OF TURBINE:

BLEED CUM BACK PRESSURE TURBINE.

SPECIFICATION:

Number of stages	11
Speed	7500rpm
Capacity	40 TPH
Inlet temp of steam	475°C
Bleed temp of steam	254°C
Outlet temp of steam	170°C
Inlet pressure of steam	63 kg/cm²
Bleed pressure of steam	7.0 kg/cm²
Outlet pressure of steam	2.5 kg/cm²

V. RESULTS AND DISCUSSION

FORMULAE USED:

01. Boiler Efficiency

$$\eta boiler = \frac{\text{Heat absorberd by the steam}}{\text{Heat liberated by the combustion of fuel}}$$

$$\% \eta boiler = \frac{ma(h3-h1)}{c.v} * 100$$

02. Actual Evaporation

$$ma = \frac{\text{mass of steam generated}}{\text{mass of fuel used}}$$

03. $Ma = \frac{Mw}{Moil}$
04. H3=hsup
=hg+Cps(tsup – ts)
05. High calorific value
HCV=(19605-19605(moisture%sample)-19605(ash%sample)-3114(brix%sample))
06. Low calorific value:
07. LCV= (18309-2076(moisture%sample)-(ash%sample)-3114(brix%sample))

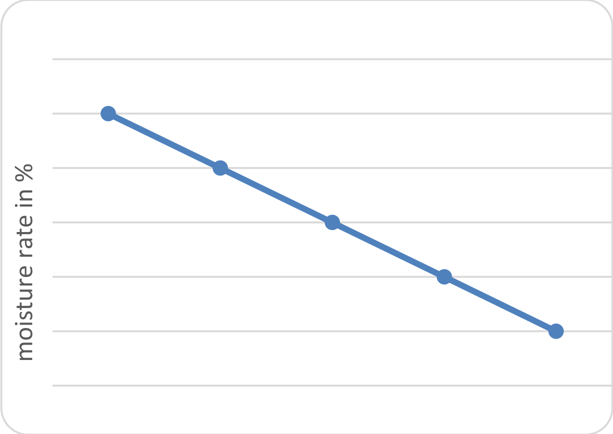
TABULATION:

Calorific value are obtained from calculation depends upon the moisture% sample, ash % sample, brix % sample.

Moisture % sample	**Ash % sample**	**Brix % sample**	**High calorific value(kj/kg)**	**Low calorific value(kj/kg)**
50	5	2	8760.0	6886.5
40	5	2	10720.5	8962.5
30	5	2	12681.0	11038.5
20	5	2	14641.5	13114.5
10	5	2	16821.3	14125.5

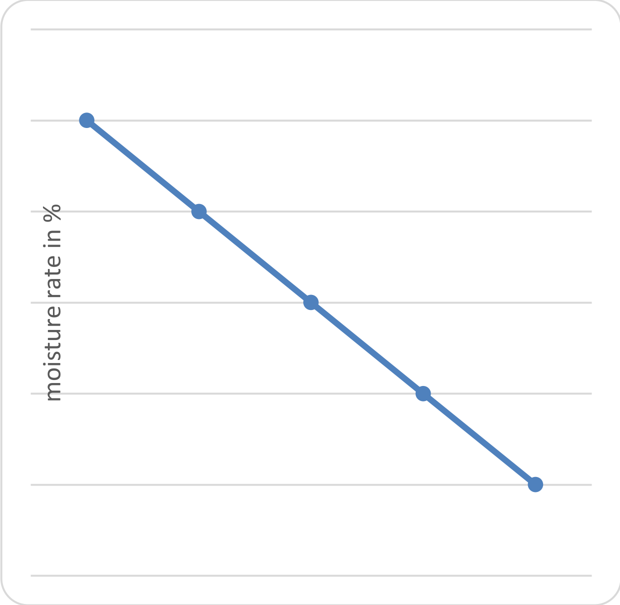
GRAPH:

High calorific value Vs moisture rate in %



GRAPH:

Low calorific value Vs moisture rate in %



STEAM AND BAGASSE FLOW RATE OF THE BOILER:

CALCULATE THE EFFICIENCY OF BOILER BEFORE REDUCES THE MOISTURE IN BAGASSE:

During the test of an bagasse fired water tube boiler the following data were observed shown in table: 10.2

Steam pressure	**Steam generated per minute**	**Feed water temperature**	**Quality of steam**	**Bagasse fired per minute**	**Calorific value of bagasse in 50% moisture**
64.75bar abs	40000kg	105°C	99%dry	20000kg	8760.0kj/kg of fuel

Calculate:

Boiler efficiency: $\%\ \eta\ boiler = \frac{ma(h3-h1)}{c.v} * 100$

Actual evaporation:Ma $= \frac{Mw}{Mf}$

H1=h2 at the feed water temperature of 105°C (From temperature based steam table, S.I.UNITS R.S KHURMI)

H1=445.968 kj/kg

From pressure based steam table
At 64.75 bar
Hg=2779.7 kj/kg
Ts=280.5°C
Tsup=485°C

h3 = hsup= hg +Cps (tsup-ts)
h3 = 2779.7+2.41 (485-280.5)

H3 =3387 kj/kg

Steam flow Rate (tons/ hrs.)	Bagasse Flow rate (tons/hrs.)	Steam Bagasse ratio	Steam Temperature (°C)	Steam Pressure (Bar)	Feed water Temperature (°C)
57.50	26.01	2.21	332.77	21.37	99.16
58.35	26.58	2.20	329.44	20.75	100.44
55.65	25.12	2.12	330.55	20.23	100.11
56.72	26.01	2.18	327.22	20.61	100.77
56.62	25.58	2.21	329.44	20.82	98.79
54.16	24.48	2.12	330.55	19.58	100.22

Ma $= \frac{40000}{20000}$

Ma = 2 kg/kg of fuel

$\eta boiler = \frac{2(3387-445.968)}{8760.0} * 100$

ηboiler= 67.41 %

CALCULATE THE EFFICIENCY OF BOILER AFTER REDUCES THE MOISTURE IN BAGASSE:

During the test of an bagasse fired water tube boiler the following data were observed shown in table

Steam pressure	Steam generated per minute	Feed water temperature	Quality of steam	Bagasse fired per minute	Calorific value of bagasse in 50% moisture
64.75bar abs	40000kg	105°C	99%dry	16000kg	10720.5kj/kg of fuel

Calculate:

01. Boiler efficiency

SOLUTIONS:

Boiler efficiency: $\%\ \eta boiler = \frac{ma(h3-h1)}{c.v} * 100$

Actual evaporation: Ma $= \frac{Mw}{Mf}$

H1=h2 at the feed water temperature of 105°C (From temperature based steam table, S.I.UNITS R.S KHURMI)

H1= 440.15 kj/kg

From pressure based steam table
At 64.75 bar
Hg=2779.7 kj/kg
Ts=280.5°C
Tsup =485°C
h3 = hsup= hg +Cps (tsup-ts)
h3 = 2779.7+2.41 (485-280.5)

H3 =3387 kj/kg

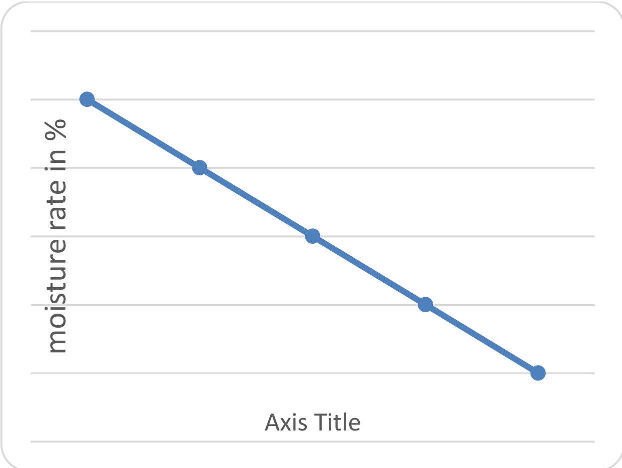
Ma $= \frac{40000}{16000}$

Ma = 2.5 kg/kg of fuel

$\eta boiler = \frac{2.5(3387-445.968)}{8760.0} * 100$

ηboiler= 68.58 %

GRAPH:
Efficiency Vs moisture rate in %



VI. CONCLUSION

Mill wet bagasse contains about 50% moisture. The calorific value of mill wet bagasse is 8760.0 kj.kg or 2280 kcal/kg. Useof driers to reduce the moisture content in bagasse before it's burnt, is regarded as a simple energy conservation measure. This bagasse drying system can also use the waste heat from the boiler flue gases for its partial heat requirement.

That the co-generation plant attached to a sugar factory can generation 2.20kgs of high pressure steam per kg bagasse and 4.40kgs of steam or required togenerate 1KWH of power in the condensing mode.

Hence 2kgs of saved bagasse can generate 1KWH of power or 200kgs of saved bagasse per ton can generate 400KWH of power. A bagasse drier plant of 100 tons per hrs. can save 20 tons of bagasse per hrs. or 450 tons per day or 72000 tons per year on 160 days of working, which is equal to 3.6 core units of electricity per year.

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