Design, Development & Analysis of Non-IBR Vertical Fire Tube Boiler for Improving the Efficiency

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Abstract :-*This paper contains the information about design and development of non-IBR vertical fire tube boiler. This boiler works on the thermodynamic principle. Many factories and plants already have this type of boiler which is capable of providing steam of required quantity to production line. The main advantage of vertical boiler is it is economically comparatively cheap and simple in design, also reducing maintenance cost it can also have an outstanding advantage in terms of safety. The main objective of our work is to increase efficiency of boiler by increasing temperature.*

Keywords*:-**boiler, efficiency, production, steam, temperature, thermodynamic.*

I. INTRODUCTION

A boiler[1] is an enclosed vessel that provides a means for combustion heat to be transferred to water until it becomes heated water or steam. The hot water or steam under pressure is then usable for transferring the heat to a process. Water is a useful and inexpensive medium for transferring heat to a process. When water at atmospheric pressure 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 an equipment that must be treated with utmost care. The boiler system comprises of: a feed water system, steam system and fuel system. The feed water system provides water to the boiler and regulates it automatically to meet the steam demand. Various valves provide access for maintenance and repair. The steam system collects and controls the steam produced in the boiler. Steam is directed through a piping system to the point of use. Throughout the system, steam pressure is regulated using valves and checked with steam pressure gauges. The fuel system includes all equipment used to provide fuel to generate the necessary heat. The equipment required in the fuel system depends on the type of fuel used in the system. The water supplied to the boiler that is converted into steam is called feed water. The two sources of feed water are:

(1) Condensate or condensed steam returned from the processes and

(2) Makeup water (treated raw water) which must come from outside the boiler room and plant processes. For higher boiler efficiencies, an economizer preheats the feed water using the waste heat in the flue gas.

II. LITERATURE REVIEW

Normally, the chimney is situated at the top of the boiler, but in this type of boiler we redesign the position of chimney. For that, we kept the chimney position at side of the cylinder and kept another cylinder (no. 4 chamber) for chimney. The main purpose of change of direction of chimney is to keep the smoke outside quickly and do not produce sludge inside of chamber and seamless pipes. So, the probability of blast inside boiler reduced. Also during the maintenance time the worker do his work easily and the dust particles or sludge inside seamless tubes remove easily by using round wire brush. And we kept this position of chimney according to expert advice and experience company head. And this redesign of boiler is going successfully.[1] There are several different chemical approaches used to treat boilers and their selection and performance depend upon many factors. Some of these include:

1. Feed water characteristics.
2. The type and reliability of external treatment.
3. Boiler type.
4. Boiler pressure and heat flux.
5. Steam load and variations in load.
6. Waterside condition of the boiler and current and long-term goals of the program such as cleaning up scale or maintaining present conditions.
7. Steam purity requirements.
8. Regulatory restrictions such as FDA

Requirements, other health and safety concerns, or process restrictions.
9. Feed, testing, and control needs or restrictions.
10. Economic considerations.
11. Boiler room layout and number of boilers.

III. MAJOR COMPONENTS & MATERIALS

- Mild steel:- It is used for boiler cylindrical body. It has good properties such as –
  1. Good tensile strength
  2. Cheap in cost
  3. Easy to form
  4. Tough
  5. Ductile
  6. Malleable
  7. Easy to weld

- Nickel alloy:- It is used as seamless tube where the fire is takes place. It has good properties such as-
  1. High thermal conductivity
  2. High electrical conductivity
  3. High curie temperature
  4. Long life duration

- Cast iron:- Cast iron is used in feed water pump and blower because of rigidity.[7]

IV. DESCRIPTION OF COMPONENT

A. Feed Pump:-

Fig1. Feed Pump

Technical Specifications

Pressure: 20-40 Kg/cm2
Revolution: 300-1000 rpm
Capacity: 6-18 L/min
Power: 1.5-2 HP

B. Blower :-

Fig2. Blower

Technical specifications

Power: 1 HP
Supply: Single Phase
Voltage : 230 V
Speed : 2800 rpm
Current : 2.7 Am
Watt : 750w

C. Pressure Gauge:-

`A pressure gauge[10] is fitted in front of boiler in such a position that the operator can conveniently read it. It reads the pressure of steam in the boiler and is connected to steam space by a siphon tube. The most commonly, the Bourdon pressure gauge is used.

D. Temperature Gauge:-

Temperature gauge is used to indicate the temperature of middle stage of boiler. It indicate highest temperature in the second stage of boiler. The performance of boiler is depend on temperature of boiler. Hence it is use to maintain performance of boiler. It ranges between 0 to 150˚C.[10]

E. Main Valve:-

Main valve[9] is fitted in the main steam supply line and is usually of the non- return type. It acts as a regulator for supply line. It operates by manually. We can control the supply of steam to production line through this valve by revolving the wheel which is fitted in main valve. When the main valve is turned in anticlockwise direction, the spindle is raised up. This will raise the valve from its seat. Thus a passage for the steam from the clearance between the valve and the valve seat is formed. In order to lower the valve, the hand wheel (main valve) is rotated in clockwise direction. This rotation will close the passage for steam. Adjusting the position of the valve based on the requirements can regulate this.

F. Float Valve:-

A float valve is a mechanism or a machine for filling water tanks. Those found in flush toilets, while avoiding overflow and backflow. It consist of valve connected to a hollow sealed float by means of a lever mounted near the top of the tank. The float is often ball shaped hence the name ball cock. The valve is connected to the incoming water supply and is opened and closed by the lever which has the float mounted on the end. When the water level rises the float rises with it.

Fig3. Float Valve

once it rises to a pre-set level the mechanism forces the lever to close the valve and shut off the water flow. [7]

G. *Carbon Tubes:-*

The boiler tubes[9] are manufactured from materials which are able to withstand high temperature and pressure. They must therefore meet the greatest technical requirements of the production process and also the most stringent control regulation in order to guarantee their durability and reliability over a period of time. Hot rolled seamless carbon and alloy (nickel) steel tubes are used in boiler.

H. Furnace:-

The term furnace can also refer to a direct fire heater used in boiler application in chemical industries. A furnace is device used for high temperature heating. The heat energy to fuel a furnace may be supplied directly by fuel combustion. In this boiler single stage furnace is used. In single stage furnace has only one stage of operation it is either on or off. This means that it is relatively noisy, always running at highest speed and always pumping out the hottest air at the highest velocity.

I. Ash Tray:-

It is normally found at the bottom of the boiler. It is always placed at below of the fuel combustions place. It is used to safely remove the ash comes from the burning of the fuel of the boiler.

J. Water Level Indicator:-

It consists of a glass tube two gun metal tubes and three cocks. The steam cock is provided on gun metal tube which connects the glass tube with the steam space in the boiler. The water cock is provided on gun metal tube which connects the glass tube with the water space. The gun metal tubes are bolted to the boiler shell. The drain cock is used to drain the water from the glass tube at intervals to as certain whether the gauge is in proper order or not. The glass tube is protected By means of a cover, made of specially toughened glass which will prevent any accident that may happen due to the breaking of glass tube.

K. Chimney(Stack):-

Normally, the chimney[1] is situated at the top of the boiler, but in this type of boiler we redesign the position of chimney. For that, we kept the chimney position at side of the cylinder and kept another cylinder (no. 4 chamber) for chimney. The main purpose of change of direction of chimney is to keep the smoke outside quickly and do not produce sludge inside of chamber and seamless pipes. So, the probability of blast inside boiler reduced. Also during the maintenance time the worker do his work easily and the dust particles or sludge inside seamless tubes remove easily by using round wire brush. And we kept this position of chimney according to expert advice and experience company head. And this redesign of boiler is going successfully.

Fig4. Modified Boiler With Chimney

L. *Filter:-*

The boiler needs the water for generating steam to production line. But the boiler needs the pure water without any dust and other particles. If the water

is feed without filtering into boiler then the probability of sludge and blast may increased. For this type of boiler we need the 5ppm filtered water. So the corrosion is not takes place. The maintenance cost reduced and life of boiler increases.

V. DESIGN

Volume of a boiler

Volume of first stage of a boiler

$=\frac{\pi}{4} \times D^2 \times h$

$=\frac{\pi}{4} \times 0.890^2 \times 1.210$

$= 0.7527\ m^3$

Where

D = Diameter of first stage of a boiler

h = Height of a first stage of boiler

Volume of second & third stage of a boiler

$=\frac{\pi}{4} \times D^2 \times h$

$=\frac{\pi}{4} \times 0.570^2 \times 1.5$

$= 0.3827\ m^3$

Where

D = Diameter of second & third stage of a boiler

h = Height of a second & third stage of boiler

Total volume of a boiler

= 0.7527 + 0.3827

$= 1.1354\ m^3$

Volume of a inner components of a boiler

Volume of a furnace

$=\frac{\pi}{4} \times D^2 \times h$

$=\frac{\pi}{4} \times 0.690^2 \times 1.210$

$= 0.4524\ m^3$

Where

D = Diameter of furnace of a boiler

h = Height of a furnace of boiler

Volume of fire tubes

$=\frac{\pi}{4} \times D^2 \times h \times N$

$=\frac{\pi}{4} \times 0.016 \times 1.5 \times 21$

$= 0.0063\ m^3$

Where

D = Diameter of fire tubes of a boiler

h = Height of a fire tubes of boiler

N= Number of tubes

Volume of a chimney$=\frac{\pi}{4} \times D^2 \times h$

$=\frac{\pi}{4} \times 0.570^2 \times 0.6$

$= 0.1531\ m^3$

Where

D = Diameter of chimney of a boiler

h = Height of a chimney of boiler

Total volume of inner components of a boiler

= volume of a furnace + volume of fire tubes + volume of a Chimney

= 0.4524 + 0.0063 + 0.1531

$= 0.6118\ m^3$

Actual volume of a boiler

= Total volume of a boiler – Total volume of Inner components of a boiler

= 1.1354 – 0.6118

$= 0.5236\ m^3$

= 523.6 litres

Efficiency calculations of boiler q ×GCV

Efficiency

$=\frac{Q(hg - hf)}{q \times GCV} \times 100$

$=\frac{175(652 - 80)}{50 \times 2500} \times 100$

= 80.08 %

VI. WORKING OF BOILER

The boiler is working on principle of thermodynamics. Here we design the NON-IBR[12] vertical fire tube boiler. In our boiler there are three chambers and one separate chamber for stack(chimney). The first chamber is called furnace. The water from sump or reservoir is fed into boiler through pump of 1.5-2 HP. Water capacity of boiler is 500kg and steam pressure is 3-4Kg for 1kg of wood (coal) whose calorific value is 2200-2500 KJ/Kg. During burning of wood into furnace the air is sucked at the bottom of furnace for combustion of wood. 1HP blower is required. First the water in feed into top chamber i.e. third chamber where temperature 80-100°c is maintained. After the water is comes into bottom chamber where temperature 100-140°c is maintained. Then the water goes to middle chamber where maximum temperature 160-200°c is maintained. Then steam is produced whose pressure and temperature is measured by pressure and temperature gauge respectively. Then the steam pressure is regulate by using main valve. This steam is used for milk factory, sugar factory, food processing, corn factory. The safety valve is used for removing the steam when it is not necessary.

VII. ANALYSIS

Before manufacturing of the boiler, we took the experiment on the 3D design of boiler. Which is done on the ANSYS software. Which is going successfully in operation. For that we take a materials and its properties. And fill this information in ANSYS software. The first step in ANSYS software is to select the type of ANSYS i.e. we select steady state thermal condition. After we select an engineering data i.e. assigning materials. Then which we created the 3D design in Auto-Cad save into (.igs) format. Then we kept this 3D design save in (.igs) convert into ANSYS software. Then we meshing the all parts of boiler. And we filled the boundary condition i.e. we filled the temperature of each part separately. Finally we found

the solution i.e. temperature distribution, total heat flux. And then we generate the final report.

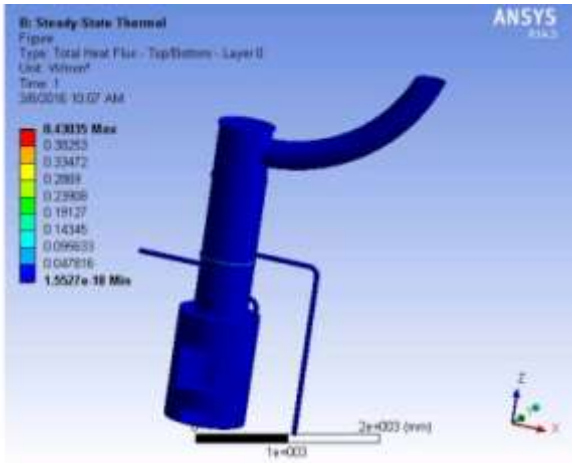

Fig5. Analysis of Minimum Heat Loss to Production

From the analysis of boiler we found that the heat flux i.e. heat losses during steam flow from boiler to production line is minimum between $1.5527e^{-17}$ -0.43035 W/mm^2 after redesigning of boiler.

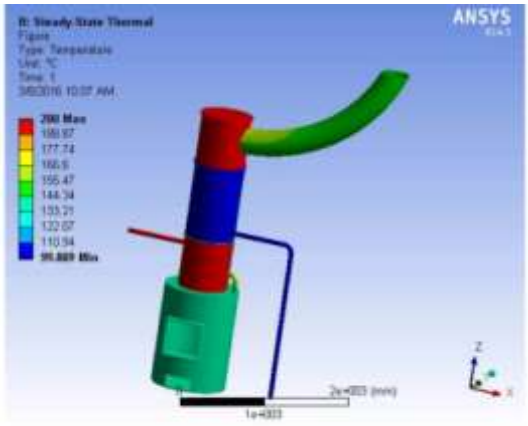

FIGURE 6
Model (B4) > Steady-State Thermal (B5) > Solution (B6) > Total Heat Flux > Figure

Fig6.Analysis of Maximum Steam Temperature

From the analysis of the boiler we found that the temperature of steam is increases to 200°c after redesigning of boiler.

VIII. TEMPERATURE OF EACH CHAMBER

A. First Chamber (Furnace):-

In this chamber the steam temperature is reached upto 140°c

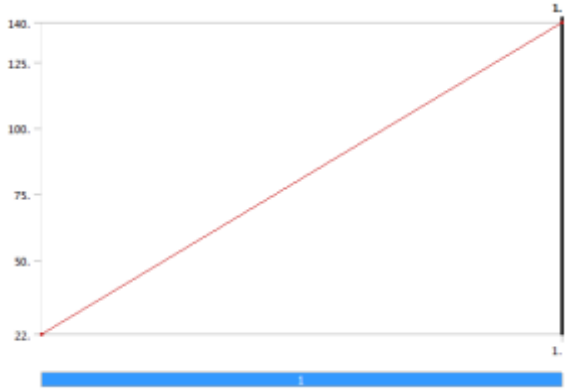

Fig7. Graph of First Stage

B. Second Chamber (Middle Stage):-

In this chamber the steam temperature reached upto 190°c - 200°c

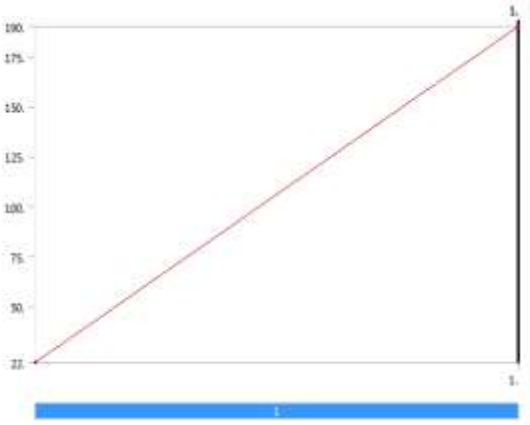

Fig8. Graph of Middle Stage

C. Third Chamber(Top Stage):-

In this chamber the steam temperature reached upto 100°c

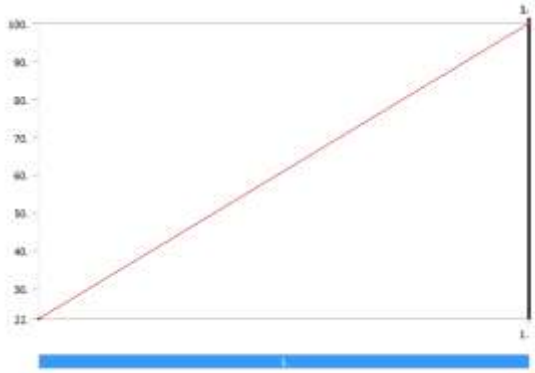

Fig9. Graph of Third Stage

D. Overall Temperature to Production Line:-

The temperature at middle stage is used to production line. The steam is produced at the

temperature 200°c and this steam is transfer to the production line. The graph is shown in below.

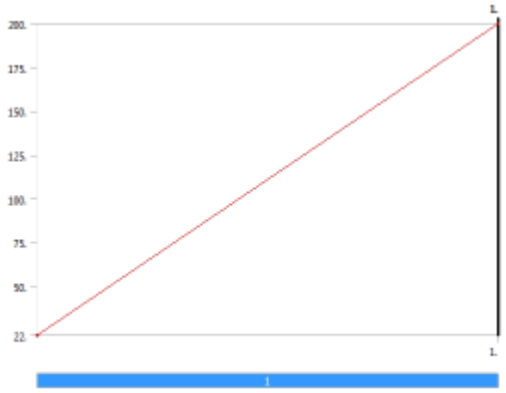

Fig10. Graph of Steam Temperature to Production Line

IX. CONCLUSION

The work carried out by us made an impressing task in the field of small scale industries. It is very useful for the workers to carry out an operations and maintenance of boiler in easy way. This boiler is very easy to use because of simple construction and less risk. This boiler is also portable in nature because of its compact size.

We can easily maintain the water level in middle stage of boiler with the help of float valve because of this the life of carbon tubes increased.

Due to ANSYS we modify the boiler such way that heat flux reduced and also temperature of steam increases.

This work has also reduced the cost involved in the concern. Our work is quite environment friendly due to less use of non-conventional fuel. The work has been designed to perform the entire requirement task which has also been provided. So this boiler and its construction is efficient for working.

ACKNOWLEDGEMENT

We have great pleasure to present a paper on **"DESIGN, DEVELOPMENT& ANALYSIS OF NON-IBR VERTICAL FIRE TUBE BOILER FOR IMPROVING THE EFFICIENCY ".**

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