PERFORMANCE ASSESSMENTS OF FLUIDIZED BED COMBUSTION BOILER

Rahul S.Patel[1], Prof. Bhavesh K.Patel[2]

[1]ME Student of Energy Engineering, Department of Mechanical engineering,

Gujarat technical University GEC Valsad, Gujarat, (India)

[2]AssistantProfessor at Department of Energy Engineering,

Mechanical Engineering GEC Valsad, GTU,(India)

ABSTRACT

Performance assessment is necessary terms for finding boiler efficiency & evaporation ratio. Efficiency improvement is better for fuel saving & energy cost. Day by day fuel consumption is increase, so use of this properly. Boiler use mainly coal as fuel, there are so many loss in boiler system which decrease performance of boiler & increase operation cost. Efficiency improvement is achieved by calculating of different reading by Excel sheet analysis. Data are taken from measurement of many parameters of CFBC boiler at GIPCL, Nani Naroli. By calculating it is found that actual value of lignite efficiency is 80.11 % & design value lignite efficiency is 82.75 %. By observing all parameter major parameter affect moisture and hydrogen in fuel which affect the boiler efficiency performance. By analysis all losses we suggest to improve performance. Outcome result from FBC boiler actual value lignite compare with design value lignite we suggest for various improvement performances.

Keywords: Efficiency of FBC, Mixture Analysis of Lignite and Limestone, CFBC Boiler, Various Heat Losses

Nomenclatures

Q_o = Heat output

Q_i = Heat input
Q = Quantity of steam generated per hour (kg/hr)
q = quantity of fuel per hour (kg/hr)
hg = steam enthalpy (kcal/kg)
hf = feed water enthalpy (kcal/kg)
GCV of fuel = gross calorific value of fuel (kcal/kg)
Cp = specific heat of flue gas (0.23 Kcal/kg·C)
Tf = temperature of flue gas (·C)
Ta = ambient temperature (·C)
Ts = surface temperature (·C)
m = mass of dry flue gas (kg/kg of fuel)
H_2 = percentage of H_2 in fuel = kg of H_2 in 1kg of fuel
Cp = specific heat of superheated steam (0.45 Kcal/kg·C)
584 = latent heat of water in Kcal/kg
M= % of moisture present in fuel = kg of moisture in 1kg of fuel
Cp= specific heat of super-heated steam (0.45 Kcal/kg·C)

AAR = actual air required (kg/kg of fuel)
M_{bw} = mass of blow down water (Kg/hr)
H_{bw} = enthalpy of blow down water at drum pressure (Kcal/kg)
H_{fw} = enthalpy of feed water (Kcal/kg)
Ma = mass of total ash generated/kg of fuel
SBC = Steffen Boltzmann constant
ϵ = emissivity factor of surface
A = total surface area (m_2)

I INTRODUCTION

Fluidized Bed Combustion boiler is steam generate device and has significant advantage over convention firing system. Performance carried out by calculating efficiency. Efficiency of the boiler should be calculated by two method, direct method and indirect method. It required various parameters for calculating the efficiency. These parameters are chemical analysis result of coal, feed waters analysis, coal feeding rate, steam pressure, steam generation per hour, flue gas analysis, and weather any heat recovery devices are attach or not, if attach, than its data, fuel consumption rate per hour, humidity factor etc. The Microsoft excel sheet is prepared for calculating efficiency of FBC boiler.

Calculation work carried out on 390 TPH CFBC boiler lignite plant at Nani Naroli, near Mangrol.Calculating actual value lignite efficiency and compare with design value lignite efficiency. Find various loss give suggestion for improved efficiency of boiler.

1.1 Method to Calculate the Boiler Efficiency

Two methods: Direct Method, Indirect Method

1.1.1 Direct method

Boiler efficiency = heat output/heat input

$$\eta_B = Q0/Qi * 100$$
$$\eta_B = Q\,(hg-hf) / (q * GCV) \quad *100$$

1.1.2 Indirect method

Efficiency calculate by consider various heat loss

L1 – loss due to dry flue gas
L2 – loss due to hydrogen in fuel
L3 – loss due to moisture in fuel
L4 – loss due to moisture in air
L5 – loss due to CO formation
L6 – loss due to un-burnt fuel in fly ash
L7 – loss due to un-burnt fuel in bottom ash
L8 – loss due to radiation and convection (surface loss)

$$\text{Boiler efficiency } \eta = 100 - Totallosses$$
$$= 100 - (L1 + L2 + L3 + L4 + L5 + L6 + L7 + L8)$$

II. FORMULA FOR COMPUTATING VARIOUS LOSSES

Step1. Theoretical (stoichiometric) air requirement

Theoretical air requirement (TA) = $(11.6C+34.8(H_2-O_2/8) + 4.35S) / 100$ kg/kg of fuel

Step2. % excess air requirement

% excess air requirement (EA) = $[O_2 \% / (21-O_2 \%)] * 100$

Step3. Actual air (total air) requirement

Actual air (total air) requirement (AAR) = theoretical air*(1+EA/100) kg of air/kg of fuel

Step4. Find all heat loss

1. Dry fluegas loss

% heat loss due to dry flue gas = m*Cp (Tf -Ta) / GCV * 100

= mass of CO_2+ mass of SO_2+mass of N_2+ mass of O_2 (water vapor mass is neglected)

= (c /100 *44/12) + (s /100 * 64/32) + AAR * 77/100) + [(AAR-TA) *23/100]

2. Heat loss due to evaporation of water formed due to H_2 in fuel

= [9*H2*[584+Cp (Tf-Ta)] / GCV] * 100

3. Heat loss due to evaporation of moisture in fuel

= [M*[584+Cp (Tf-Ta)] / GCV] * 100

4. Heat loss due to moisture in combustion air

= [AAR * humidity factor * Cp (Tf – Ta) / GCV] * 100

Cp =specific heat of super-heated steam(0.45Kcal/kg^{o}C)

Humidity factor =% of water in dry air

= kg of water in dry air / kg of dry air

5. Heat due to un-burnt in fly ash

= [Ma * GCV of fly ash / GCV of fuel] * 100

6. Heatloss due to un-burnt in bottom ash

= (Ma * GCV of bottom ash / GCV of fuel) * 100

7. Blow down loss

% blow down loss = Mbw *(hbw-hfw) / GCV of fuel * 100

8. Heat loss due to radiation & convection

=1 to 2% for smaller capacity boiler

=0.2 to 1.2 for large capacity boiler

% surface heat loss = radiation loss + convection loss

% radiation loss = [SBC* ϵ *A *(Ts^4 –Ta^4) * 860] / [GCV of fuel *100]

% convection loss = [c * A * (Ts – Ta) ^1.25* 860] / [GCV of fuel * 100]

Step 5: find sum of all heat losses

%total losses =sum of all heat losses

=1 +2 +3+4 +5 +6+7 +8

Step 6: estimate boiler efficiency

η_B=100 – (1 +2 +3+4+5 +6 +7+8)

% η_B=100-(%total losses)

III. FOLLOWING PERFORMANCE HAS BEEN CARRIED OUT ON 390TPH LIGNITE FIRED CFBC BOILER AT GUJARAT INDUSTRIES POWER COMPANY LIMITED (SLPP), NANI NAROLI.

	Unit	Lignite Design Value	Lignite Actual Value	Limestone	Mixture
Carbon	%	42.10	34.46	0.00	**32.82**
Hydrogen	%	4.77	2.62	0.00	2.3
Sulphur	%	1.62	0.85	0.00	0.55
Nitrogen	%	0.59	0.50	0.00	0.46
Oxygen	%	10.42	8.45	0.00	7.75
Ash	%	19.30	11.32	98.90	15.12
Moisture	%	21.20	41.80	1.10	40
Gcv	Kcal/kg	4210	3492	0.00	3200

- **Lignite + limestone mixture analysis for actual value.**

EX. The mixture analysis is arrived at by the weight ratio of lignite and limestone

Wfe = feed rate of lignite fired = 105 t/h

Wls = feed rate of limestone = 5 t/h

C mixture = (C in lignite *Wfe + C in limestone *Wls) / (Wfe +Wls)

= 34.46*105 + 0.00*5 / 110

= **32.82**

MIXTURE ANALYSIS FOR DESIGN COAL

	UNIT	Lignite design value	Lignite actual value	Limestone	Mixture design value
Carbon	%	42.10	34.46	0.00	40.18
Hydrogen	%	4.77	2.62	0.00	4.55
Sulphur	%	1.62	0.85	0.00	1.54
Nitrogen	%	0.59	0.50	0.00	0.56
Oxygen	%	10.42	8.45	0.00	9.96
Ash	%	19.30	11.32	98.90	22.91
Moisture	%	21.20	41.80	1.10	20.30
Gcv	Kcal/kg	4210	3492	0.00	3990

Measured data

Type lignite coal fired

Steam generation rate 390000 kg/hr.

Steam pressure 130 kg/cm2

Steam temperature 540 c

Coal firing rate 110000 kg/hr.

GCV of coal 3200 kcal/kg(actual) ,3990 kcal/kg (design)

Total surface area 150 m2

Surface temperature 140 c

Wind velocity 3.9 m/s

Ambient temperature 32 c

Humidity factor 0.021 kg /kg of dry air

Flue gas analysis

Flue gas temperature 140 c

% O2 in flue gas 3.43

% CO2 in flue gas 15.89

% CO in flue gas 00

Ash analysis

GCV of bottom ash 500 kcal/kg

GCV of fly ash 200 kcal/kg

Bottom ash to fly ash ratio 35: 65

IV. RESULT FROM CALCULATION FROM INDIRECT METHOD

	DESIGN VALUE OF LIGNITE	ACTUAL VALUE OF LIGNITE
Theoretical air requirement (kg/kg of coal)	5.8954	4.4103
Method 1	19.52%	19.52 %
Method 2	7.002%	18.418 %
Method 3	7.352%	18.909 %
Actual Air Requirement(kg/kg of coal)	7.0463	5.2226
Mass Of Dry Flue Gas Exhausted From Stack	7.3151	5.5451
Heat Loss In Dry Flue Gas	4.5540%	4.2975 %
Heat Loss DueToH2InFuel	6.4924%	4.0921 %
HeatLossDueTo MoistureIn Fuel	3.2184%	7.9075 %
HeatLoss DueTo MoistureIn Air	0.1802%	0.1665%
HeatLoss DueToUn-burnt Fuel InFlyAsh	0.7461%	0.6134 %
HeatLoss DueToUn-burnt Fuel InBottom Ash	2.0661%	1.6987 %
HeatLoss DueTo Radiation And Convection(kcal/m^2)	3053.483	3053.483
SurfaceLoss	1.0435%	1.3012 %
BoilerEfficiency	**82.75 %**	**80.11%**

TOTAL EFFICIENCY DIFFERENCE = 82.75 – 80.11

= 2.64 %

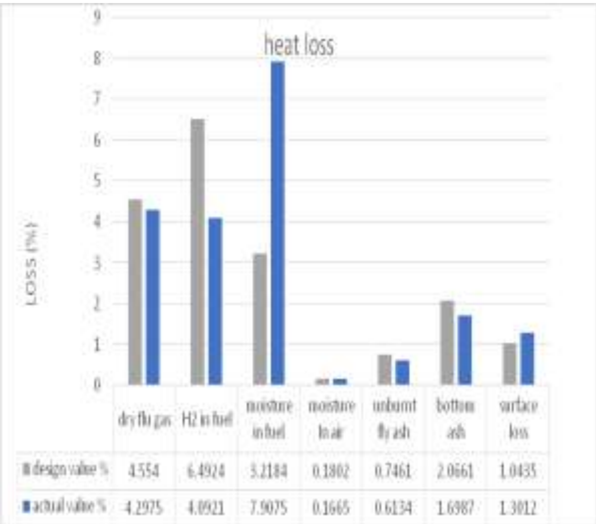
V.GRAPHICAL ANALYSIS OF RESULT

5.1 Comparison with Actual Value vs. Design Value

By comparing heat loss maximum heat loss occur due to moisture in actual value lignite Compare to design value. Major loss occurs by moisture by 7.9075 % in actual value lignite Coal compare to 3.2184 % which in design value coal. From H2, heat loss in fuel are4.0921% actual value and for design value is 6.4924 %. From dry flue gas loss are4.2975 % for actual and 4.554 % for design value coal as shown in Fig 1.

5.2 GCV of coal

From indirect method efficiency calculation, CFBC boiler is actual value efficiency come 80.11% which is less than design value lignite coal efficiency 82.75 %. If higher GCV fuel use for combustion than increase efficiency of boiler as shown in Fig 2.



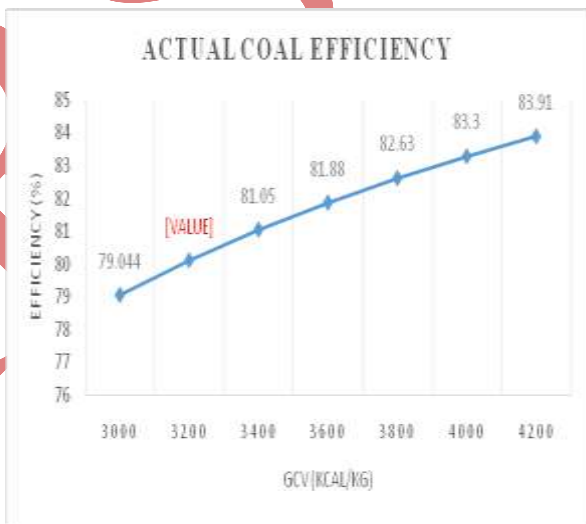


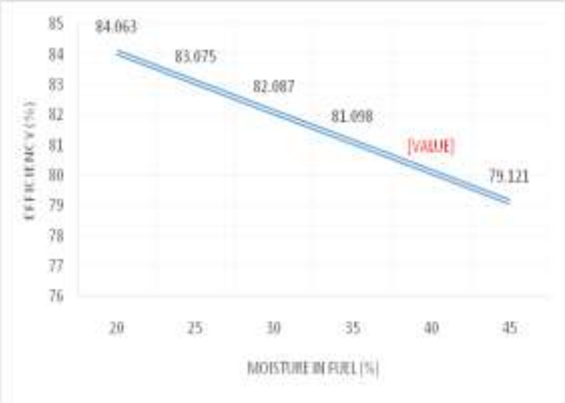
Fig 1: Actual Value Lignite VS Design Value Lignite Fig 2: Efficiency With GCV

5.3 Moisture in fuel

Boiler efficiency decrease with percentage moisture increase. Moisture creates major loss efficiency of boiler which creates more heat loss .In fuel 40% moisture which create 7.90 % heat loss. so it require pretreatment of coal before combustion as shown in Fig 3.

5.4 Ash in fuel

If percentage of ash increase in combustion than boiler efficiency decrease. 15.12%.Ash in fuel which create Fly ash loss is 0.6134 % and bottom ash loss is 1.69 % as shown in Fig 4.



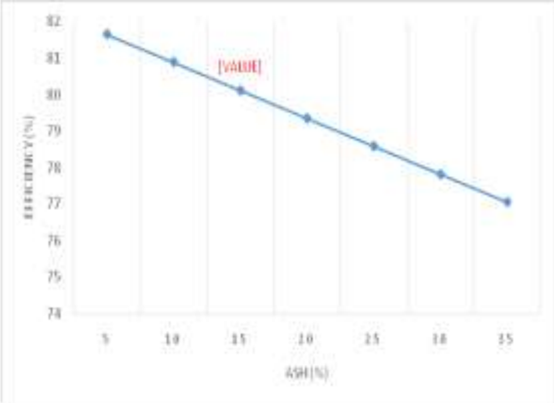


Fig 3: Efficiency With Moisture **Fig 4: Efficiency With Ash**

5.5 H2 in fuel

If percentage H2 increased in fuel for combustion it decrease efficiency of boiler.2.3 % H2 in fuel which create the 4.09% loss decrease in boiler efficiency.

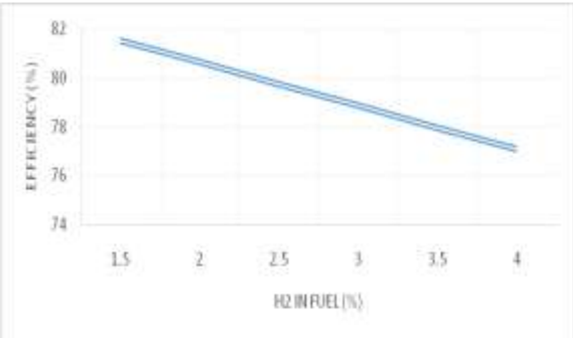


Fig 5: Efficiency with H2

VI. EFFICIENCY IMPROVEMENTOPPORTUNITY IN FBC

Various parameters which use for improvement of boiler

1. Coal up gradation technology

It refers to a class of technologies developed to remove moisture and certain pollutants from low rank coals such as sub-Bituminous coal and lignite (brown coal) and raise their Calorific values because of inherent high moisture content, all lignite need to be dried prior to combustion. Depending on the technology type drying is achieved either via a discrete operation or part of a process.

- Indirect contact drying in tubular dryers
- Flash dry coal fines.
- Mixing crushed coal with oil, heating the mixture
- Drying achieved using low temperature waste heat to provide evaporative drying

2. Proper water treatment

Various forms of contaminations arise with water and they must be removed before feeding to the boiler system by proper water treatment.

A. TDS control

Total dissolves solids comes with feed water into the boiler ,water is heated and converted in to the steam but TDS are remaining in the boiler and concentrated, and eventually reach at a level where their solubility in the water in the water is exceeded and they deposit from the solution. Thus they form scale and reduce heat transfer and also over heat the tubes and puncture those tubes. Thus TDS control is essential by manual blow down or automatic blow down system.

B. 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.

3. Proper fuel preparation:

Fuel contaminants (dirt, dust, suspended particles, moisture etc.) , they must be removed by proper fuel treatment otherwise, they forms the scales and reduces the heat transfer rate or excessive moisture uses a lot of energy as required to change the phase and this energy carried over with flue gas as loss. A quality feed into the boiler raise the efficiency level of boiler and also reduce the maintenance costs.

4. Fuel selection:

The proper fuel specification can also have an effect on efficiency. In the case of gaseous fuel, the higher the hydrogen content, the more water vapour 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.

5. 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:

- Excess fuel supply
- Shortage of combustion air
- Improper firing of fuel
- Improper sizing of fuel (in case of solid fuels)
- Poor atomization of fuel (in case of liquid fuel)
- Poor mixing of fuel and air
- In effective turbulence and residence time of fuel in the furnace.

6. Pre heat the combustion air

The waste hot flue gas has enough heat to raise the temperature of combustion air before using for the combustion

7. Reduces cale and soot formation

Formation of deposits (scale sand 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 waterside:

- by proper water treatment
- cleaning the tube sat shutdown period

8. Reduce surface heat losses

Losses can be reduced by installing a proper thermal insulation over the outside surface and good refractory lining inside the boiler furnace.

VII. CONCLUSION

Major efficiency gap between design value of coal & actual value of coal. If higher GCV coal is used than efficiency should be increased. CFBC boiler give 80.11 % efficiency with lignite coal at GUJARAT POWER COMPANY LIMITED, NANI NAROLI Which is less compare to efficiency of design lignite coal (82.75 %) so company should use coal upgrading technology to improve efficiency. Major moisture content inside the fuel which affect the efficiency. All lignite needs to be dried prior to combustion. Coal up gradation technology should be used by company and Ensure proper fuel particle size maintain 10 mm size of coal. From study mixture analysis of limestone for capture sulphur with lignite coal there is GCV down after mixing so there is an alternative fuel formation should be used as per chemical analysis. From this study we improve the performance of FBC boiler

REFERENCES

[1] Shivraj Kumar B., Dr.N.S.Venkatesh Gupta. “Effect of Smart Blowing System in Boiler furnace on cycle efficiency and costing”.IJERT Vol.2. 2013

[2] Ankit Patel. “Energy and exergy analysis of a boiler with different fuel like Indian coal”.IJERT Vol.1 2012

[3] Mr. M. G. Poddar. , Mrs. A. C. Birajdar. “Energy audit of boiler, case study of Thermal power plant, Parli, Maharastra”IJERT Vol.2 2013

[4]M. de las Obras, A. Rufas, L.F. de Diego, F. García, P.Gayan. “Effects of temperature and flue gas recycle SO2 and NOx emission in oxy fuel fluidized bed combustor” energy procedia, 2013

[5] Jong-Min lee, Dong-Won Kim, Jae-Sung Kim, Kyoungil Park, Tae Lee Hee. “Evolution of the performance Of commercial CFD boiler by IEA CFBC model”Korean j chem.Engg.2013

[6] Thenmozhi Ganesan, Dr.Sivakumar Lingappan “A survey of CFD combustion boiler” IJAREEIE Vol 2, 2013

[8] V. K. Gaudani, EnergyEfficiencyinThermal System. Vol.III.IECC Press. Delhi2009