Pak. j. life soc. sci. (2004), 2(1): 36-39

Pakistan Journal of
Life and Social Sciences

Efficiency Calculations of Bagasse Fired Boiler on the Basis of Flue Gases Temperature and Total Heat Values of Steam

Anjum Munir, A.R.Tahir, M.Shafi Sabir, Khuram Ejaz
Department of Farm Machinery and Power, University of Agriculture, Faisalabad-Pakistan

Abstract

The proposed study was conducted at Pahrianwali Sugar Mills, Lalian District Jhang. Data was collected for a 60 tons bagasse fired boiler. The boiler was of natural circulation and bi-drum type water tube boiler. The boiler was equipped with super heater, air heater and economizer in order to utilize maximum available heat of flue gases. Boiler efficiency was calculated on the basis of flue-gases temperature leaving the boiler and total heat values of steam. Different instruments and devices were used to record bagasse flow rates and steam flow rates separately. The efficiencies on both methods were found to be 77.86 % and 78.36 %, respectively. The results obtained from both the methods were not significantly different. Steam produced per ton of bagasse was found to be 2.20 tons for 23 kg/cm^2 pressure and 350 °C temperatures.

Keywords: Bagasse, Boiler, Air heater, Economizer, Flue gases

Introduction

Main power generating plants in Pakistan are either hydro-power or thermal-power plants. At present, about 30 % of total electricity consumed in the country is being generated by hydro-power plants and the rest is generated by thermal power units i.e. steam run turbines, internal combustion engines, gas turbines and nuclear power plants. With the increasing population and industrial development, the required demand of electricity is being compensated by thermal power plants. Moreover, power generated by all types of engines including motor vehicles, aircrafts and marines is thermal based. All these prime movers use fossil fuels in the form of furnace oil, diesel or petrol. A huge amount of foreign exchange is invested to import these liquid fuels in order to meet the required electricity demand. As a result, per unit cost of electricity production is increasing with time and hence the local power companies cannot compete the prices of international market.

Corresponding author: Anjum Munir,
Department of Farm Machinery and Power,
University of Agriculture, Faisalabad-Pakistan
E.Mail: anjum_uaf@hotmail.com

Moreover, to meet World Trade Organization (WTO) requirements, one must see whether any reduction in the cost of production is possible or not. In thermal power plants, steam boiler is a device which can be run on solid fuel like fire wood, coal, bagasse, etc. Analysis has shown that some of agricultural residues have high percentages of hydrocarbons and can be used to fire boilers. If we utilize the available energy out of these wastes, the problem of solid waste disposal will not only be solved but also a significant amount of power will be generated for industrial and farm use. In sugar industries, all of the electric power is generated using bagasse which is used to run the plant. The facts and figures of last few years indicate that unlike the other industrial products, the prices of sugar have decreased. This is due to the self-sufficiency of sugar mills in power generation by modifying and enhancing the efficiency of bagasse fired boilers. Several studies in this field have shown promising results.

Minhas (1985) calculated the efficiency of a bagasse-fired boiler having a steam generating capacity of 35 tons/hr whose super-heated steam pressure was 23 kg/cm^2 and steam temperature 350 °C. The efficiency calculations were based on "total heat values of steam". The bagasse flow rate was determined by fitting a glass strip in the bagasse chute and the average value was found to be 16 tons/hr. The steam flow rates were recorded from steam totalizer installed at boiler control panel and the average value was found to be 35.40 tons/hr. The boiler efficiency was recorded as 78.57 %.

Ansari (1988) calculated the efficiency of a bagasse fired boiler having steam generating capacity of 90 tons/hr. Working pressure of steam was 24 kg/cm^2 and working temperature was 350 °C. The temperature of feed water was 100 °C. He conducted the experiment with 50 % moisture in bagasse. The average quantity of bagasse consumed was 53 tons/hr. The efficiency was found to be 61 % under the existing condition of boiler house.

The main objective of this study was to determine the best utilization of available heat of bagasse by calculating the boiler efficiency, steam generated per unit weight of bagasse and to compare different methods based on total heat value of steam and flue gases temperature leaving the boiler of Pahrianwali Sugar Mills, Lalian under prevailing condition.

Materials and Methods

The proposed study was conducted at Pahrianwali Sugar Mills, Lalian District Jhang. The boiler was a drum type water tube boiler. Steam generation tubes had been arranged vertically between two drums which have a common vertical center line at 9.95 meters. Super heater is arranged in front of the boiler bank and is screened from the furnace by two rows of tubes. Boiler is designed for natural circulation of water and is of bottom-supported type. Boiler was equipped with induced draught fan, forced draught fan and secondary air fans with air flow rates of 3750, 1500 and 460 m3/minute respectively to maintain a balanced draught inside the furnace.

Gas- pass is baffled in a two passes arrangement to give maximum heat transfer rate with low draught loss and gas velocities are within the accepted limits. Boiler accessories air heater and economizer were used to enhance the thermal efficiency of the boiler by utilizing high temperature out going flue gases. A multistage centrifugal feed water pump was used to maintain the feed water pressure 1.5 times the steam working pressure.

The maximum continuous rating of steam of the boiler was 60 tons/hr. The designed superheated steam pressure and temperature were 23 kg/cm^2 and 350 °C respectively. Heating surface of boiler, super heater, air heater and economizer were found to be 1565, 115 and 1015 and 135 m2, respectively. The furnace was a spreader stroker type with a volume of 254.5 m3 under the existing condition of the plant. Dumping grate area of the furnace was 251 m^2 comprising of eight sections. Four bagasse feeders rectangular in cross-section were used to supply bagasse from main carrier to furnace.

Bagasse is a fibrous material which is left by last mill of the tandem, after the extraction of juice. The calorific value of bagasse mainly depends upon the moisture content and sucrose content in bagasse. Under the mill working conditions, the average values were taken as:

Moisture content of bagasse (w) = 50 %
Sucrose in bagasse (s) = 3.0 %

The calorific values were calculated by using formulae (Hugot, 1986)

Gross calorific value (G.C.V)

= 8280 (1 - w) - 2160 s Eq. (1)
= 8280 (1 - 0.50) - 2160 (0.03)
= 4075 BTU/lb

Net calorific value (N.C.V)

= 7650 - 8730 w - 2160 s Eq. (2)
= 7650 - 8730 (0.50) - 2160 (0.03)
= 3220 BTU/Lb

Both of these equations included the latent heat of vaporization of water formed during combustion of hydrogen contained in the bagasse and the latent heat of vaporization of water content of bagasse.

Results and Discussions

The experiment was conducted for 60 tons bagasse fired boiler. Two methods were used to calculate the boiler efficiency which is detailed below.

Boiler efficiency on the basis of flue gases temperature

During boiler operation, the flue gases temperature leaving the boiler at stack section remained within the limits of 310 to 330 °F as recorded from totalizer. So the average flue gases value was taken as 320 °F for further calculation.

In order to calculate the quantity of steam obtainable from unit weight of bagasse, following heat losses were considered in the furnace and at the boiler.

a) Latent heat of water formed by combustion of hydrogen in the bagasse.
b) Latent heat of vaporization of water contained in the bagasse.
c) Sensible heat lost in the flue gases leaving the boiler.
d) Losses due to un-burnt solids.
e) Losses by radiations from furnace and especially from boiler.
f) Losses due to incomplete combustion of carbon giving CO (carbon mono oxide) instead of CO_2 (carbon dioxide).

Out of these six losses, (a) & (b) have already been considered in Eq.(1) & Eq.(2) while calculating calorific value of bagasse.

A considerable loss (c), which remains to be accounted for is the sensible heat lost in the flue gases, which is given by the following equation (Hugot, 1986).

q = [(1 - w) (1.4 m - 0.13) + 0.5] (t - 32) Eq. (3)

Where

q = Sensible heat lost in the flue gases in BTU/lb of bagasse.
t = Temperature of flue gases at the stack. Its value is taken as 320 °F
w = Weight of moisture per unit weight of bagasse.
m= Ratio of weight of actual air required for combustion to weight theoretically necessary. Its value depends on the type of furnace used. For spreader stroker furnace, the excess air required is 50 % of the theoretical air required (Hugot, 1986). Its value is taken as 1.50.

Substituting these values in Eq. (3)

q = [(1 - 0.50) (1.4 x 1.50 - 0.13) + 0.5] (320 - 32)
q = (0.50 x 1.97+ 0.5) (288)
q = 1.485 x 288
q = 428 BTU/lb.

The other three losses (d), (e) and (f) were taken into account by means of co-efficient applied to the total quantity of heat which is still available after the first three losses.

The quantity of remaining heat transferred to steam is given by the expression. (Hugot, 1986).

Mv = (7650 - 2160 s - 8730 w- q) Eq. (4)

Where

α = Co-efficient representing heat loss due to un-burnt solids. For spreader stroker furnaces, its normal value is taken as 0.975.

β = Co-efficient to account for heat losses by radiation. This value varies from 0.95 to 0.99 for more or less efficient lagging. Its value is taken as 0.97.

γ = Co-efficient of incomplete combustion. Its value is taken as 0.95.

M_v = Heat transferred to steam per pound of bagasse in BTU/lb.

Substituting the values of w, s, q , α,β & γ

M_v = [(7650 - 2160 x 0.03 - 8730 x 0.50) - 428)] x 0.975 x 0.97 x 0.95

= (7650 - 64.80 - 4365 - 428) x 0.898

= 2792 x 0.898

= 2507 BTU/lb

Boiler efficiency = M_v / N.C.V

Boiler efficiency = 2507/3220

= 77.86 %

Boiler efficiency based on total heat values of steam

This method is based on determination of bagasse and steam flow rates separately. The boiler has four bagasse chutes. Each bagasse chute has a cross-sectional area of 26.5″ x 29.5″. A glass strip of 10″ long was fitted on the chute. With this height, the volume of chute was calculated. The flow time of bagasse along the total length of the glass strip was recorded. The height of main bagasse carrier to the feeder is 6.5 feet. The density of bagasse at 5-7 feet height is 11 lbs/ft^3 (Hugot, 1986)

Volume of chute = 26.5″ x 29.6″ x 10″

= 7844 cubic inches

= 4.54 ft^3

Density of bagasse = 11.0 lb/ft^3

Weight of bagasse in 4.524 ft^3 volume = 11.0 x 4.54

= 49.94

= 50 lbs approx.

Time taken by 0.022686 tons bagasse to drop into the boiler furnace = 12.56 seconds

Bagasse flow rate = 6.5025 tons/hr

Total bagasse flow rate

= 6.5025 x No. of chutes

= 26.01 tons/hr

The calculation is made for serial No.1 of Table 1. Other values can be calculated by the same procedure.

Table 1: Steam and bagasse flow rate of the boiler

Steam flow rate (tons/hr)	Bagasse flow rate (tons/hr)	Steam bagasse ratio	Steam temperature (°F)	Steam pressure (psi)	Feed water temperature (°F)
57.50	26.01	2.21	631	310	210.5
58.35	26.58	2.20	625	301	213.7
55.65	25.12	2.12	627	292	212.2
56.72	26.01	2.18	621	299	213.4
56.62	25.58	2.21	625	302	209.8
54.16	24.48	2.12	627	284	212.4

Average values and data are as under:

Steam flow rate = 25.63 Tons/hr

Bagasse flow rate = 56.50 Tons/hr

Steam Temperature = 626 ^oF

Steam pressure = 298 psi

Steam pressure (absolute) = 298+14.7= 312.70 psia

Total heat (Q_1) taken from enthalpy Table 14.1 (Hugot, 1986) at 626 °F and 312.70 psia = 1327 BTU/lb

Feed water temperature (t_1) = 212 °F

Steam produced per pound of bagasse = 56.50/25.63

= 2.204

Total heat (Q) put into one pound of steam = total heat of steam (sensible & latent heat) – total heat of feed water (sensible heat)

But sensible heat of feed water is always equal to rise in temperature from freezing point

Total heat (Q) put into one pound of steam

= Q_1 - (t_1 - 32)

= 1147 BTU/lb

Total heat put to into one pound of bagasse (M_v)

= 1147 x2.204

= 2523.40 BTU/lb

Boiler efficiency = M_v/N.C.V

= 2523.4 /3220

= 78.36 %

Conclusions

- The efficiency of bagasse fired boiler was calculated using flue gases temperature leaving the boiler and on the basis of total heat values of steam. The boiler efficiency found with both the methods was 77.86 % and 78.38 %, respectively under prevailing conditions of the boiler.
- Steam produced per pound of bagasse was found to be 2.20 at a pressure of 23 kg/cm^2 and at a temperature of 350 °C.
- Both the methods of efficiency calculations gave similar results.

References

Ansari, A.S. Trimming Boiler Losses, Saving Steam. Proceedings of 24th Annual Convention of Pakistan Society of Cane Sugar Technologists. 1988. pp: 223-229.

Hugot, E. Hand Book of Cane Sugar Engineering 3rd Edition. Elsier Science Publishers B.V., 1000 AE Amsterdam, Netherlands. 1986. pp: 872-884.

Minhas, M.J. Boiler Efficiency calculations for the new 35 Tons Boiler at Hussain Sugar mills, Jaranwala, Proceedings of Pakistan Society of Sugar Technologists. 1985. pp: 362-375.

Munir, A. Optimization of Milling Performance of a Sugar Plant by Using Linear Programming Technique. M.Sc. Thesis, Faculty of Agricultural Engineering and Technology, University of Agriculture, Faisalabad. 1995. pp: 42-47.