# ENERGY AND EXERGY ANALYSIS OF REHEATER TUBE PERFORMANCE IN A 210MW THERMAL PLANT

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## ABSTRACT

Thermodynamic systems are analyzed using two essential tools (i.e., Energy and exergy analysis). However, system analysis based on the energy law has quantity alone, but the exergy shows that energy has quantity as well as quality. Optimum Scale thicknessis formed in the Re-heater tubes. In this project, an iterative procedure has been adopted to evaluate performance of the boiler tube in terms of tube temperature, heat loss, energy and exergy Efficiencyand irreversibility.This oxide scale reduces the heat transfer from the hot flue gas into the steam within the tube. Typical steady state plant operation conditions were determined based on available trending data in Mettur Thermal Power Plant. Energy and Exergy analysis helps designers to find ways to improve the performance of a system.

Keywords: *Energy, Exergy, Reheater*

## *I. INTRODUCTION*

Boiler is an enclosed vessel that provides a means for combustion heat to be transferred into water until it becomes heated water/steam. The hot water or steam under pressure is then usable for transferring the heat to a process. Water is a useful and cheap medium for transferring heat to a process. This causes the boiler to be extremely dangerous equipment that must be treated with utmost care.

Boiler tubes can be categorized into water tube and fire tube. A water tube refers to the flow of water inside the tube with combustion gasses flow externally. On the other hand, a fire tube refers to combustion gasses that flow inside the tube with the tube being surrounded by water on its exterior. The analytical evaluation in this project will only consider for the water tube category.

The performance of the rankine cycle can be improved by increasing the mean temperature of heat addition i.e. increasing the degree of superheat, steam pressure by multistage expansion with reheating.The research sofar was focused on increasing the mean temperature of heat addition by increasing steam pressure by multistageexpansion of steam. The efficiency of the steam power cycle can be improved to a large extent by theincorporation of feed water heater or by the use of regenerative feed heating system. At present there are two traditional way to analysis the performance of the feed heating system. One is by theenergy balance across the system. The other is by calculating separately the rate of entropy generation inprocess. In our study, energy and exergy balance of feed heaters are provided based on the first law and secondlaw. The energy assessment must be made through the energy quantity as well as the quality. But the usualenergy analysis evaluates the energy generally on its quantity only. However, the exergy analysis assesses theenergy on quantity as well as the quality

## *II. POWER CYCLE DESCRIPTION*

A steam based thermal power plant operates on the Rankine cycle and the power plant efficiency can be improved by improving the cycle efficiency. To increase the cycle efficiency re-heater, regenerative heating systems are incorporated in the system. A power cycle continuously converts heat into work, in which a working fluid repeatedly performs a succession of processes.

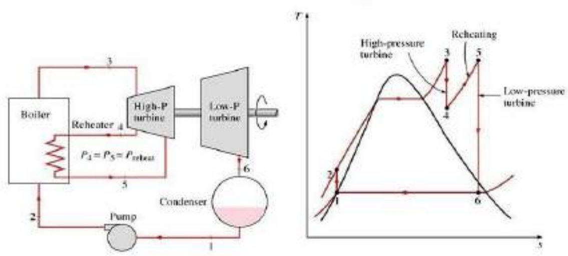


**Figure 1.2 Modified Rankine Cycle**

### A. SUPER HEATER

Super heater means to raise the temperature above the saturation temperature by absorbing heat from flue gas. By increasing the temperature of steam the useful energy that can be recovered increases thus efficiency of the cycle is improved. The Super heater is composed of four sections. They are steam cooled wall and roof section, Low temperature Super heater, Platen super heater and Pendant super heater.

The dry saturated steam flow first through the roof and steam cooled wall and then enters the low temperature super heater located in rear vertical gas path above the economizers. From the low temperature steam flows through the radiant super heaters which is placed in the boiler to see the flame. The heat transfer in this super heater is by radiation. The last stage superheated known as Pendant Super heater is placed in the second pass of the boiler horizontally or allowed to hang vertically, Here the heat transfer is by convection superheated steam from pendant Super heater outlet header goes to the turbine through the main stream lines.

### B. REHEATER

Re-heaters are used to raise the temperature of cold stream from which pat of the energy has been extracted in high pressure turbine. This is another method of increasing the efficiency cycle. Reheating requires additional equipments (i.e.) heating surface, boiler turbine connecting piping, steam temperature equipments, etc.., Because of these additional investment the operation is to complicated and reduced availability of such systems so the efficiency of the systems get minimized.

## *III. ENERGY AND EXERGY*

Energy Efficiency is using less energy to provide the same service. Exergy is the energy that is available to be used. After the system and surroundings reach equilibrium, the **exergy** is zero. Determining **exergy** was also the first goal of thermodynamics.Exergy is the maximum theoretical work which can be obtained when a system of interest interacts with a reference environment to equilibrium (Dincer, 2000). The order of exergy destructions and losses in the processes and components of a thermal system can be revealed by the exergy analysis of the system. The results of exergy analysis can be used for pinpointing the processes in a thermal system on which further studies must be concentrated for better energy source utilization.

Total energy consists of available energy plus unavailable energy. Considering flows of energy in aSystem, total energy is simply called energy and available energy is called exergy. Exergy flows toand from components however do not balance indicating a disappearance or "consumption" of exergy. This disappearance is really a conversion from available energy to unavailable energy. Consumption is a descriptive term indicating the loss of available energy. Components consume exergy by virtue of the ineffectiveness of their ability to transfer available energy. In order to compare the quality levels of various energy carriers, e.g. fuels, it is necessary to determine the equivalents of each energy quantity at a particular grade level. This can be done by using exergy concept, which overcomes the limitations of the first law of thermodynamics; and is based on both The First and The Second Laws of thermodynamics.

## *IV. HEAT TRANSFER MECHANISM*

Heat transfer is defined as the thermal energy in transit due to a spatial temperature difference (Incropera et al., 2007). Heat transfer processes can be grouped into three types of modes; conduction, convection and radiation. Conduction process startswhen a temperature gradient is present in a stationary medium where the heattransfer is across that medium. Heat transfer between a surface and a moving contactfluid of different temperature is referred to as the convection process. On the otherhand, radiation is the heat transfer between two non-contact surfaces at differenttemperatures by emitting energy in the form of electromagnetic waves.
In this research, only conduction and convection modes are taken into account. Based on the cross sectional model developed by Purbolaksono et al. (2010),it is found that the steam section and the flue gas section experiencesinternal forced convection with turbulent flow and external forced convection due tocross flow respectively. The oxide and metal tube section experiences one dimensional steady-state conduction.

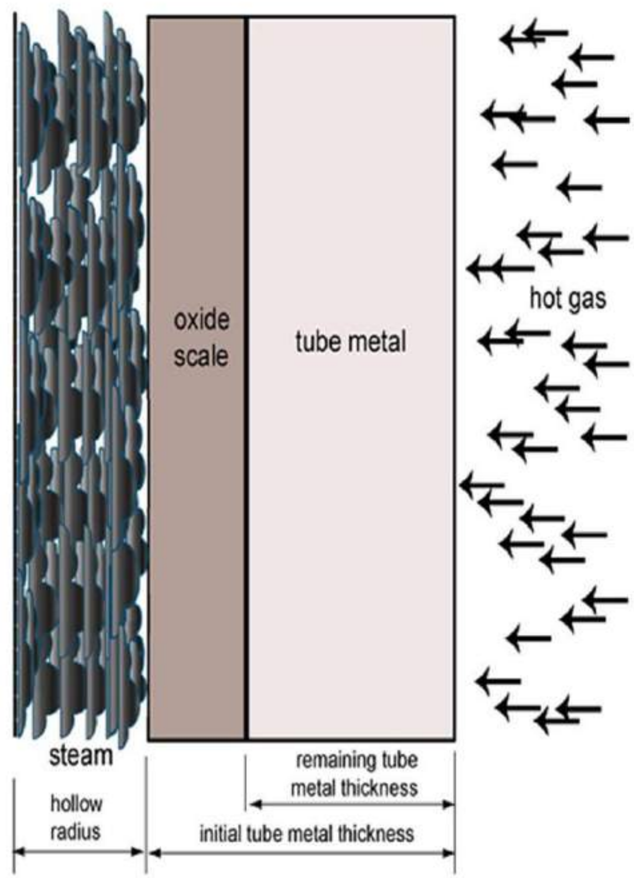


**Fig 1.1 MODEL OF WATER TUBE BOILER**

## *V. RESULT AND DISCUSSION*

### A. WATERSIDE CORROSION AND SCALE DEPOSITION IN BOILER TUBES

Waterside corrosion is often present in any water tube boilers. This type of corrosion

Greatly influences the reliability of the heat recovery boilers as it deteriorates the tube Material. The deposition of scale due to waterside corrosion is caused by the Chemical reaction between the tube material and the chemical composition inside the water. These corrosion failures are the result of ineffective control of water chemistry.

The water used for steam production may contain gaseous impurities and dissolve solids which may result in scaling in the boiler tube. For instance, tube temperature increases during its lifetime due to the oxide build up in the interior of the tube which insulates the tube from the flow of water.

As the tube temperature increase, the scale deposition rate increases

### B. BOILER TUBE MATERIALS

Boiler tubes are usually manufactured using alloy materials which can withstandboth high temperature from the flue gases and high pressure steam generation withinthe tube. The use of high temperature heat resistant alloys not only improves thesupercritical steam quality for better efficiency, they also allow reduction involumes of material for fabrication, both which promotes positive economy benefits.

### C. MATERIAL AND ITS COMPOSITION

Table 1 Material and its composition

| | C | S | Si | Cr | Mo | P | M |
|---|---|---|---|---|---|---|---|
| SA213 T22 | 0.15 | 0.03 | 0.5-1 | 1.0-1.5 | 0.44-0.65 | 0.03 | 0.3 |

### D. ALLOYING ELEMENTS AND ITS FUNCTIONS

Table 2 Alloying Element and its functions

| Alloying | Element Functions |
|---|---|
| Carbon (C) | Increase solid-solution strength, hardness |
| Manganese (Mn) | Improve solid solution strength, hardness and harden ability<br><br>Improve wear and abrasion resistance |
| Chromium (Cr) | Increase resistance to corrosion and high temperature Oxidation<br><br>Provide high temperature strength<br><br>Increase solid-solution strength, hardness and hardenability |
| Molybdenum (Mo) | Improves high temperature properties such as creep strength<br><br>Enhance corrosion resistance in stainless steel |
| Sulfur (S) | Considered as impurity in most steels<br><br>Improve machinability |
| Phosphorus (P) | Considered as impurity in most steels<br>Increase strength and hardness in in low-carbon steels |

## E. SPECIFICATIONS OF SUPERHEATER TUBES

Table 3 Specifications of Re-heater Tubes

| | Superheater |
|---|---|
| OD of the tube | 46.27mm |
| ID of the tube | 39.89mm |
| Inlet flue gas temperature | 568°c |
| Inlet steam temperature | 303°c |
| Pressure of steam | 32.8bar |
| Velocity | 6.3m/s |
| Tube length | 21m |
| No. of tubes | 59 |
| Mass flow rate | 180.5kg/s |
| Material | SA213T22 |

## F. ENERGY AND EXERGY EFFICIENCY WITH DIFFERENT SCALE FORMATIONS

Table 4 Energy and Exergy Efficiency with different scale formations

| Scale thickness | Heat transfer coefficient | Surface Temperature | Energy Efficiency | Exergy efficiency |
|---|---|---|---|---|
| 0.1 | 65813.985 | 562.15 | 0.82 | 0.673 |
| 0.2 | 65246 | 562.16 | 0.819 | 0.665 |
| 0.3 | 64917.270 | 562.17 | 0.817 | 0.657 |
| 0.4 | 64756.604 | 562.175 | 0.816 | 0.650 |
| 0.5 | 64682.966 | 562.18 | 0.815 | 0.642 |
| 0.6 | 64527.321 | 562.182 | 0.814 | 0.635 |
| 0.7 | 64354.94 | 562.198 | 0.817 | 0.628 |
| 0.8 | 64229.421 | 562.202 | 0.816 | 0.621 |
| 0.9 | 63936.541 | 562.216 | 0.814 | 0.614 |
| 1.0 | 63802.653 | 562.221 | 0.8175 | 0.607 |
| 1.1 | 63628.598 | 562.228 | 0.815 | 0.601 |
| 1.2 | 63534.876 | 562.234 | 0.797 | 0.595 |
| 1.3 | 63318.982 | 562.241 | 0.783 | 0.588 |
| 1.4 | 63109.782 | 562.247 | 0.771 | 0.582 |

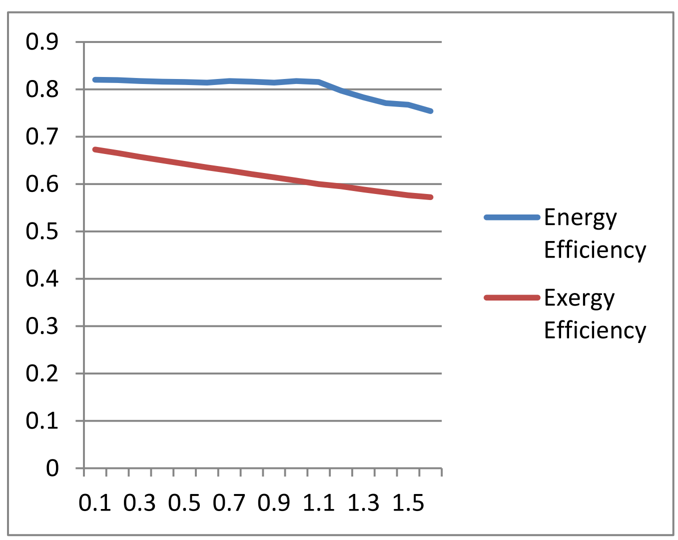


Fig 2 Scale thickness v/s Efficiency

## *VI. CONCLUSION*

This project has presented the results of an energy and exergy analysis performed on 210MW power plant. The analysis was applied on the unit with running load of 210MW. The Oxide layer that increase in the inner surface results in an increase of tube surface temperature and the heat transfer rate is decreases then the energy and exergy efficiency also decreases.These results help designers to find ways to improve the performance of a system

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