Thermal Analysis of Heat Transferring Components in the Power Plant - A Review

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Abstract

Heat Transferring components play a major role in the power plants. Heat transferring components are intended to transfer heat between two flowing fluids. There are different heat transferring components used in power plant steam cycles like water wall tubes, super-heater tubes, economizer tubes, air pre-heater, feed-water heaters, condensers, oil coolers, tube and shell type heat exchanger, flat plate heat exchanger etc. on these various heat exchangers analysis is conducted in different dimensions such as thermal analysis, hydraulic analysis etc to ensure if the boiler tubes are in proper working conditions, to avoid possible failures, to identify the scale formation on the inner surface of tubes. In the heat generator also called as boiler the heat source is used to heat and vaporize the feed water. This paper formalizes certain analysis techniques on water tube boilers.

Keywords: Heat exchangers, heat generators, hydraulic analysis, thermal analysis, water tube boilers.

1. Introduction

Heat transferring components intended to transfer heat hold a key role in the power plant. Water walls are the walls made up of number of tubes and their fins so that it will form a continuous wall which will provide a large heating surface area. These walls are used to construct the boilers. These are covered by refractory at the bottom which will provide the surrounding to the furnace. Inner portion of these walls are in continuous contact with the flue gas and the outer surface of wall will be insulated by the insulating material like glass wool and the aluminium sheets. So the temperature variation throughout the surface of the water wall tube at various points is very important to understand the full evaporation process. Water walls are used to convey the steam generated at the in-bed evaporator to the riser header. These are tubes in the Boiler where water is evaporated to steam and are also called "Steam Generating Tubes". These Tubes also form the Walls of the Boiler and are hence called "Water Walls" or "Water Wall Panels".

A superheater tube is a device used to convert saturated steam or wet steam (also called as non-superheated steam) into dry steam used in steam engines or in processes, such as reformation. Three different types of superheater exists are radiant, convection, and separately fired. A superheater can vary in size from a few tens of feet to several hundred. In a steam engine, the steam generated by the boiler is re-heated by superheater, increasing its thermal efficiency. Steam that has been superheated is logically known as superheated steam. The bundle of superheated tubes is places at the start of flue gas path or at the end part of boiler. The reduced fuel and water consumption is the main advantage of using a superheater.

Shell and tube heat exchangers consist of a series of tubes. One set of these tubes contains the fluid that must be either heated or cooled. The second fluid runs over the tubes that are being heated or cooled so that it can either provide the heat or absorb the heat required. A set of tubes is called the tube bundle and can be made up of several types of tubes: plain, longitudinally finned, etc. Shell and tube heat exchangers are typically used for high-pressure applications. The shell and tube exchanger provides larger ratio of heat transfer area to volume and weight. The different components of shell and tube type heat exchangers are tubes, tube sheet, shell and shell-side nozzles, tube-side channel and nozzles, channel covers, pass drivers and baffles.

In this paper we are summarising the thermal analysis of heat transferring components in the power plant.

2. Prediction of riser's temperature in water tube boilers

Author [1] has proposed the dynamic thermal model for riser tubes and computed the wall temperature at thermal equilibrium. The author has computed the heat transfer coefficient for riser tubes as well. The fluid dynamic model of water tube boiler is developed which will give the relation between the volume, pressure, flow rate, evaporation rate of the steam and the steam quality. He prepared the fluid dynamic model for natural circulating boiler by using global mass balance, energy balance, downcomer – riser flow loop equations. The different parameters are compared at different loads. This comparison gives the reference point for the operation of the boiler so that the operational changes and safety can be obtained for the different load condition of the boiler. To increase the steam generation the firing order get increased as well as the steam header pressure also get increased which leads to increase in the temperature of tubes. Thus the prediction of the tube temperature is essential for smooth functioning of boiler and also to acquire safety. This methodology is useful for online temperature assessment to avoid the tube failures as well as the overheating of the riser tubes which will be very helpful for operation engineers.

3. Iterative technique and finite element simulation for supplemental condition monitoring of water-tube boiler

In [2] author has proposed a iterative technique and finite element simulation for condition monitoring of water-tube boiler. The technique of condition monitoring is used to monitor the condition parameters in a system where a momentous change indicates the possibility of failure. Also it can be said that it allows actions to be taken to evade the consequences of failure, before its occurrence.

The fundamental principle of condition monitoring is to select a material measurement that indicates the occurrence of deterioration.

The proposed method uses the empirical formula to estimate scale thickness that is developed on the inner surface of the tube over period of time. An iterative procedure is conceded to determine the average temperature in the tube as oxide scale thickness on its inner surface increases. The method uses finite element simulation in order to avoid failure due to increase in temperature in the tube. The finite element simulation is done by using the software ANSYS.

In this paper author give s the variation of scale thickness, temperature increase of tube with respect to time, so that the life of the tubes can be identified.

4. Thermal analysis of tubular heat exchanger by using Ansys

In [3] author has discussed the temperature analysis of tubular heat exchanger by using the software called Ansys. The tube and shell type heat exchanger is composed of four tubes that are made up of Aluminium. The author initially analyses these tubes for temperature and velocity of cold and hot water in tube and Shell. These aluminium tubes are then replaced with the copper tubes. After replacement again the analysis is made for temperature and velocity of hot and cold water in tube and shell by using CFD from Ansys software. The exchanger works on the atmospheric pressure. The obtained parameters are compared between tubes of copper and aluminium metals. The analysis shows that the output temperature for both the material is found nearer to the actual value.

5. Identification of Local Heat Flux to Membrane Water-Walls in Boilers

In [4] author explored the new technique in order to find the local heat flux to the water walls of boiler. The flux tube welded to the water tube of water walls is used. The water walls are having more than three numbers of holes to insert the thermocouples. Out of these three thermocouples one is placed on the backside of the flux tube which is not facing the furnace of boiler. The readings observed by thermocouples will help to find out the parameters like temperatures of water steam mixture at different locations of flux tube, the absorbed heat flux, the heat transfer coefficient on the inner side of tube. The heat transfer coefficient is obtained by using the Least Square method in order to minimize the obtained temperature differences. The unknown parameters can be finding out by Levenberg-Marquardt method. For experimentation author has used the Ansys Software and found out the temperature of tubes at different locations. This paper is used for the on line assessment of slagging of boiler tubes to improve the thermal efficiency and in turn the performance of the boiler.

5. Tube temperature distribution in water tube boiler – A parametric study by finite element method

Author [5] has formulated the finite element model for the boiler tube and analysed the temperatures at different conditions of the operation of boiler. The 2-D model of the inner side of the tube with the scale deposited on it is designed. The temperature distribution is studied in both the conditions that are scaling inside the tube and tubes without scale.

Temperature distribution -

i) Due to the variation of mass flow rate inside the boiler-

As the mass flow rate decreases, the temperature of flue gas increases and that of tube decreases.

ii) Due to different thermal conductivity of tube-

The tube material is changed from carbon steel to stainless steel and it is found that when the thermal conductivity decreases, the tube temperature inside the tube will be decreased and temperature of outer surface of tube will be increased.

iii) At different steam inlet temperature –

As the temperature of the inlet steam increases the temperature of the inner side of tube will get increase in both cases, with scale and without scale.

iv) At different scale thickness –

Scale reduces the heat transfer rate and hence the temperature outside the tube increases to maximum and the temperature inside the tube decreases as the scale thickness increase.

For this analysis the MSC Patran -Nastran software is used. This analysis uncovers the disadvantages of scale formation inside the tube.

6. Mathematical modelling and thermal-hydraulic analysis of vertical water wall in an ultra supercritical boiler

The Author in [6] has explored the mathematical model of a water wall tube of the ultra supercritical boiler and calculated the metal temperature distribution as well as the mass flux distribution at 35%, 50%, and at 100%

BMCR. The water walls are considered as the circuit and it is divided into eight parts on the basis of position as upper, lower, rear, front, etc. The same parameters are obtained at different location of water wall of the boiler at Yuhuan Power plant of China experimentally. Both the obtained results are compared to get the graphs of i) mass flux, ii) outlet fluid temperature in furnace, ii) metal temperature along the height of the water wall at different load and at different location. From the graph it is clear that both the calculated and the experimental data are near about same. From the analysis it is concluded that at higher BMCR load the mass flux distribution is also higher.

7. Failure Analysis on Deformed Superheater Tubes by Finite Element Analysis

The author in [7] focuses on the deformed superheater tubes to find out the maximum allowable stresses by the expansion and contraction of the material of coil as well as the location of the maximum stress occurred. The superheater tubes are having welded joints and U-shaped bend. The analysis is carried out on the already deformed tubes by using the MSC Patran Nastran Software. The author has proposed the model of superheater tube and applied the boundary condition to find the numerical results by using finite element analysis.

The first boundary condition assumed is that one end near the header will be considered fixed and applied constraints for all six degree of freedom. Second boundary condition is to find the tube deformation at seven different cases considering different constraints by simulation. Assumptions made for the analysis are

i) The temperature and pressure inside the tube are constant and uniform.

ii) The metal tube temperature is found out by using the overall heat transfer coefficient.

These results give the correlation between the maximum and the allowable stress. The analysis provides guidance to the plant inspector for the inspection of the boiler.

8. Conclusion

For the proper functioning of boiler and assurance of safety during the operation analysis of various parameters of the boiler is of the essence. This paper addresses the review on various methods related to thermal analysis of heat transferring components in the power plant. The results of the survey shows that there is a broad room for such analysis considering various parameters like temperature, pressure, water volume etc. This will provide better estimation over a period of time and improve the methodology of operation as well as avoid accidental condition.

8. References

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