Performance and Exergy Analysis of the Boiler

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Abstract: ***Exergy analysis has sparked interest within the scientific community to require a more in-depth check up on the energy conversation devices and to develop new techniques to rise utilize the prevailing restricted resources. Exergy analysis gives entropy generation, irreversibility percentage exergy loss and second law efficiency. The exergy loss or irreversibility is maximum at boiler. Thus to know about actual flow of exergy in the cycle thermodynamic analysis based on second law is desirable. In this paper exergy analysis of operating condition of boiler has been carried out based on mass and exergy balance. The power plant boiler was simulated based on the measured operating data and the thermodynamic states of the plant components. . It has been found that maximum exergy destruction occurs due to combustion process. . Exergy efficiency of boiler according to second law analysis and the best exergetic efficiency of the boiler is seen when bituminous coal is used.***

Keywords: Boiler exergy analysis, exergy efficiency and destruction, irreversibility's.

1. Introduction

Exergy: The introduction of exergy (also referred to as availability) which is that the most useful work that (Ref-1 & 2) might be obtained from the system at a given state in a very given atmosphere, and we continue with the reversible work, that is the most helpful work that may be obtained as a system undergoes a method between two given state. the exchangeability (also called the exergy destruction or lost work),which is that the wasted work potential throughout a method as a result of irreversibility's , and be outlined as second law potency .We then develop the exergy balance relation and apply to closed systems and management volumes.

Why Study Exergy:
In the last several decades, exergy analysis has begun to be used for system optimization.
*By analyzing the exergy destroyed by each component in a process, we can see where we should be focusing our efforts to improve system efficiency.
*It can also be used to compare components or systems to help make informed design decisions.

Exergy Distruction: Irreversibility's like friction , mixing, chemical change, heat transfer through a finite temperature distinction, unrestrained growth, non-equilibrium compression or expansion always generate entropy and something that generate entropy invariably destroys exergy. The exergy destroyed is (Ref-4) proportional to the entropy generated, it is expressed as,

$$\mathbf{X\ destroyed = (To\ S) > 0}$$

Therefore, and the exergy of the universe which might be thought-about to be associate degree isolated system is ceaselessly decreasing. The more irreversible a method is, the larger the exergy destruction throughout that method. No exergy is destroyed throughout a reversible process.

$$\mathbf{X\ destroyed = 0}$$

The exergy amendment of a system will be positive or negative throughout a method however the exergy destroyed will not be negative.

$$\mathbf{X\ destroyed,\ impossible < 0}$$

Exergy Balance for Closed and Open System
It is used to determine the location, type and magnitude of losses (Ref-3) of potential energy resources (fuels) and way can be found to reduce such losses for making the energy system more efficient.

A closed system encompasses a fixed mass. The full energy of a straightforward, compressible closed system is that addition of its internal, kinetic, and potential energies. Therefore, the exergy of such a system is that addition of the exergies of its internal, kinetic, and potential energies. The unit-mass kind is,

$$\mathbf{\Phi = (u - u_0) + P\ (v - v_0) - T_0(s - s_0) + V^2/2 + gz}$$
$$\mathbf{= (e - e_0) + P\ (v - v_0) - T_0(s - s_0)}$$

A open system that total energy of a flowing fluid during a management volume is that the total of the physical property, K.E., and P.E. Therefore, the exergy of such a system is that the total of the exergies of its physical property, K.E., and P.E.
The unit-mass type is,

$$\mathbf{\Psi = (h - h_0) - T_0(s - s_0) + V^2/2 + gz}$$

2. Background

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. With this information, efficiencies can be evaluated, and the process steps having the largest losses (i.e., the greatest margin for improvement) can be identifie

The word 'Exergy' was derived from Greek words ex (meaning out) and ergon (meaning work). Exergy is that the helpful work potential of the exergy. Exergy isn't preserved. Once the Exergy is wasted, it will never be recovered. We tend to use exergy we don't seem to be destroying any exergy; weare just changing it to a less helpful kind, a kind of less Exergy. Theuseful work potential of a system is that the quantity of exergy we tend to extract asuseful work. The helpful work potential of a system at the desired stateis referred to as Exergy (also called availableness or exergy). Exergy could be a propertyand is related to the state of the system and therefore the atmosphere. Exergy losses area unit additive (i.e. the entire Exergy loss for the plant is that thesum of all the part losses), sanctioning attribution of the losses toplant parts .Exergy is usually destroyed once a method involves atemperature modification. This destruction is proportional to the entropyincrease of the system beside its surroundings.

3. Literature Review

The following literature review describes important research results regarding boiler of the exergy analysis of thermal power plants

Isam H. Aljundi (2009) – is studied that the exergy analysis of Al-Hussein power plant (396MW) in Jordan is presented. The performance of the plant was estimated by a component wise modeling and a detailed break-up of energy and exergy losses for the considered plant has been presented. It was found that the exergy destruction rate of the boiler is dominant over all other irreversibility in the cycle. It. Exergy analysis provides the tool for a clear distinction between energy losses to the environment and internal irreversibility in the process (1)

Kiran Bala Sachdeva and Karun (2012) – are determined that the magnitude, location and source of thermodynamic inefficiencies of thermal power plant. The first law of thermodynamics introduces the concept of energy conservation, which states that energy entering a thermal system with fuel, electricity, flowing streams of matter, and so on is conserved and cannot be destroyed. Exergy is a measure of the quality or grade of energy and it can be destroyed in the thermal system. The second law states that part of the exergy entering a thermal system with fuel, electricity, flowing streams of matter, and so on is destroyed within the system due to irreversibility.(2)

Mali Sanjay D and Dr. Mehta N S (2012) – are observed that the energy and exergy analysis method for thermal power plant and analysis carried out on 125 MW coal base thermal power plants is presented. Most of the power plants are designed by the energetic performance criteria based on first law of thermodynamics only. The real useful energy loss cannot be justified by the fist law of thermodynamics, because it does not differentiate between the quality and quantity of energy. Also presents major losses of available energy at combustor, super heater, economizer and air-pre heater section. In this article exergy efficiency, exergy destruction and energy losses comparison charts are also define. The definite value of thermal energy can only be obtained by a qualitative or exergy analysis of its conversion, transport and distribution. (4)

Naveen Shrivastava, Seema Sharma and Kavita Chauhan (2012) – are presented that the efficiency assessment and benchmarking of thermal power plants in India. Performance improvement of very small amount can lead to large contribution in financial terms, which can be utilized for capacity addition to reduce demand supply gap. With this view, relative technical efficiency of 60 coal fired thermal power plants (being main source of electricity in India) has been evaluated. In India, total energy shortage and peaking shortage were recorded as 11.2% and 11.85%, respectively in 2008–09 (Central Electricity Authority, 2009a,b,c,d), reflecting non-availability of sufficient supply of electricity. According to National Perspective Plan for R&M, Central Electricity Authority (Central Electricity Authority, 2009c), and some power plants have completed or about to complete their economic life. Replacement of over aged power plants with latest technology power plants is also recommended in order to improve overall efficiency [6].

4. Methodology

A. Research Design

For our research we will take up descriptive Research design as it answers the question what is going on? A good description is a fundamental to the research enterprise and it adds immeasurable of the shape and nature of the society. [10]

- Secondary Phase: - Based on the outcome of the preliminary phase; a detailed questionnaire will be developed to collect information for the study.
- Sampling Technique: - All these data will help in formulating very comprehensive case study. The methodology which will be used for carrying out the report is as follows:-

Type of Data Sources: For present research work, secondary data will be used.

B. Testing methodology

The Direct methodology Testing

This is conjointly called "input-output method" thanks to the fact that it desires solely the helpful output (steam) and also theheat input (i.e. fuel) for evaluating the potency. Thisboiler potency is evaluated exploitation the formula given higher than and also the heat flow within the boiler

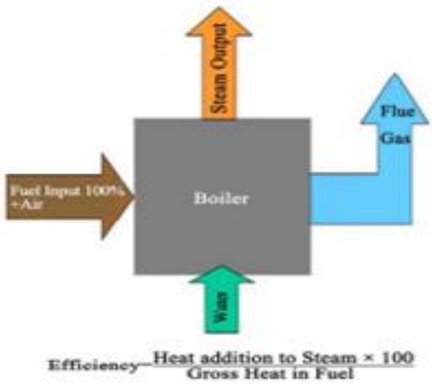

Figure 1: Heat flow in boiler

Exploitation the method of direct testing is shown within the figure.

The Indirect technique Testing

The disadvantages of the direct technique will be overcome by this technique, which calculates the varied heat losses associated with boiler. The varied losses that had occurred in the boiler are shown within the Figure three. The potency can be acquired, by subtracting the warmth loss fractions from a hundred. An important advantage of this method is that the errors in measuring don't build significant modification in potency.

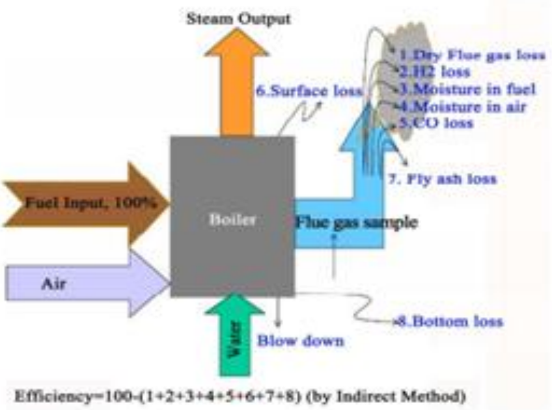

Figure 2: Losses occurring in the boiler

Thus if boiler potency is ninetieth, a slip of a hundred and twenty fifth in direct method can end in important modification in potencyi.e. 90 ± 0.9 = 89.1 to 90.9. In indirect technique, 1% errorin measuring of losses can end in potency = a hundred - (10 ± 0.1) = ninety ± zero.1 = 89.9 to 90.1. So as to calculatethe boiler potency by indirect technique, all the losses that occur within the boiler should be established. These losses are handily associated with the number of fuel burnt. Theoretical (stoichiometric) air-fuel magnitude relation and excess airsupplied square measure to be determined 1st for computing the boiler losses.

Efficiency of boilers in steel plant is calculated by Indirect Method and a sample calculation is shown below. The Heat balance sheet is also prepared. The calculations are shown along with the heat balance sheet. The parameters are obtained from the shift operator log book from Main Control Room, TPP.

C. Experimental Parameters

One of the indicators which show the development and living standards a community is Exergy Consumption. The performance of the boiler is evaluated through exergetic performance criteria which are based on 2nd rst law of thermodynamic. The exergy destruction and exergy efficiency analysis will provide and improve the plant efficiency.

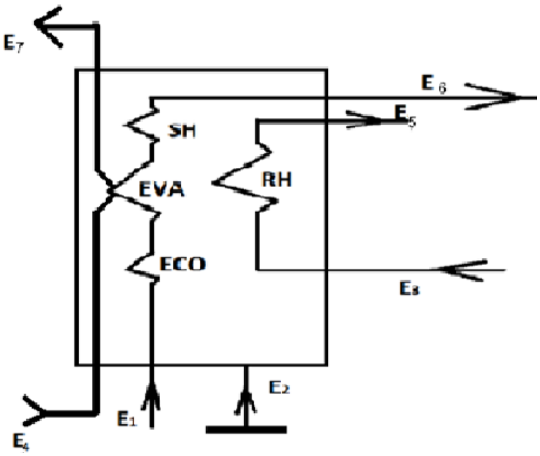

Figure 3: Showing energy and exergy input-output balancing:

Boiler efficiency:-

Boiler efficiency = <u>steam flow rate x (steam enthalpy – feedwater enthalpy) x100</u>

Fuel firing rate calorific value of fuel

Boiler = $m_s (h_2-h_1)+m_r (h_4-h_3) / (m_f) \times LHV$

Exergy analysis:-

Exergy in (E_{in}) $=E_1+E_2+E_3+E_4$

Exergy out (E_{out}) $=E_6+E_5+E_7$

Work input (W_{in}) $=W_{fan} =1978$ kW

Exergy destruction (E_d) $=W + E_{in} – E_{out}$

% Energy Destruction (E_d)

$$= \frac{Ed}{Wfan + Ein} x100$$

Second law efficiency:-

$$(\text{Efficiency})\ E_{II} = \frac{Eout}{Wfan + Ein} x100$$

5. Analysis Results

Performance and Exergy Distruction Analysis of Boiler

In this thesis the boiler of power plant was (8 & 12) analyzed using the above relation on the environment reference temperature and pressure are 298.15K and 1.013 bar respectively. The distribution of exergy addition, exergy losses and exergy consumption for boiler has been worked out on the basis of analysis exergetic efficiency for boiler, has been calculated.

Calculation

Work input (W_{in}) $=W_{fan} =1978$ kW

Exergy in (E_{in}) = 1562628.12 kW

Exergy out (E_{out}) = 575487.82

Exergy destruction (E_d) $=W_{fan} +E_{in} –E_{out}$

= (1978+1562628.12)-575487.82

=989118.3 kW

$$\%\ \text{Energy Destruction}\ (E_d) = \frac{Ed}{Wfan + Ein} x100$$

$$= \frac{989118.3}{1978 + 1562628.12} x100$$

=63.218%

$$(\text{Efficiency})\ E_{II} = \frac{Eout}{Wfan + Ein} x100$$

$$= \frac{575487.82}{1562628.12+1978} x100$$

= 36.781%

It is clear that the boiler shows 36.781 % exergy efficiency and 63.218 % exergy destruction.

Performance of boiler with the usage of different grades of coal in the power plant:
It is notify that as the grade of coal used in the (8) power plant is changed, a change in exergetic efficiency and exergy destruction of Boiler. This type of change in performance is mainly due to inability of the components to harness the exergy thus leading to higher exergy destruction and low exergetic efficiency.

Calculation:
For Bituminous 1:
Work input (W_{in}) =W_{fan} =1978 kW

Exergy destruction (E_d) =W + E_{in} – E_{out}
= (1978+1069033)-572702.2
= 498308.8 kW

(Efficiency) $E_{II} = \frac{Eout}{Wfan + Ein} x100$
$= \frac{572702.2}{1069033 + 1978} x100$
= 53.473%

For Bituminous 2:
Work input (W_{in}) =W_{fan} =1978 kW
Exergy destruction (E_d) =W + E_{in} – E_{out}
= (1978+973776) - 572575.7
= 403178.3 kW

(Efficiency) $E_{II} = \frac{Eout}{Wfan + Ein} x100$
$= \frac{572575.7}{1978 + 973776} x100$
= 58.680%
For Indonesia:

Work input (W_{in}) =W_{fan} =1978 kW
Exergy destruction (E_d) =W + E_{in} – E_{out}
= (1978+1358847) - 573553.9
= 787271.1 kW

(Efficiency) $E_{II} = \frac{Eout}{Wfan + Ein} x100$
$= \frac{573553.9}{1978 + 1358847} x100$
= 42.147%

For A Grade:
Work input (W_{in}) =W_{fan} =1978 kW

Exergy destruction (E_d) =W + E_{in} – E_{out}
= (1978+1562629) - 575486.8
= 989120.2 kW

(Efficiency) $E_{II} = \frac{Eout}{Wfan + Ein} x100$
$= \frac{575486.8}{1978 + 1562629} x100$
= 36.781%

We find that the best exergetic efficiency of the boiler is seen when bituminous coal is used. This is mainly because of low exerg destruction, while for higher grades of coal there is poorer combustion leading to poor exergetic efficiency. The GCV (kcal/kg) value is 3500, 4000. 5500 & 6454 kcal/kg for different type of coal which used in the boiler and graphical representation is given blow:

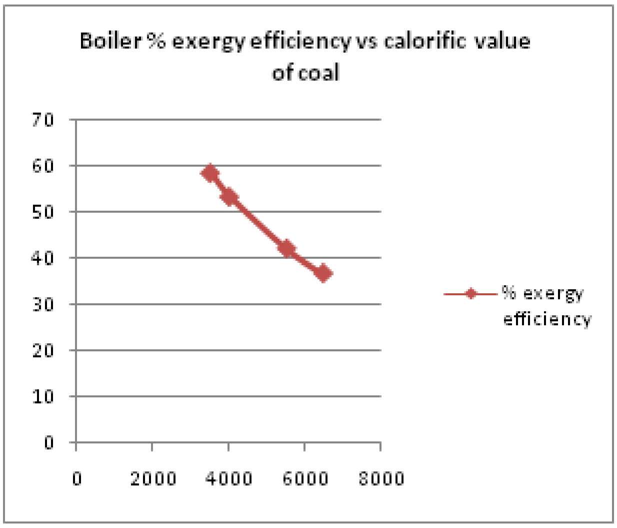

Figure 4: Graphical representation of the variation of highest exergetic efficiency of 58.680% is obtained for calorific value of 3500 kJ/kg while efficiency of 36.781% is observed for calorific value of 6454 kJ/kg

We find that highest exergy efficiency of 58.680% is obtained for calorific value of 3500 kJ/kg while efficiency of 36.781%is observed when high grade coal with calorific value of 6454 kJ/kg is used.

6. Conclusions

Exergy analysis gives entropy generation, irreversibility percentage exergy loss and second law efficiency. The exergy loss or irreversibility is maximum at boiler. Thus to know about actual flow of exergy in the cycle thermodynamic analysis based on second law is desirable.

In the present work a exergy analysis of operating condition of boiler has been carried out based on mass and exergy balance.. It has been found that maximum exergy destruction occurs due to combustion process. Also there is significant exergy destruction occurs in the boiler pressure parts.

Exergy destruction and exergy efficiency of the boiler are presented in Table 1 and corresponding temperature comparison diagram is shown in Table 2. Exergy efficiency of boiler is 36.781 % according to second law analysis and the best exergetic efficiency of the boiler is seen when bituminous coal is used. This is mainly because of low exergy destruction, while for higher grades of coal there is poorer combustion leading to poor exergetic efficiency that highest exergetic efficiency of 58.680% is obtained for calorific value of 3500 kJ/kg while efficiency of 36.781%is observed when high grade coal with calorific value of 6454 kJ/kg is used

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