Analysis of Boiler Blow down Heat Recovery Using Shell & Tube Type Heat Exchanger

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***Abstract:** During the generation of steam, most water impurities are not evaporated with the steam and thus concentrate in the boiler water. The concentration of the impurities is usually regulated by the blow down, which controls the amount of water (and concentrated impurities) purged from the steam drum. In a normal steam generator about 4% of hot water is wasted as blow down. This study has been undertaken for heat recovery with the help of shell and tube type heat exchanger to prevent heat losses in boiler blow down. The modeling of heat exchanger in CATIA V5 software which is having inner diameter 40 mm and outer diameter 80 mm. Here assembly of shell and tube are done with water and steam as medium. The process of simulation consists of meshing, solution method and results using CFD package ANSYS 16. The calculations for blow down heat losses are also done in this study.*

***Keywords** – Blow down, Shell & Tube Heat Exchanger, Impurities, CATIA V5, ANSYS (CFX) 16.0*

1. INTRODUCTION

In the boiler, steam formation is takes place by giving heat energy by using fuels like coal, oil, natural gas, bagasse. As steam is generated, water is evaporated in its pure form leaving practically all of the dissolved minerals behind. Steam is essentially distilled water. Thus the remaining boiler water contains the minerals which are left behind by the evaporation. In order to keep the limits and to remove sludge, loose scales and corrosion products, a certain quantity of boilers is to be regularly drained. This process is called as blow down. Boiler blow down is the removal of water from a boiler. Its purpose is to control boiler water parameters within prescribed limits to minimize scale, corrosion, carryover, and other specific problems. Blow down is also used to remove suspended solids present in the system. These solids are caused by feed water contamination, by internal chemical treatment precipitates or by exceeding the solubility limits of otherwise soluble salts. In the boiler blow down operation large amount of water is wasted i.e. 4 to 8% of total feed water. To prevent boiler tube chocking and overheating of the boiler tubes the blow down is necessary. The quantity of water to be blow down will depend on the dissolved solids entering the boiler through the feed water.

1.1 Types of Boiler Blow down:

1. Continuous Blow down.
2. Intermediate Blow down.

1. Continuous Blow down:

In the continuous boiler blow down operation some amount of steam-water mixture is continuously taken out from boiler. For the large capacity of power plant continuous blow down is necessary, to avoid chocking & to maintain the feed water level inside the boiler. The exact location of the continuous blow down take-off line depends primarily on the water circulation pattern. Its position must ensure the removal of the most concentrated water.

2. Intermediate Blow down:

The manual blow down valve and discharge lines are located at the bottom or low point of the boiler. This also provides a means of draining the boiler when it is not under pressure. The intermittent blow down should be opened fully for a short duration (approximately 10 to 20 minutes), at least once per shift thus insuring proper removal of accumulated solids that have settled out in the mud drum. In cases where the feed water is exceptionally pure, blow down may be employed less frequently since less sludge accumulates in the pressure vessel.

1.2 Heat Recovery Using Parallel flow Shell and Tube Heat Exchanger

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. Heat exchangers are widely used in industry both for cooling and heating large scale industrial processes. The type and size of heat exchanger used can be made to suit a process depending on the type of fluid, its phase, temperature, density, viscosity, pressures, chemical composition and various other thermodynamic properties.

In a parallel-flow exchanger suggests, the two fluid streams (hot and cold) same direction. The two streams enter at one end and leave at the other end. The flow arrangement of the fluid stream in case of parallel flow heat exchangers are shown in figure. The heat exchanger is performing at its best when the outlet temperatures are equal. The temperature difference between the hot and cold fluids goes on decreasing from inlet to outlet. Since this type of heat exchanger needs a large area of heat transfer. Examples are oil heater, water heater.

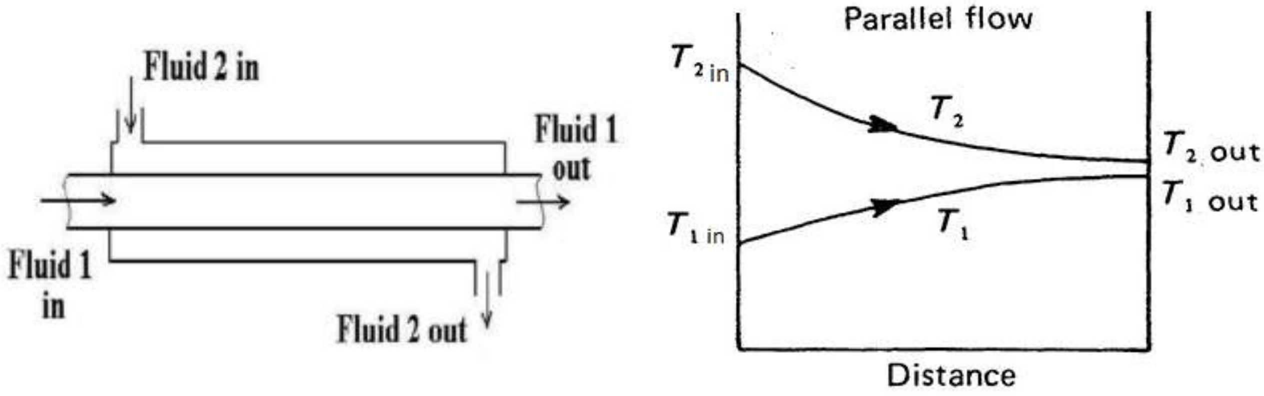

Figure 1: Parallel flow heat exchanger

2. Nomenclature

F= Feed Water TDS (PPM)
q = Steam Generation Rate (kg/h)
K = Require Boiler TDS (PPM)
Q = Heat Transfer Rate Per Unit Time
U = Overall Heat Transfer Coefficient (W/ m^2K)
θ_m = Log-mean Temperature Difference (K)
A = Area (m^2)
C_p = Specific Heat of Fluid at Constant Pressure (J/ kg K)
t = Temperature of fluid (K)
Δt = Temperature Drop or Rise of a Fluid Across The Heat Exchanger
$\dot{m}$ = mass flow rate (kg/s)
ρ = Density of Fluid (kg/m^3)
V= Velocity of Fluid (m/s)
Ɛ = Effectiveness of Heat Exchanger

3. Calculations:

Blow down rate = $\frac{f\times q}{K-f}$
Feed water TDS = 50 ppm.
Max. Allowable Boiler TDS = 900 ppm
Max Boiler Capacity = 70 TPH = 70000 kg/hr
Steam Generation Rate = 50 TPH = 50,000 kg/hr
Blow down Rate = $\frac{50\times 55000}{900-50}$
= 3.2352 TPH
= 3235.2 kg/hr
= 0.8986 kg/sec

Mass Flow Rate = $\dot{m} = \rho AV$
Heat given up by the hot fluid = $Q= m_h\, c_{ph}\, (t_{h1}-t_{h2})$
Heat picked up by the cold fluid = $Q= m_c\, c_{pc}\, (t_{c2}-t_{c1})$
Effectiveness of shell & tube heat exchanger Ɛ = $\frac{Qact}{Qmax}$
$Q_{act}= \dot{m}_h\, c_{ph}\, (t_{h1}-t_{h2})$
$Q_{max}= \dot{m}_h\, c_{ph}\, (t_{h1}-t_{c1})$
Overall Heat Transfer Coefficient = $Q= UA\theta_m$

4. Design and Simulation

4.1 Design of shell and tube

Software used for design is CATIA (computer-aided three-dimensional interactive application). CATIA enables the creation of 3D parts, from 2D sketches, sheet metal, composites, molded, forged or tooling parts up to the definition of mechanical assemblies. CATIA provides a wide range of applications for tooling design, for both generic tooling and mold & die. Also CATIA offers a solution to facilitate the design and manufacturing of routed systems including tubing, piping, Heating, Ventilating & Air Conditioning. The following designs are made in CATIA V5.

Figure: Model of heat exchanger

4.2 CFD Analysis Using ANSYS (CFX)

ANSYS CFX software is a high-performance, general-purpose fluid dynamics program that engineers have applied to solve wide-ranging fluid flow problems. ANSYS CFX is a computational fluid dynamics (CFD) software tool that delivers reliable and accurate solutions quickly and robustly across a wide range of CFD and multi-physics applications. CFX is recognized for its outstanding accuracy and speed with rotating machinery such as pumps, fans, compressors, and gas and hydraulic turbines.

4.2.1 Meshing:

The mesh has been generated to perform finite element analysis. In generating the mesh a compromise between computer speed and mesh quality has been adopted. Initially the fine mesh is generated. This mesh contains tetrahedral cells having triangular faces. The generated mesh along with its information has been shown in the following figure.

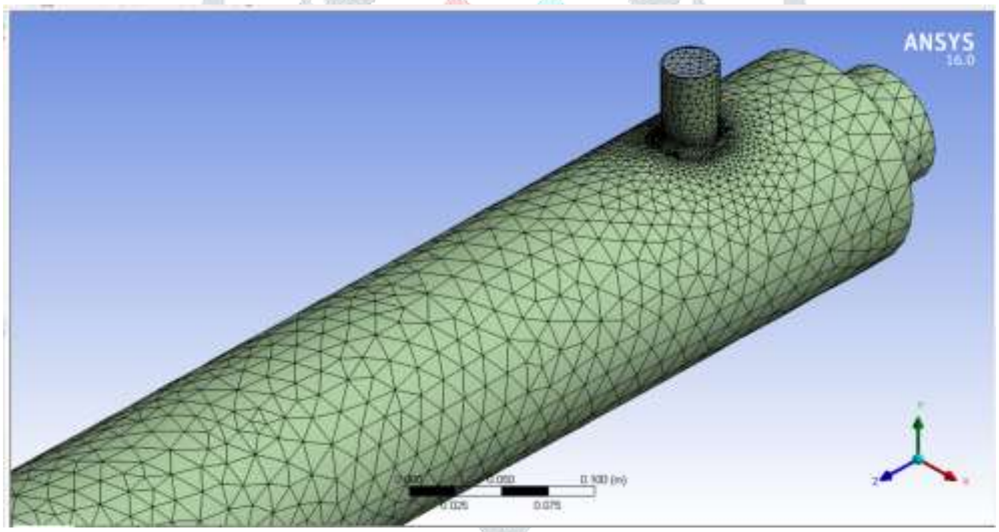

Figure: Mesh generation

4.2.2 Boundary Conditions:

Boundary conditions are used according to the need of the industry requirement. The inlet and outlet conditions are defined as mass flow inlet and pressure outlet. As this is a parallel flow with two tubes so there are two inlets and two outlets. The walls are separately specified with respective boundary conditions. No slip condition is considered for each wall. Except the tube walls each wall is set to zero heat flux condition. The details about all boundary conditions can be as given below.

Inlet hot fluid temperature = 573 K
Inlet cold fluid temperature = 300 K
Hot fluid flow rate = 0.8986 kg/s
Cold fluid flow rate = 4 kg/s

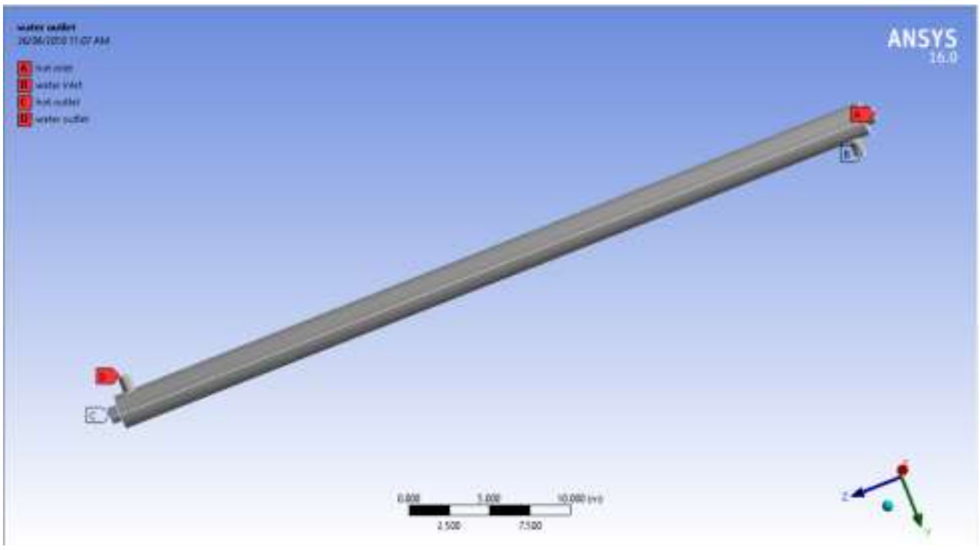

Fig: Boundary Conditions

4.2.3 Solver

- Problem Setup The mesh is checked and quality is obtained. The analysis type is changed to Temperature Based type. The velocity formulation is changed to absolute and pressure to steady state.
- Models Energy is set to ON position. Viscous model is selected as "k-ε model. Radiation model is changed to Discrete Ordinates.

4.2.4 Cell zone conditions

The parts are assigned as water and mixture of water & steam and stainless steel as per fluid/solid parts

4.2.5 Solution

The no of iteration is set to 150 and the solution is calculated and various contours, vectors and plots are obtain.

5. Results:

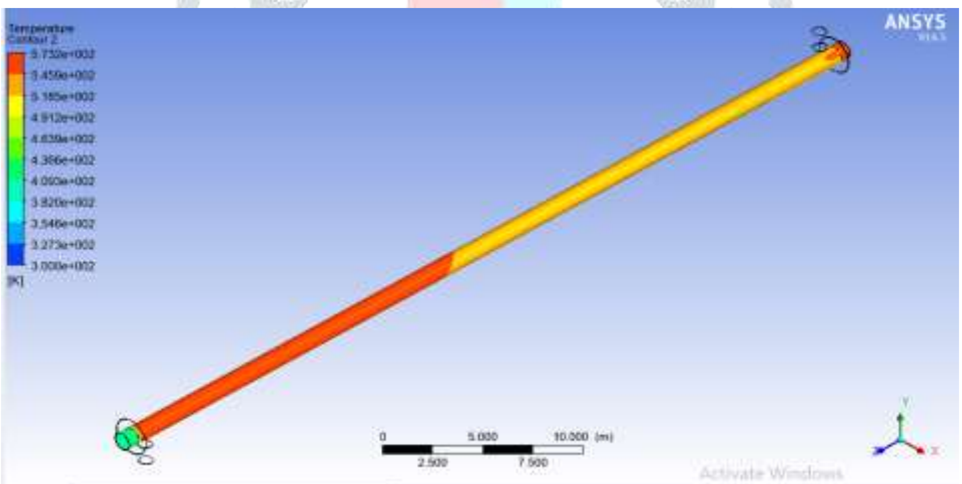

Figure5: Inside temperature variation from inlet to outlet of heat exchanger

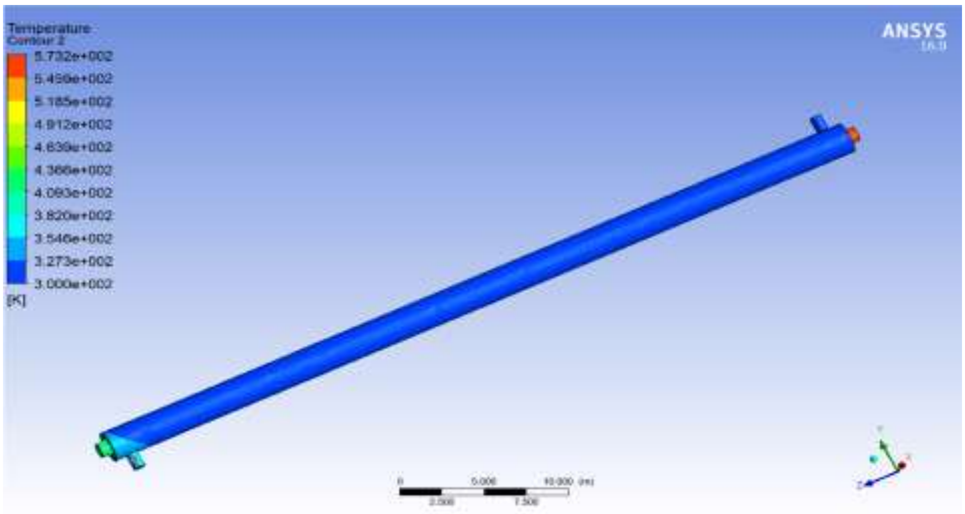

Figure6: Temperature contour for shell

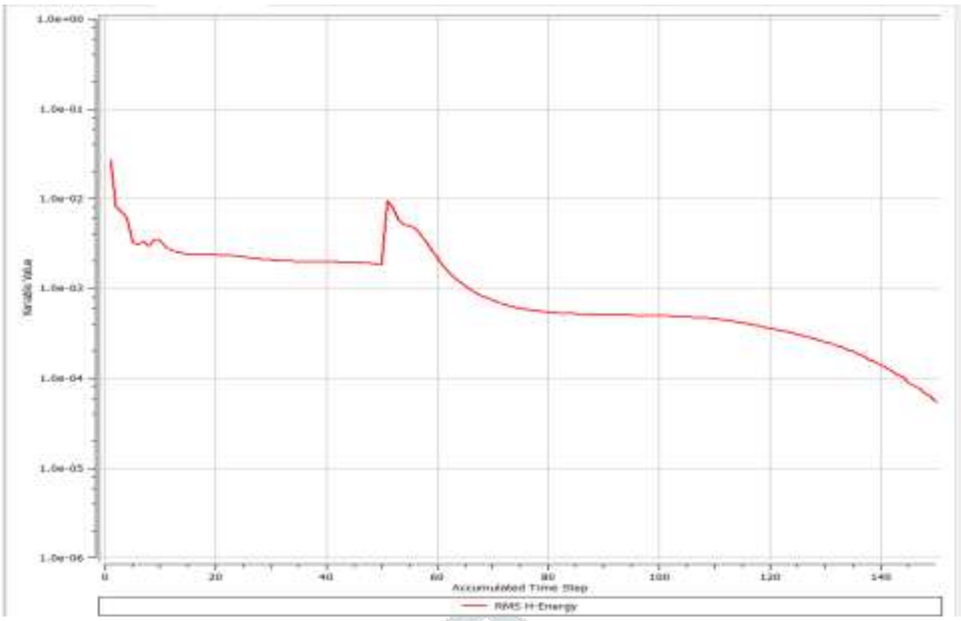

Figure7: Heat flow rate

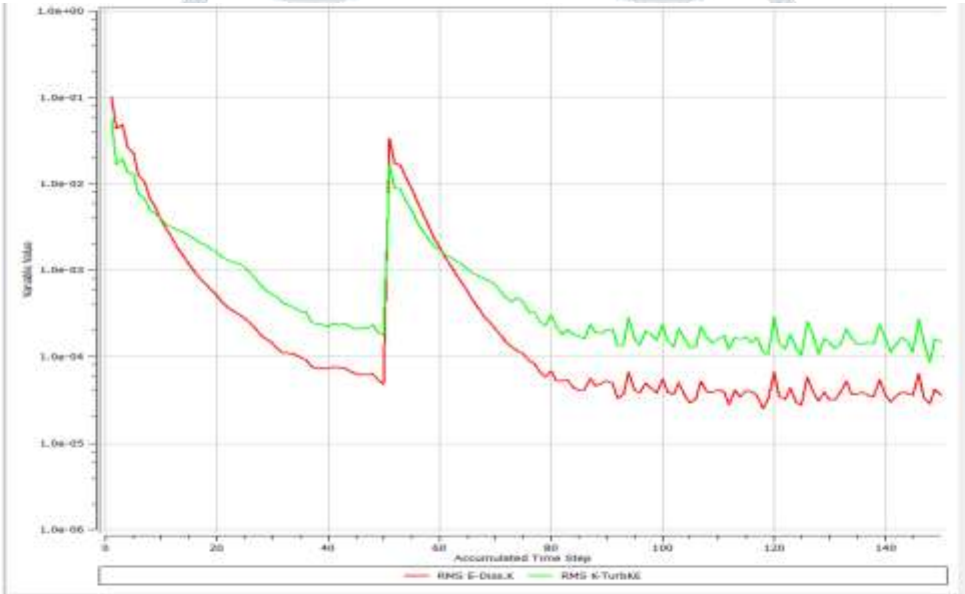

Figure8: Mass Momentum

6. Conclusion

As the total energy was initially wasted i.e. given to the environment. After using this shell & tube heat exchanger temperature of cold water is at outlet 330 K & the temperature hot fluid at outlet is 420 K. Hence some amount of heat is recovered by the heat exchanger. Blow down heat recovery system may provide you with significant savings

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