Bio-Mass Utilization in High Pressure Cogeneration Boiler

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Abstract. Coal is widely used all over the world in almost all power plants. The dependence on coal has increased enormously as the demand for electricity has reached its peak. Coal being a non-renewable source is depleting fast. We being the engineers, it's our duty to conserve the natural resources and optimize the coal consumption. In this project, we have tried to optimize the bio-mass utilization in high pressure cogeneration boiler. The project was carried in Seshasayee Paper and Boards Limited, erode related to Boiler No:10 operating at steam pressure of 105 kscg and temperature of 510˚C. Available bio-mass fuels in and around the mill premises are bagasse, bagasse pith, cane trash and chipper dust. In this project, we have found out the coal equivalent replacement by the above bio-mass fuel(s) to facilitate deciding on the optimized quantity of coal that can be replaced by biomass without modifying the existing design of the plant. The dominant fuel (coal) which could be displaced with the substitute biomass fuel had been individually (biomass) analyzed

Key Words: Boiler, Coal, Biomass, Bagasse

NOMENCLATURE

GCV-Gross Calorific Value
FMP-Free Moisture & Moisture produced from Hydrogen in Fuel
DA -Dry air
MA –Moisture in Air
WA -Wet air
WG -Wet gas
FMPA-Free moisture, Moisture produced and moisture in air.
DG-Dry gas
UBC-Unburnt combustibles
UBCL-Unburnt combustibles loss
DGL -Dry gas loss
FMPL-Free moisture produced loss
MAL -Moisture in air loss
NCV -Net Calorific Value
MM- Manufacturer margin
RL-Radiation loss
VM: Volatile Matter
FC: Fixed Carbon
A: Ash

INTRODUCTION

Coal is widely used all over the world in almost all power plants. The dependence on coal has increased enormously as the demand for electricity has reached its peak. Coal being a non-renewable source is depleting fast. An attempt has been made to conserve and reduce the consumption of coal in Seshasayee paper and mills limited. This industry uses coal for its power generation and even had the availability of biomass. The boiler number 10, operating at a steam pressure of 105 kscg and temperature of 510˚C is being used to produce 20MW of power by using 100% coal. Available bio-mass fuels in and around the mill premises are bagasse, bagasse pith, cane trash and chipper dust in that industry. We have given the optimized quantity of biomass that can be mixed with coal and reduce the consumption of coal without modifying the design of the plant. By adopting this, there will be a reduction in the cost of running the plant.

PROXIMATE ANALYSIS

Description	**Unit**	**Imported coal**	**Bagasse**	**Bagasse pith**	**Cane trash**	**Chipper dust**
Ash	% BY WT	4	1.3	2.76	4.9	1.5
Moisture	% BY WT	25	50	60	20	40
Volatile Matter	% BY WT	36	42	30	64	40.8
Fixed Carbon	% BY WT	35	6.7	7.24	10	17.8
Gross Calorific Value(wet basis)	Kcal/kg	5175	2267	1600	3520	2630

ULTIMATE ANALYSIS

Description	**Unit**	**Imported coal**	**Bagasse**	**Bagasse pith**	**Cane trash**	**Chipper dust**
Carbon	% BY WT	73.8	47	48.3	73.8	48
Hydrogen	% BY WT	4.9	6.5	2.32	4.9	6.8
Sulphur	% BY WT	0.1	Traces	0.04	0.1	0.1
Nitrogen	% BY WT	0.9	0.2	0.15	0.9	0.2
Oxygen	% BY WT	20.3	46.2	49.19	20.3	44.9

FORMULAE

FMP = $(9H_2+M)/100$
DA = (1.3 X GCV)/1000
MA = (0.018 X DA)
WA = (DA + MA)
WG = (WA + (1-ASH))
FMPA= FMP + MA
DG = WG – FMPA

Heat loss computation

$$UBCL = \frac{(UBCL)\times(A)\times 8080}{(100-UBC)\times GCV}$$

$$DGL = \frac{(DG\times 0.24\times(T_G - T_A)\times(100-UBL)}{GCV}$$

$$FMPL = \frac{FMP\times(587-T_A+(0.46\times T_G))\times 100}{GCV}$$

$$MAL = \frac{MA\times 0.46\times(T_G - T_A)\times 100}{GCV}$$

SL = DGL + FMPL + MAL

Radiation & Convection Losses
MM: Manufacturer’s margin/Instrument tolerance
UAL: Unaccounted loss
Total loss(TL) = SL +RL+ MM + UBCL + UAL
Boiler Efficiency(GCV)= 100-TL
NCV = GCV (Wet basis) - 590 X FMP
Boiler Efficiency (NCV): (ηGCV x GCV)/NCV

The efficiency of boiler is calculated for different fuels by using the above formulae and by considering the following parameters which were recorded in the industry.

Temperature of dry air (Ta)=30°C
Temperature of the exhaust gas (Tg)=140°C
Excess air inlet = 30%
Unburnt combustibles=10%
Radiation loss = 1%
Note: All Calculations done in MKS Unit System.

RESULTS OF CALCULATION

Particulars	Coal	Bagasse	Bagasse pith	Cane trash	Chipper dust
Ash	4	1.3	2.76	6	1.5
Moisture	25	50	60	20	40
H_2 (dry basis)	4.9	6.5	2.32	4.9	6
Gcv(dry basis) kcal/kg	6900	4534	4000	4400	4383.34
Gcv(wet basis) kcal/kg	5175	2267	1600	3520	2630
Ncv	4832.36	1799.42	1196.72	3193.84	2202.84
Dgl(%)	3.6001	3.6396	3.8481	3.6654	3.6750
Fmpl(%)	6.9734	21.7229	26.5462	9.7588	17.1061
Mal(%)	0.1184	0.1184	0.1184	0.1184	0.1184
Sl(%)	10.6922	25.4810	30.5127	13.5426	20.8996
Tl(%)	14.3861	28.9958	35.0613	18.0729	24.4117
Boiler efficiency(gcv) %	85.6138	71.004	64.9386	81.9270	75.5882
Boiler efficiency(ncv) %	91.684	89.4543	86.8218	90.2933	90.2458

EVAPORATION CALCULATION

Operating conditions of boiler is 105 kscg at 510°C
Heat input to water with boiler efficiency and moisture = GCV (Wet basis in kJ/kg) X boiler efficiency(GCV)
Enthalpy of water at 27°c and 1 atm = cp Δt
=4.18 x 27
=112.86 kJ/kg
Enthalpy of steam at 510°C and 105 ksc
hsup = hg + cpΔt
= 2718.7 + 2.18(510-314.6)
= 3144.672 kJ/kg.
Therefore, enthalpy added = 3144.672 – 112.86
= 3031.812kJ/kg

$$Evaporation = \frac{Heat\ input\ to\ the\ water\ with\ boiler\ efficeiency\ and\ moisture}{Heat\ added\ to\ water}$$

Evaporation for Coal

Boiler efficiency(GCV) = 85.6138%
Heat input to water with boiler efficiency and moisture = GCV (Wet basis) x 4.18x 0.70853 = 18519.54 kJ/kg
Head added to water = 3031.812 KJ/kg
Evaporation = 6.1084 ton of steam/ton of fuel.

Evaporation for bagasse

To find out the equivalent coal replacement when mixing the bagasse with coal, the exhaust gas temperature increases by 2 to 3 degrees. Hence the efficiency comes down.
Boiler efficiency(GCV) = 70.853%
Heat input to water with boiler efficiency and moisture = GCV (Wet basis) x 4.18x 0.70853 = 6714.0727 kJ/kg
Head added to water = 3031.812 KJ/kg
Evaporation = 2.2145 ton of steam/ton of fuel.

Evaporation for bagasse pith

To find out the equivalent coal replacement when mixing the bagasse pith with coal, the exhaust gas temperature increases by 2 to 3 degrees. Hence the efficiency comes down.
Boiler efficiency(GCV)=64.771%
Heat input to water with boiler efficiency and moisture = GCV (Wet basis) x 4.18x 0.64771 = 6714.0727 kJ/kg
Head added to water = 3031.812 KJ/kg
Evaporation = 1.42881 ton of steam/ton of fuel

Evaporation for Cane Trash

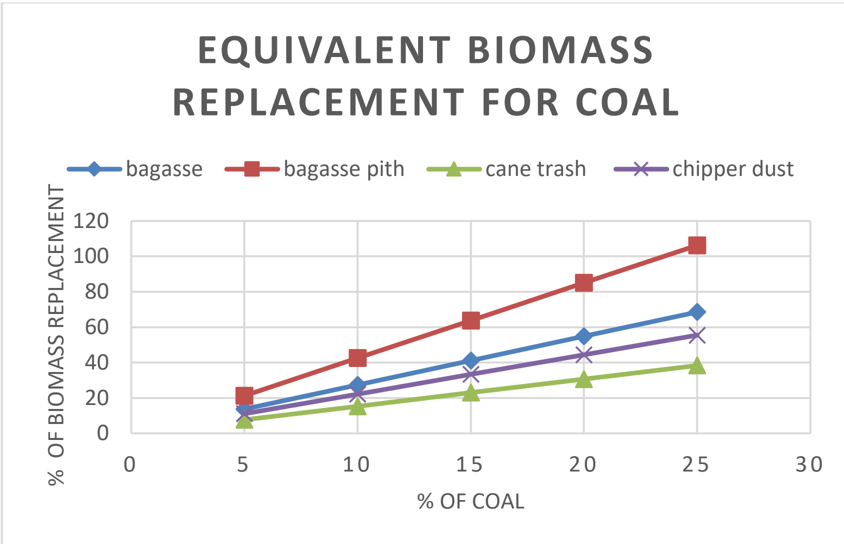
To find out the equivalent coal replacement when mixing the cane trash with coal, the exhaust gas temperature increases by 8 degrees. Hence the efficiency comes down.
Boiler efficiency(GCV)=81.5940%
Heat input to water with boiler efficiency and moisture = GCV (Wet basis) x 4.18x 0.815940 = 12004.82 kJ/kg
Head added to water = 3031.812 KJ/kg
Evaporation = 3.9596 ton of steam/ton of fuel

Evaporation for Chipper dust

To find out the equivalent coal replacement when mixing the chipper dust with coal, the exhaust gas temperature increases by 3 degrees. Hence the efficiency comes down.
Boiler efficiency(GCV)=75.4467%
Heat input to water with boiler efficiency and moisture = GCV (Wet basis) x 4.18x 0.75446 = 8293.420 kJ/kg
Head added to water = 3031.812 KJ/kg
Evaporation = 2.7354 ton of steam/ton of fuel

EQUIVALENT PERCENTAGE OF BIO MASS

The evaporation of coal decreases when mixed with biomass, due to rise in exhaust gas temperature by 2 to 3 degrees. The new efficiency will be 85.0923%
The new evaporation of coal will be 6.07120
The evaporation ratio of coal-bagasse = 1 :2.7415
The evaporation ratio of coal-bagasse pith= 1 :4.2491
The evaporation ratio of coal-cane trash = 1 :1.5332
The evaporation ratio of coal-chipper dust= 1 :2.2194



In the existing plant design, the excess fuel that can accommodated is 16%. Therefore, the percentage of coal that can be replaced by biomass are shown in the below table.

Biomass	Percentage of coal that can be replaced	Equivalent percentage of biomass
Bagasse	9.2	25.2
Bagasse-Pith	5	21.2
Cane trash	30	46
Chipper dust	13.1	29.1

ECONOMIC ANALYSIS

The quantity of coal that is used per day is 340 tons/day. Total cost of coal/day is Rs13,60,000. Net save per day by adding biomass to coal is given in the below table.

Biomass	Percentage of Coal Replacement	Equivalent Percentage of Biomass for coal replacement	Coal Quantity/day with biomass	Cost of coal/ton in Rs.	Biomass quantity/day	Cost of biomass/ton in Rs	Net save/day in Rs
Bagasse	9.2	25.2	308.72	4000	85.68	1200	22,304
Bagasse Pith	5	21.2	323	4000	72.08	600	24,752
Cane Trash	30	46	238	4000	156.4	1250	2,12,500
Chipper Dust	13.1	29.1	295.46	4000	98.94	1400	39,644

CONCLUSION

The biomass which are available in the plant can be used to lower the steam cost in high pressure steam generation. Biomass does contribute to lower gas emission to the landscape. In the event of restricted usage of biomass with dominant fuel (coal), there would not be any major change in high pressure boiler design. In this plant, Maximum percentage of coal that can replaced is by using cane trash. 30 percent of coal can be replaced. This project can be further improved by conducting the emission test and small modifications can be made to get the maximum benefit and conclusions can be drawn.

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REFERENCES

1. T.G.Sundara raman, “Operational Experiment with High Pressure Captive Cogeneration Plant”, IPPTA, 2006.
2. T.G.Sundara raman, “Energy Conservation in pulp and paper industry to sustain climate change development”, 3rd annual energy efficiency conference, 2008.
3. ASME CODE and STANDARDS PTC 4.1 Performance test code steam generating units, USA; 1972 (date of specific issue adopted: 1964).
4. V. Triembomblia, Thermotechnical test in boilers, MIR, Moscow (1979) in Russian.
5. E. Hugot, Handbook for sugar engineers (3rd ed), CECSA Continental, S.A. Mexico (1974) in Spanish.
6. Bagasse-Based Cogeneration in India: A Market Primer for US Companies, Prepared by the National BioEnergy Industries Association, March 1995.
7. A. Rubio, Steam boilers, MES, La Havana (1982) in Spanish
8. A. Andriuchenko, Thermal cycles and process optimization in the electric power station, MIR, Moscow (1974) in Russian.
9. Y.P. Abbi, R.K. Bhogra, Cogeneration in sugar industry-technology and prospects in India. TERI Energy Environment Monitor, Special Issue on Biomass Based Cogeneration, Vol. 10, No. 1, 1994, pp. 19–25.
10. Pinch technology/process optimization. Vol. 5: Case Study—Champion International Corporation Pulp and Paper Mill in Sheldon, Texas, Report Number: EPRITR-101147, 1992.
11. S. Balamurugan and R Xavier, J., “Modeling of Biomass Power Plant Having Low Turbine Rotor Time Constant for Stability Studies”, in IEE Sponsored National Conference on Power Engineering Practices and Energy Management PEPEM’05, Thapar Institute Engineering and Technology, Patiala, Punjab, 2005.
12. S. Balamurugan, “Fuzzy Based Load Frequency Controller for Biomass Power Plant”, in National Conference on Mathematical and Computational Models NCMCM 2003, PSG College of Technology, Coimbatore, 2003.