A Theoretical Investigation of Efficiency Improvement in Thermal Power Plant Boiler

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Abstract

Thermal power plants generate 75-80 % of the total electricity produced in the world. A boiler of thermal power plant is an important component to increase the efficiency of the power plant The generation process of electricity in thermal power plants greatly depends on the efficiency of boiler. The energy calculation for boiler efficiency can help us to improve the performances of a thermal power plant boiler.The objectives of this paper are to analyze the scope of improvement for efficiency of a coal fired boiler. To achieve above objectives the boiler performance is to be assessed and find factors which affect the performance of a boiler.

Keywords: Exergy, Boiler Efficiency, Boiler, Thermal Power Plant.

Introduction

In the present world the development of a nation is measured in terms of per capita of energy consumption India has world's fastest growing energy markets due to economic expansion. India is expected to be the second largest user to increase the world energy demand by 2035.

An energy resource is limited and our demand for this is huge. This huge demand is met mainly by thermal power plant so it is necessary to utilize the plant capacity at their best levels. In thermal power plant boiler is the main component for efficiency improvement. Boiler efficiency can be explained as the fraction of fuel energy which is converted into useful steam energy.

An exergy analysis shows that the loss of exergy is mainly in the boiler where entropy is produced. In a plant, maximum theoretical useful work (reversible work) is known as exergy. Exergy destruction is the measure of irreversibility. Heating related energy saving is related to efficiency of boiler. Different types of losses from the boiler includes hot flue gas losses radiation losses, blow down losses etc.

To maximize the efficiency of boiler it is required to find the path where energy wastage is occurred. Flue gases from boiler are prime carrier of heat loss, about 20-30 % of heat energy is lost through it. As most of the heat losses from the boiler appears as heat in the flue gas, the recovery of this heat results in energy saving. Deterioration of fuel quality and water quality and also leads to lower the performance of the boiler

Boiler performance reduces over time due to poor combustion, heat transfer fouling and operational maintenances. In a coal fired boiler heat of coal is transferred to water to make steam. This steam runs the turbine to generate electricity.

General Description of Plant

Various component of the plant are shown in figure-1. The condenser extract pump (EXP) feeds the feed water to the ejector from the hot well feed water passes through the cooler and low pressure heater (LP). The condensate enters into the boiler feed pump (BFP) from here condensate is pumped high pressure heater HP1 to high pressure heater HP3. Now it goes to economizer and then enters into the boiler. Part of feed water is converted into steam, before supply to the super heater section steam is separated in the boiler. Super-heated steam from super heater then enters into the turbine stop valve and rotates the generator.

Boiler Accessories

There are 3 main elements of boiler, the combustion room: the economizer: the ball of boiler.

The combustion room – It consists tubular bundles of pipes inside which water circulates combustion of mixture of "air-fuel" takes place here calorific energy supplied the quantity of heat that will be transmitted to water to produce steam.

The economizer: It recovers a part of calories remaining in the gases of combustion to raise the temp. Of feeding water which increase the thermal output of installation.

The ball of boiler: From the exit of the economizer the water of feeding reaches to a reservoir situated in the part upside of the boiler is known as the ball of boiler.

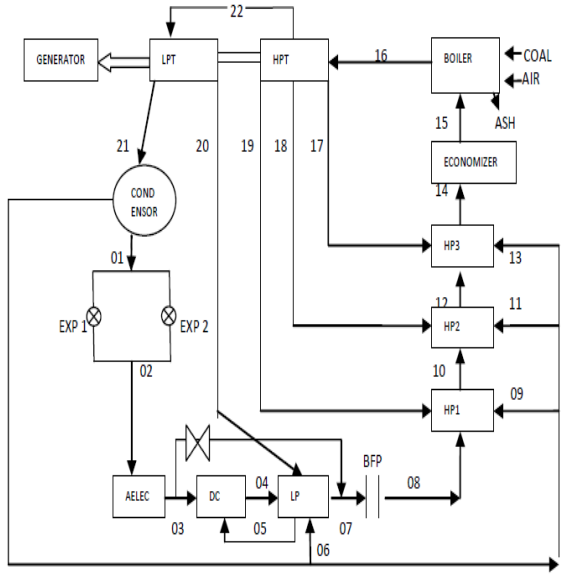

Fig- 1 Schematic Diagram Of Thermal Power Plant

9, 11, 13 outlet from condenser at level HP1, HP2 & HP3.

17, 18, 19, outlet from high pressure turbines towards HP1, HP2 & HP3 (High pressure heaters)

21, outlet of low pressure turbine to condenser.

1, 2 condenser extract pump (exp) feeds the feed water.

14, 15 HP3 to boiler via economizer.

Boiler Efficiency

There are many factors that can lower the efficiency of a thermal power plant boiler. Some of them are:

1. Quality of fuel is not up to the mark.
2. Inadequate heating of fuel.
3. Bad combustion(incomplete combustion)
4. Leakage of water and steam.
5. Loss by humidity.
6. Loss by radiation.
7. Leakage at the level of boiler tubes.
8. Blow down losses.

The efficiency of the boiler is the % of useful heat available.

For calculation of boiler efficiency IS8753, ASME Standard: PTC-4-1 Power test code and BS845 codes are there.

But blow down loss is not considered in these standards

Methods for Efficiency Calculations

Boiler efficiency can be calculated by the following methods

1. Input output method (known as direct method)
2. Method of heat losses (known as indirect method)

Input output method

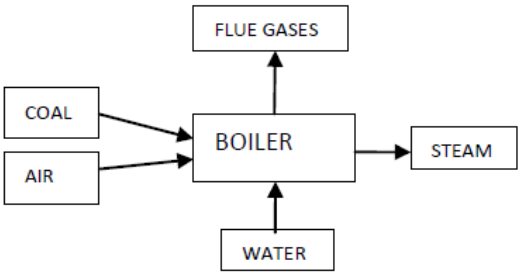

Fig- 2 Heat Flow In Boiler

For evaluating the efficiency it needs to use full heat output (steam) and heat input (fuel) here the working fluid is water and steam which gain energy from the fuel.

$$\text{Efficiency} = \frac{\text{Heat addition to steam X100 \%}}{\text{Gross heat in fuel}}$$

$$\text{Boiler efficiency} = \frac{\text{steam flow rate x (steam enthalpy – Feed water enthalpy) x 100\%}}{\text{Fuel firing rate x Gross calorific value.}}$$

Both heat input and heat output should be measured. Calorific value is determined by sealed sample. This method is quick and less instruments are needed but if steam is wet the efficiency is not correct.

Method of heat losses

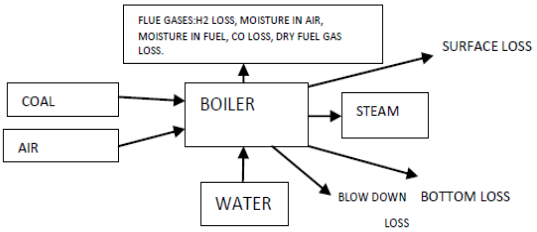

Fig-3 Different Types Of Losses In The Boiler

In this method the efficiency can be calculated by subtracting the heat loss fraction from 100. To find out the efficiency all the losses which occurred in the boiler must be established. Heat loss method is better than input and output method because:

1. Measurement of flow rate of coal is difficult in input-output method.
2. It is more accurate compare to direct method.
3. Give information about decreasing efficiency.

Boiler Efficiency = 100 – Total Losses in %

Generally calculation of efficiency shows a variation of 10 % depending upon the method use. The boiler efficiency comes out in most of the cases in between 70 % - 80 %.

The measure cause of heat loss is due to flue gases

Theoretical Exergy Analysis of Boiler:

The amount of energy we extract as useful work is known as the work potential of the system. This useful potential of system at a particular state is called exergy. Exergy is a property and is associated

with the state of system. In a dead state the system has zero exergy.

Exergy analysis of boiler can be finding out by following exergy analysis of

1. Fuel: this can be find out by the equation by shieh and fan.
   Exergy of fuel = 34183016(C)+21.5(N)+11659.9(H)+18242.9(S)+13265.9(O)
   C=% of Carbon content, N=%of nitrogen content, H=% of hydrogen content, S=% of sulphur content, O=% of oxygen content.
2. Feed water: exergy of feed water can be calculated by the following formula.
   Xfw=(Cp)w (Tfw - Ta) – Ta Ln (Tfw/Ta)
   Where (Cp)w = sp. Heat of water, Tfw =temp. of feed water, Ta =Ambient temp.
3. Air: with help of following formula exergy of air can be calculated
   Xa=(Cp)a (Tah - Ta) –Ta L n (Tah/Ta)
   Where (Cp)a=sp. Heat of air, Tah=temp. of air after pre-heater, Ta =Ambient temp.
4. Flue gas:
   Xfg= =(Cp)g (Tfg - Ta) –Ta L n (Tfg/Ta)
   Where (Cp)g=sp. Heat of flue gas, Tfg=temp. of flue gas, Ta =Ambient temp.
5. Economizer: the exergy can be found as followsXe=(Cp)w (Ti – To) –To L n (Ti/To)Ti & To are the temp. of economizer's in the an outlet.

Findings of this exergy analysis are:

1. As the working load increases, exergy of fuel increases.
2. As the load increases, the exergy of water increases.
3. Combustion air temperature and flue gas temp. Both have effect on the exergy of air.
4. Exergy of economizer increases as load increases.
5. Exergy of flue gases increases with increase of load but it also depends upon the temp. of the flue gases.

It is also found that the boiler has exergy destruction around 80-85% at low load such as 1 MW and for higher load such as 5 MW it is 70-75%.

Therefore we have to run the plant at peak load to reduce the irreversibility and hence efficiency is increased.

Discussion of Results

Exergy view – By comparison of exergy losses between different components of thermal power plant, it can be found maximum exergy loss occurs in boiler the reason may be irreversibility of the combustion process in the boiler .

Tubes fouling, defective burners, fuel quality, air heater fouling, valve steam traps are main factors that contribute to high irreversibility. Exergy destruction in combustion chamber is greatly affected by temp. of air at inlet and excess air fraction.

This exergy destruction can be reduced by reducing the air fuel ratio and pre-heating the combustion air.

Performance Improvement

From heat loss method we find that due to moisture content in fuel heat energy Is wasted from flue gases therefore we have to extract heat from flue gases also note that if flue gas temp. is decreased , acid corrosion will increase in the boiler . Flue gas loss in boiler is higher than any other loss. This loss can be minimized by maximum extraction of heat in the surface of boiler. Leakage from pipe system and valve system also contribute to poor efficiency of the boiler. Faulty insulation also leads to poor efficiency.

Flue dampers are always helpful to reduce exergy loss.

Boiler losses are reducing at the time of peak load runs. Air pre-heater and economizer can be used to capture the heat from exhaust gases. Management of fuel air ratio is important to save energy. Dry cycling should be avoided. Timely maintenance of boiler improves the performance. Soot removal, minimize lime scale build up can help to improve the efficiency. With regard to fuel it should have higher calorific value, low ash content and low level of moisture.

Efficiency can be as high as 85 % if proper measures and checks are there.

Conclusion –

A boiler is like a heart of thermal power plant. To improve the performances of boiler the detail study of boiler in the plant is needed. This paper deals with scope of improvement of boiler efficiency with the help of proven theoretical analysis.

Best relationship between Oxygen, Air flow, coal supply & main stream flow is needed. From overall investigation it get concluded that there are so many ways to improve the boiler performances. Importance to proper check and balance of every process should be given.

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