IMPROVEMENT OF BOILER EFFICIENCY USING BAGASSE DRYER

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Abstract: - In most sugar industry, sugarcane bagasse is used as fuel to generate steam for sugar Milling and electricity generation. It consists of cellulose, hemicelluloses, lignin, ash and moisture Content. The bagasse Moisture content is an important parameter to control combustion in boilers. Simulated bagasse was used to monitor the effects of moisture content on gross calorific value (GCV) and net calorific Value (NCV) and equilibrium analysis. So burning of bagasse at suitable level of moisture is Essential from the viewpoint of boiler performance.

Keywords— Bagasse, Fuel, Sugar cane residue, moisture content.

1. Introduction

Sugarcane based industry has a tremendous potential and its future is bright in many countries including Egypt. It is an old idea to concentrate on producing sugar alone from sugarcane. The by- products of sugar industry (such as bagasse, filter cake and molasses) today attract as much attention as the conventional main product, sugar. The trend in the sugar producing nations now is to concentrate more and more on by-products - thus rendering sugar ironically, as the by-product

In the past, bagasse was considered as waste material. Today, bagasse has become valuable material. Aside from being used as a fuel, it is a starting material for different products such as paper, paper board, fiberboard, particle board, animal feed, etc. In Brazil, today's leader of sugar industry, the emphasis is on developing a variety of cane having up to 25 % of fiber content since more bagasse signifies higher profits.

Moreover, in Pakistan, the price of bagasse per ton is higher than the price of sugar cane. The value of bagasse may be more than the value of sugar. So it is necessary to optimize the use of bagasse, because of the competition between its use as fuel in boilers and as starting material.

The moisture content in bagasse varies considerably with the degree of extraction, but under average conditions it may be taken as 50 % of the total weight leaving the mills (The average value of the moisture content in bagasse reaches 52 % in almost all the cane sugar factories of the Sugar and Integrated Industries Company SIIC of Egypt in the 1998 harvesting season. The higher the moisture content, the lower is the amount of combustible material per unit weight of bagasse and total available heat, therefore, inversely with the moisture content. Furthermore, the portion of heat which is used to evaporate the bagasse moisture and to superheat the resulting steam to the temperature of the flue gases must be deducted from the total available heat. (Each kg of water in bagasse requires 418 kJ (100 kcal) to reach its boiling point and 2,259 kJ (540 kcal) to convert it into steam.

1.1 Problem Statement

During combustion process in a boiler considerable amount of furnace energy is wasted in evaporating the water contained in the fresh bagasse; therefore decrease the efficiency of combustion. Due to this, it decrease the calorific value, furnace temperature, reduces stability of boilers operation, decreasing the vaporization coefficient and combustion velocity, decreasing the speed of boilers response to load changes and also increment of the losses and decreasing steam production giving rise to flue gases. So in present, work design of such model is necessary which overcomes above parameter up to some extent.

1.2 Objective

Objective of this project is to dry the wet bagasse or remove moisture in the bagasse by using bagasse dryer. To improve the efficiency of combustion, increase the calorific value, increasing the furnace temperature, increasing the energy production, increasing the stability of boiler operation, increasing the vaporization coefficient, increasing the combustion velocity, Increasing the speed of boiler response to load changes, reduction of losses, increasing steam production, decreasing flue gases volume. So, above all efficiency improvement parameter can help to increase the output of boiler efficiency.

1.3 Scope Of The Work

There is a need to decrease the moisture content level in the bagasse because wet bagasse decreases the combustion rate, calorific value & efficiency of boiler. Due to which a sugarcane factory has to face various problems like decrease in production rate, low quality production & loss of energy which can be minimized up to some level. This affects the overall turnover of a factory in good sense.

2. Methodology

i) Firstly determine the moisture content level in wet bagasse & also determine the calorific value & efficiency of boiler.

ii) Discuss alternating methods to reduce moisture content up to large extent.
iii) Selection proper method.
iv) Design of bagasse dryer system.
v) Evaluation of bagasse dryer system.
vi) Availability of various parts of dryer model.
vii) Actual construction of dryer model. Testing of dryer.
viii) Calculation of moisture content level in bagasse.
ix) Calculation of calorific value & efficiency of boiler.

2.1 Drying Mechanism

For the drying process, heat is necessary to evaporate moisture from the surface and a flow of air is needed to carry away the evaporated moisture. During drying, moisture from the interior has to migrate towards the surface, where the evaporation of moisture has to take place. Water vapor diffuses through a boundary film of air and is carried away by the surrounding air. This creates a region of lower water vapor pressure at the surface of the material and a water vapor pressure gradient is established from the moist interior of the material to the dry air. This gradient provides the driving force for the removal of water from the material. Water movement to the surface of the product may be effected due to the following mechanisms; Liquid movement by capillary forces. Diffusion of liquid, caused by differences in the concentrations of solutes in different regions of the materials. Diffusion of liquid which is adsorbed in layers at the surface of the solid components of the material. Water vapor diffusion in air spaces within the material caused by vapor pressure gradients. Typical drying is divided into constant rate and falling rate periods.

The controlling resistance for a drying study may be of energy or mass transfer due to internal or external conditions. The drying rate in the constant rate period is determined by conditions external to the material being dried including temperature, gas velocity, total pressure and partial vapor pressure.

The controlling resistance may be associated with the transfer of energy to the solid or the transfer of mass away from the solid. Mass transfer during the constant rate period involves diffusion of water vapor from the material surface through a boundary layer into the drying medium. During the falling rate period, the drying rate decreases with time, and the rate of internal mass transfer to the material surface typically controls the process. A falling drying rate may be observed when external mass transfer resistance controls and the surface vapor pressure of the solid decreases as the moisture content drops.

2.2 Drying Kinetic

For each and every product, there is a representative curve that describes the drying characteristics for that product at specific temperature, velocity and pressure conditions. This curve is referred to as the drying rate curve for a specific product. The drying rate refers to the rate of evaporation of water from the material. A plot of the drying rate versus product moisture content (MP) is called the drying rate curve. Figure 2.1 shows a typical drying rate curve displaying an initial constant rate period, and at the critical moisture content the drying rate begins to fall with a further decrease in moisture content.

The mechanism underlying this phenomenon depends both on the material and the drying conditions. The drying rate in the constant rate period is governed fully by the rates of external heat and mass transfer, since a film of free water is always available at the evaporating surface. The drying rate in this period is essentially independent of the material being dried.

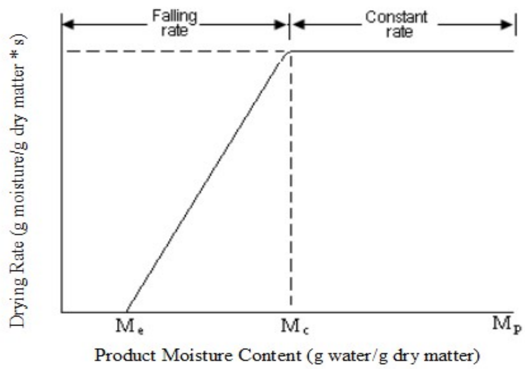

Figure 2.1 Schematic representation of a drying rate curve.

The falling rate period begins to drop at the critical moisture content, since water cannot migrate to the surface at the same rate as in the constant rate drying period because of internal transport limitations. Under these conditions, the drying surface becomes first partially unsaturated and then fully unsaturated until it reaches the equilibrium moisture content. Depending on the nature of the material and conditions of drying, the existence of a continuous drying rate or falling rate period or combined drying rate can exhibit for the drying conditions.

In the most general case, after an initial period of adjustment, the dry basis moisture content decreases linearly with time, following the start of the evaporation. This is followed by a non-linear decrease in moisture content with time until the solid reaches its equilibrium moisture content (Me) where drying stops. The equilibrium moisture content is the limiting moisture to which a given material can be dried under specific conditions of drying air, i.e., air temperature and humidity.

2.3 Important parameters which are useful for improvement of the boiler efficiency

1) Eliminate incomplete combustion.

The heat produced from incomplete combustion of fuel is less compared to complete or good combustion of fuel. It is ultimately a heat loss.

The main causes of incomplete combustion are:
i) Excess fuel supply
ii) Shortage of combustion air
iii) Improper firing of fuel
iv) Improper sizing of fuel (in case of solid fuels)
v) Poor atomization of fuel (in case of liquid fuel)

2) Preheat the combustion air

The waste hot flue gas has enough heat to raise the temperature of combustion air before using for the combustion. Thus waste heat can be recovered from the boiler flue gas. Approximately, 1% thermal efficiency will be increased by raising air temperature by 20^0C. Pre heated combustion air is supplied to the burner, which properly mix this air with fuel and fires into the boiler. Most oil & gas burner in the existing boiler system cannot withstand high air temperature. Which can be raised the combustion efficiency of boiler.

3) Controlling the excess air

Excess air is the additional air supplied beyond the theoretical air to ensure the complete combustion of fuel, so that C, H, & S of fuel are converted into CO2, H2O, & SO2 respectively. Excess air is supplied to the combustion of fuel because a boiler firing without sufficient air or "fuel-rich" is operating in a potentially dangerous condition. So, excess air is supplied to the burner to provide a safety factor above the actual air required for combustion. A quality design will allow firing at minimum excess air levels of 15% (3% of O2). O2 represents oxygen in the flue gas. Excess air is measured by sampling the O2 in the flue gas. If 15% excess air exits, the oxygen analyzer would measure the O2 in the excess air & shows a 3% measurement. The optimum excess air level is depending on burner design & type, furnace design, fuel and process variables. It can be estimated by conducting various performance tests with different fuel/air ratios.

4) Reduce scale and soot formation

Formation of deposits (scales and soot) on water sides or gas sides can reduce the heat transfer and increase the flue gas temperature. The deposits are like a thermal insulation on the tubes, they must be cleaned periodically for better heat transfer and better efficiency.

Reduction of scaling on water side:

i) By proper water treatment and blow down

ii) Cleaning the tubes at shut down period

These deposits are corrosive and may damage to the water tubes in the boiler furnace, economizer, and air preheated or super heater. Thus deposits can reduce the efficiency of all heat exchangers throughout the flue gas path.

Reduction of soot on gas sides

iii) Use of soot blowers, soot blowers are used to soot out the deposits from the tube surface and clean the heat transfer surface by utilizing steam at high pressure. Stack temperature should be recorded regularly, when the flue gas temperature increased about 20°C above the normal value, soot blowers are operated and remove the soot deposits. it is advisable to install a dial type thermometer at the stack to monitor the exhaust flue gas temperature.

iv) Periodic off line cleaning of furnace surfaces, tube banks, heat recovery equipment.

5) Reduce surface heat losses

Radiation and convection heat losses are the surface heat loss depends on surface temperature and ambient temperature. The boiler surface temperature is higher than surrounding ambient temperature; hence heat is naturally flows from high temperature zone to low temperature zone. Wind velocity also affects these losses.

6) VSD for fans, blowers and pumps

Variable speed drives are available for variety of applications and equipment for better speed control with reduction in power consumption. The power consumption by fan or pump is directly proposal to cube of speed. Hence little speed reduction can reduce significant power consumption. Boiler system contains fans, blowers, and pumps for various purposes.

7) pH control

pH is the measure of how acidic or basic the feed water. Feed water must be neutral which save the energy. pH is controlled by either removing impurities or adding other chemicals to neutralized the water or by blow down of water.

8) Fuel selection

The proper fuel specification can also have a effect on efficiency. In the case of gaseous fuel, the higher the hydrogen content, the more water vapor is formed during combustion, which leads higher heat loss due to evaporation of water form by hydrogen in fuel. To get an accurate efficiency calculation, a fuel specification that represents the job site fuel to be fired must be used.

3. DESIGN DATA

3.1. Data collected from Karmayogi Sahakari Sakhar Karkhana.

Fuel firing	5599.17kg/hr
Steam generation rate	21937.5kg/hr
Steam Pressure	43kg/cm²
Generated steam pressure	485°C
Feed water temperature	96°C
Co_2 in flue gas	14%
Co in flue gas	0.55
Average flue gas temperature	190°C
Ambient temperature	31°C
Humidity in ambient air	0.0204kg/kg dry air
Surface temperature of boiler	70°C
Wind velocity around the boiler	3.5m/s

3.2. Fuel Analysis (in %)

Ash content in fuel	8.63
Moisture in fuel	31.6
Carbon content	41.65
Hydrogen content	2.0413
Nitrogen content	1.6
Oxygen content	14.48
GCV of coal	3501Kcal/kg

3.3 Ultimate analysis of bagasse (in %):

Carbon	22.16
Hydrogen	2.84
Oxygen	21.0
Nitrogen	0
Sulphur	0
Ash	4
Moisture	50

3.4 Design of Bagasse Dryer Model In CATIA

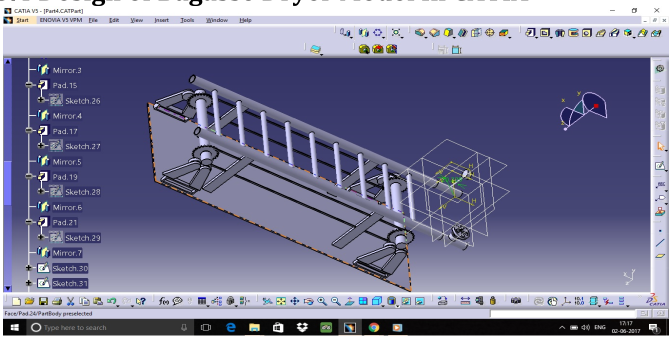

Figure 3.1 Actual model

3.5 Specification of component for experimentation

Sprocket	Teeth=40 Pitch=12.7mm Diameter=161.84mm
Dryer	Small steam tube=10 Length=701.04mm External Diameter=34mm Internal Diameter=27mm Large steam tube=2 Length=1371.6mm Outer Diameter=72mm Internal Diameter=65mm
Chain	Length=3435mm Chain pitch=15.875mm No of links=216

3.6 Component used in bagasse Dryer

3.6.1 Sprocket

Figure 3.6.1 Sprocket

Sprocket is a profiled wheel with teeth, cogs or even sprockets that meets with chains, trap or other perforated or indented material. It is distinguished from a gear in that sprockets are never meshed together directly and differs from a pulley in that sprockets have teeth and pulleys are smooth.

3.6.2 Tubes of Bagasse Dryer

Figure 3.6.2: Tubes of Bagasse Dryer

Bagasse dryer is used to dry bagasse on the conveyor. Due to bagasse dryer moisture in the bagasse decreases which increases boiler as well as system efficiency. So bagasse dryer is very important in sugar industry for decreasing the moisture in the bagasse.

3.6.3 Chain Conveyor

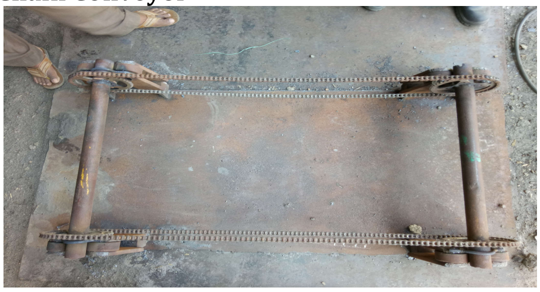

Figure 3.6.3: Chain Conveyor

Conveyor is used to move bagasse from one place to another place that is crushing place to furnace. Conveyor includes sprocket, chains, shaft etc. Conveyor mostly used in industries for moving material from one place to another.

3.7 Actual Bagasse Dryer

Fig: 3.7 Actual bagasse dryer

4. Boiler efficiency

The efficiency of a boiler is the energy imparted to the boiler feed water in its conversion to superheated steam as a percentage of the energy in the fuel. It can be expressed either in terms of the net or gross calorific value. Because the latent heat in the flue gas is not normally recovered, only the boiler efficiency on NCV is of practical value and the one commonly used. For the purpose of boiler calculations, calorific values must be corrected to ambient temperature. One of the standards for determining boiler efficiencies is BS 845 (Anon 1987) but there are other methods being practiced, often with different results. Whichever way it is done it is based either on the 'direct method' or the 'indirect loss method.'

4.1 Direct method

This method calculates boiler efficiency by using the basic efficiency formula-

$$\eta = \text{(Energy output)}/\text{(Energy input)} \times 100$$

In order to calculate boiler efficiency by this method, we divide the total energy output of a boiler by total energy input given to the boiler, multiplied by hundred.

Calculation of direct efficiency-

$$E = [Q\,(H-h)/q*GCV]*100$$

Where,

Q= Quantity of steam generated (kg/hr)

H= Enthalpy of steam (Kcal/kg)

h= Enthalpy of water (kcal/kg)

GCV= Gross calorific value of the fuel.

L2 = Sensible heat loss in flue gas

L3 = Loss due to unburned carbon

L4 = Radiation loss

L5 = other losses

4.2 Moisture Reduction of bagasse

Enthalpy decrease in flue gas = $m_g C_{pg}[T_{gi}-T_{go}]$
Enthalpy increase in dry bagasse = $m_b C_{pb}[T_{bi}-T_{bo}]$
Enthalpy increase in moisture = $M_f h_2 + [M - M_f] \times h_{go} - Mh_1$
Where,
M = Initial moisture content in the bagasse
M_f = Final moisture content in the bagasse
h_{go} = specific enthalpies of H_20 at temperature T_{bo} , T_{bi} , T_{go}
h_1 = 146.7 KJ/KG
h_2 = 227.512 KJ/KG
h_{go} = 2761.099 KJ/KG
Data taken by steam table

The energy balance eq^n. for the bagasse dryer:

$$m_g C_{pg}[T_{gi} - T_{go}] = m_b C_{pb}[T_{bi}-T_{bo}] + M_f h_2 + [M - M_f] \times h_{go} - Mh_1$$

4.3 Result

i) The moisture reduction of bagasse is 10-15 %
ii) Due to reduction of moisture of bagasse by 10-15 % the, GCV of bagasse is increased from 4522 kCal/kg at 50 % moisture to 4628 kCal/kg at 35 % bagasse moisture.
iii) The boiler efficiency is improved from 69% to 81%.

CONCLUSION:

The aim of the introduction of dryer was to reduce the moisture content in wet bagasse in order to improve boiler efficiency and reduce device costs. The obtained results show clearly that these aims were succeeded. The boiler efficiency was improved from 69% to 81%.

REFERENCES

1) Anthony Anukama,b,n, Sampson Mamphweli a, Prashant Reddy c, Edson Meyer a, Omobola Okoh b"Pre-processing of sugarcane bagasse for gasification in a downdraft biomass gasifier system: A comprehensive review", "Renewable and Sustainable Energy Reviews", 2016
2) Prof. V. V. Patil1, Prof. A.M. Patil2, Prof. P. D. Kulkarni3,"design and development of bagasse dryer for modern jaggery house", "International Journal of Advance Research In Science And Engineering" ,September 2014
3) Juan H. Sosa-Arnao1, Jefferson L. G. Corrêa2, Maria A. Silva3 and Silvia A. Nebra4, "Sugar cane bagasse drying - a review", www.researchgate.net /publication/ 239556788, june2016.
4) Anisha Agarwal, Vyoma Maroo, "bagasse power in India: meeting challenges of energy, environment and sustainable development", "International Journal of Recent Scientific Research", July, 2013.
5) International Journal of Innovative Research in Science, Engineering and Technology Vol2, Issue 5, May 2013