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"Maximum possible work of a Boiler system obtained by Exergetic Analysis with different types of fuel mixing with Bagasse which is used in Economicaly in industy for Chemical Process Plant – A Case study"

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Abstract – *in this study Exergy is the maximum useful work a system can perform as it comes into thermodynamic equilibrium with its surroundings, representing the quality or work potential of energy. Unlike energy, which is conserved according to the First Law of Thermodynamics, exergy is destroyed by irreversibility in real processes, a concept rooted in the Second Law of Thermodynamics. It helps engineers design and evaluates the efficiency of energy conversion processes by quantifying the useful energy available for work. Energetic and exergetic analysis of steam generation device which is use in Chemical process plant, also in town ship or other. To performance of boiler in detailed in exergetic losses has been presented. Due to economically and reduce environmental pollution by mixing of fuel is best for steam generation plant. Energy analysis is give information on quantities basis result while energy per formation analysis presents qualitative result about actual energy consumption. Exergy is maximum theoretical useful work at dead state that may be received from energy in a system of ideal machines. Take all data from Anupam Rasayan Industries PVT. LTD., Ankleshwer - Bharuch. So here, exergetic analysis, exergetic destruction by mixing of various fuels and coal used in boiler to analyze exergetic analysis done and select best for (40% B+ 60% L) used to produce economical for steam generation.*

Keywords— **Steam generation Plant, Fuel and its combustion, Exergetic analysis, Efficiency calculation, exergetic destruction.**

I. *INTRODUCTION*

Now today a current recently worlds energy problems and its generation process is so difficult and costly, which is complicated so continues updated techniques and methods are used to solve this issue so low pollution and economically produce sources of energy now a day's mixing with other fuels option is taken by engineers and try to solve this problem because fuel which is use day by day is reduces. So try to solve various alternative source of energy for developed countries.

World's number one country is Brazil which produces sugar in the world and India is second largest country to produce Bagasse in the world approximately 10%. In India presently there are more than 617 sugar mills in operation and they produce 30.52 million tons of sugar. Bagasse is the fibrous residue of the sugar cane stalk coming from the mill after crushing and extraction of juice. So there is largest raw material like a fuel is used for Boiler to economical compare to other fuel and produce low pollution. The main problem is to present moisture contents in Bagasse is reduce the performance. So Fuels like Bituminous coal, Anthracite Coal and Bagasse is mixing with different ratio find performance of Boiler on basis of 1^{st} and 2^{nd} law, after completing the result which is economic fuel and best suitable for power generation.

The objective of this paper is to study the process plant components using the 1^{st} and 2^{nd} laws of thermodynamics. The Fundamentals of exergy destruction enable us to evaluate the efficiency with which the available energy is consumed.

Exergy analysis is a methodology for the evaluation of the performance of devices and processes, and involves examining the exergy at different points in a series of energy conversion steps. ***The analysis shows that the first law efficiency of Boiler Plant with different fuels like Bagasse, bituminous, Anthracite and Lignite coal also to use different percentage of them mixing respectively for (40% B+60% L) is best & as well as exergetic rational efficiency of Boiler Plant is 35.65 % .***

2. OVERVIEW OF BOILER SYSTEM:-

A boiler steam generation unit is an enclosed pressure vessel that provides a means for combustion heat to be transferred into water until it becomes heated water or steam. Water is a useful for no change in chemical phase changes with only mass fraction and cheap medium for transferring heat to a process. When water is boiled into steam its volume increases about 1,600 times, producing a force that is almost as explosive as gunpowder. This causes the boiler to be extremely dangerous equipment that must be treated with utmost care.

3 INTRODUCTION OF FUELS:-

Fuel represents a combustible substance which is carbon hydro composition energy which is stored in a from which is released into heat, once raised to ignition temperature, continues to burn without any external support provided a sufficient quantity of oxygen is available for combustion. A fuel may be also defined as a substance which on burning with oxygen in the atmospheric air produces a large amount of heat.

The various types of fuels like liquid, solid and gaseous fuels are available for firing in boilers, furnaces and other combustion equipments. The selection of right type of fuel depends on various factors such as availability, storage, handling, pollution and landed cost of fuel. The knowledge of the fuel properties helps in selecting the right fuel for the right purpose and efficient use of the fuel.

4 INTRODUCTIONS TO COMBUSTION:-

Proper amount of air is required for complete combustion so primary and secondary air is important for complete combustion of fuel which creates no pollution in environment. Combustion takes a chemical reaction during which the interatomic bonds of the molecules of fuel and oxygen are broken and there is rearrangement of atoms in new molecular combination. The new compounds have less energy, and the energy released during combustion equals the difference in the energy of reactants of that of products formed.

Theoretical air is use only for primary reaction and excessive air is used for complete combustion with proper time for burning fuel and releases its heating value which is absorb by water and converts into water vapor like steam. Combustion is obviously an exothermic reaction; during combustion energy is released to the surroundings in the form of heat which can be used economically for industrial and domestic purposes.

Nitrogen reduces combustion efficiency by absorbing heat from the combustion of fuels and diluting the flue gases. This reduces the heat available for transfer through the heat exchange surfaces.

1. Temperature high enough to ignite & maintain ignition of the fuel,

2. Turbulence or intimate mixing of the fuel and oxygen, and

3. Time sufficient for complete combustion.

5 LITERATUE REVIEW

The present reviews the work carried out by various investigators on energy and exergy analysis. Steam and Gas Turbine Plant, Co – Generation Plants and chemical and process Industries. More emphasis is given on the power generation industries as it is the aim of the present study.

There seems to have less number of studies or reports on the energy and Exergy analyses of bagasse based systems because of using bagasse for producing power and process heat is relatively new technology compared to the conventional coal fired power generation.

TABLE 1 SUMMERY OF LITEARTURE REVIEW

R. NO	AUTHOR (YEAR)	TITLE	WORK CARRIED OUT
1	Chin W. W. & El Masri 1987.	Exergy analysis of combined cycle Part-2.	Exergy balance analysis of steam bottoming cycle shows the selection of the two pressures evaporator cycles results in improvement in efficiency.
2	Larson E.D. 1991.	Bio-mass Gasifier gas turbine co-generation in the pulps and paper industries.	Bio-mass Gasifier gas turbine is a technology for bio-mass electricity generation and reduces co_2 emissions at turbine exhaust.
3	Si-Doek Oh Hyo-Sun Pang 1996.	Exergy analysis for a gas turbine co-generation system.	Analysis of co-generation system at part load and full load condition & influence of inlet air temp. and relative humidity of inlet air on the performance of the system.

4	Lalwnai L N. 1991.	Exergy analysis for a captive power plant.	Exergy studies and parametric studies to analyze the effect of various parameters on the performance of the plant.
5	PJ Prasad Rao 1993.	Exergy Analysis for a gas turbine co-generation plant	Analysis of co-generation system at part load and full load condition.
6	RD Patel 2001.	Energy & exergy analysis for a captive power plant.	Exergy audit of the plant & comparison of 1^{st} law and 2^{nd} law efficiency of the plant.
7	CP Panchal 2003.	Energy and exergy analysis of a combined cycle power plant.	Exergy analysis of the combined cycle power plant with Grassman and Sankey Diagram, with computer programme.
8	Patel K. T. 2009	Energy and exergy analysis of boiler with different fuels like indian, imported coal & LSHS oil	1^{st} law of efficiency of boiler theoretical is more but 2^{nd} law exergy efficiency is more reduce and losses of various system identified. Mixing with different fuels to procduced power economical and environmental aspect required.

6 ANALYSIS METHODOLOGY

Following assumptions are made for present analysis

1. Consider Combustion products are as an ideal gas.

2. Consider complete combustion process in the combustion chamber.

3. Consider Kinetic and potential components of energy are negligible.

4. Consider Losses in various pumping devices are not considered.

7 EXERGY ANALYSIS:-

The exergy analysis of boiler plant is carried out in order to find out the lost work. i.e. the difference in exergy supplied and exergy output is the lost work of the system or component. The basic Exergy equation for one kg substance in flowing open systems, disregarding kinetic and potential exergy terms is as follows:

$$Ex = (H - H_0) - T_0 (S - S_0) \qquad \text{....(1)}$$

Hence from 'T. J. Kotas'[4] for dry organic substance contained in solid fuels consisting of C, H, O, and N, with a mass ratio of oxygen to carbon less than 0.667, the following expression was obtained in terms of mass ratios.

$$\boldsymbol{\Phi_{dry}} = 1.0437 + 0.1882 \text{ x } (h/c) + 0.0610 \text{ x } (o/c) + 0.0404 \text{ x } (n/c) \qquad \text{....(2)}$$

For the fossil fuels with the mass ratio 2.67 > o/c > 0.667, which in particular, includes wood.

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$$\Phi_{dry} = \frac{1.0438 + 1882 \times (h/c) - 0.2509 \left[1 + 0.7256 \times (h/c) - 0.0383 \times (n/c)\right]}{1 - 0.3035 \times (o/c)} \quad \text{....(3)}$$

Now Chemical Exergy is given as,

$$\boldsymbol{\varepsilon^0} = [\text{C.V.} + 2442 \times (\text{Moisture})] \times \boldsymbol{\Phi} + 9417 \times S \quad \text{....(4)}$$

Here different sub regions are as follows,

Sub Region I	Combustion Chamber
Sub Region II	Heat Transfer to Water
Sub Region III	Flue gas mixing with atmosphere

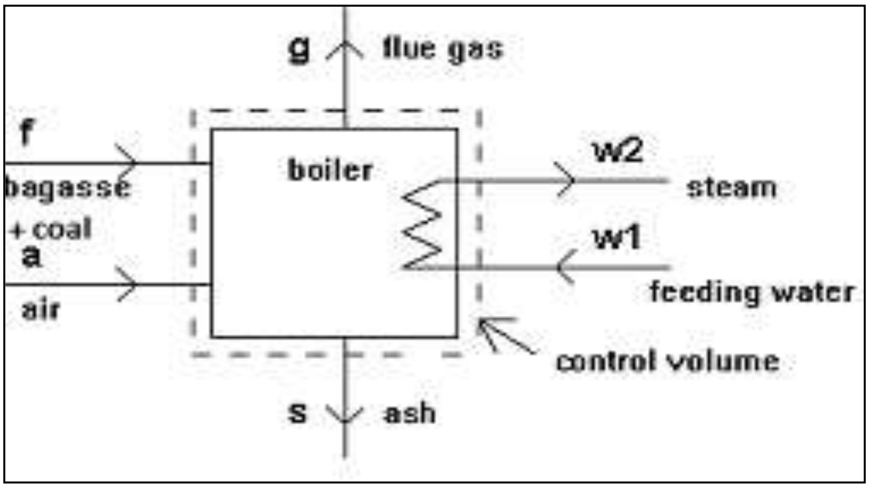
Exergy balance in the sub region I gives,

$$I_1 = Ex_1 - Ex_2 \quad \text{....(5)}$$

$$Ex_2 = n_{p2} \times \varepsilon_{p2}{}^{0} + \Sigma\, n\, \varepsilon_p{}^{h} \quad \text{....(6)}$$

$$\Sigma\, n\, \varepsilon_p{}^{h} = (\theta_2 - \theta_0)\, \Sigma\, n\, Cp^{\varepsilon} \quad \text{....(7)}$$

$$\text{And, } Ex_1 = m_{Fuel} \times \varepsilon^{0}{}_{Fuel} \quad \text{....(8)}$$



Block diagram for Simplified view of Boiler Analysis

So, the 2nd law efficiency of region I is

$$\eta_{2^{nd}law} = (Ex_2 / Ex_1) \times 100\% \qquad ....(9)$$

$$I_2 = (Ex_2 - Ex_3) - (Ex_S - Ex_{FW}) \qquad ....(10)$$

$$\eta_{2^{nd}law} = [(Ex_S - Ex_{FW}) / Ex_2] \times 100\% \qquad ....(11)$$

So, Irreversibility $I_3 = Ex_3$

Hence the rational efficiency of the boiler is

$$\psi = [(Ex_S - Ex_{FW}) / Ex_1] \times 100\% \qquad ....(12)$$

A short calculation of flue gas exergy will be provided based upon certain assumptions. Fuel used in calculation is Bagsse with standard composition which is given in Data. Combustion is complete with 50% of air excess and outgoing flue gas temperature is 151 ^{0}C.

- Chemical composition as per data
- Stoichiometric air to fuel ratio: λ = 5.59 ***: 1*** (Total mass of air supplied = 5.59 which is calculated in Energy analysis)
- Flue gas temperature: θ_{fg} = ***151 ^{0}C***
- Lower heating value: $$\Delta h_L = 33900c + 117000\left(h - \frac{o}{8}\right) \qquad ....(13)$$
- Stoichiometric air quantity: $$O_{min} = \frac{c}{12} + \frac{h}{4} + \frac{s}{32} - \frac{o}{32} \qquad ....(14)$$
- Flue gas composition: $n_{fg} = n_{CO2} + n_{H2O} + n_{SO2} + n_{N2} + n_{O2}$ ....(15)
- Flue gas mole mass and mole heat capacity:

$$[C_{mp\,fg}]_0^{151} = n_{CO2}[C_{mpCO2}]_0^{151} + n_{H2O}[C_{mpH2O}]_0^{151} + n_{SO2}[C_{mpSO2}]_0^{151} + n_{N2}[C_{mpN2}]_0^{151} + n_{O2}[C_{mpO2}]_0^{151}$$

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n_{fg} ....(16)

- Fuel mass flow rate:

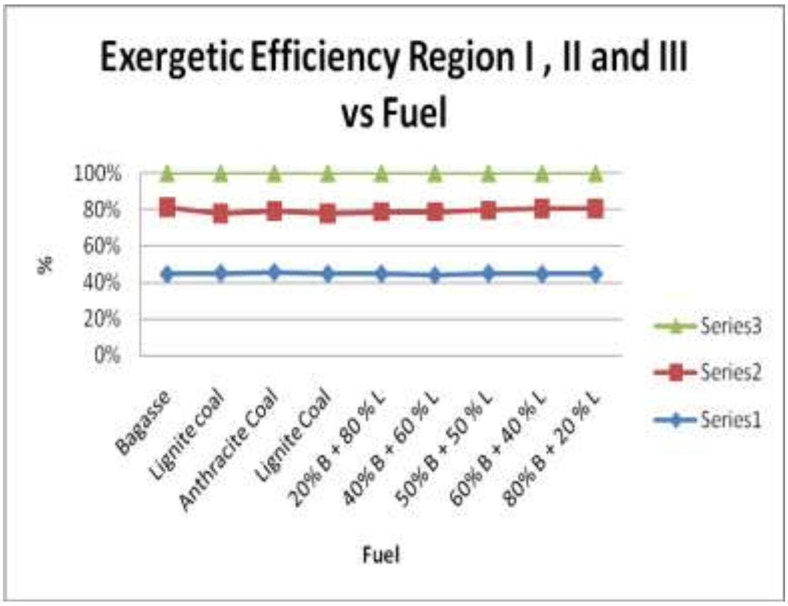
$$q_{mF} = [m_s (h_S - h_W)] / [\Delta h_L - (n_{fg} [C_{mp\ fg}]_0^{151} \theta_{fg})] \quad ....(17)$$

8 RESULTS AND DISCUSSION

Exergetic analysis like maximam possible work of a system the rational efficiency of this plant takes into account destruction includes the physical and chemical exergy during combustion of fuel in presence of air. In the 2nd law analysis the maximum loss of exergy is while converting the chemical energy of fuel to that in to heat energy. This is due to the high production of entropy during the process of conversion.

TABLE Exergetic Efficiency of fuel used in Boiler

Sr No	Fuel	Sub Region		
		I	II	III (Rational efficiency)
1	Bagasse	72.47	60.00	31.00
2	Lignite coal	73.45	53.35	36.54
3	Anthracite Coal	74.50	54.98	34.59
4	Lignite Coal	75.00	55.21	38.00
5	20% B + 80 % L	73.14	55.30	35.25
6	40% B + 60 % L	72.68	57.42	35.65
7	50% B + 50 % L	73.51	56.32	33.99
8	60% B + 40 % L	72.23	58.28	32.06
9	80% B + 20 % L	72.61	58.64	32.18



9 CONCLUSION

Now for current work here mixing fuel with Bagasse and Lignite coal with different percentage (40% B + 60% L) is the best for economical and environment aspect performance of the boiler for the generation of steam. Here huge difference between first and second law efficiency of the boiler such as 72.68% and 35.65% respectively. Maximum saving the annually fuel and financial for using this composition of fuel in the industries process plant.

After completion of combustion process of Bagasse, ash is mostly use for the raw material of the Brick and Cement manufacturing so pollution is also reduce and complete the cycle of environment. This is due to large amount of energy degradation. This degradation of energy increases the entropy and hence a decrease in the exergy or second law efficiency.

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