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Modelling and Simulation of Feed Water Heater for Steam Power Plant Systems

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ABSTRACT

The efficiency of power plant systems can be increased by studying feed water heater analysis. The analysis of feed water is a new concept and the performance can be improved by carrying out trial runs based on the analysis. The testing and analysis of the feed water experimentally is a laborious, time consuming and expensive process. The present work emphasizes on one-dimensional modeling and simulation of low pressure closed feed water heater using available computational fluid dynamics (CFD) simulation software, Flownex SE. The analysis comprises of evaluating the efficiency of feed water heater in a steam power plant by considering the effect of inlet tube temperature on the outlet tube temperature, pressure of steam drum and steam drum level in transient condition. In the present work an optimum inlet tube temperature is recommended for better performance of the steam power plant.

Keywords *- Flownex SE software, efficiency, feed water heater, steam drum pressure, inlet tube temperature and outlet tube temperature.*

1. INTRODUCTION

A Feed water heater is a heat exchanger designed to preheat boiler feed water by means of condensing steam extracted (or “bled”) from a steam turbine.

From an efficiency standpoint, the primary means of improving the operation of such heat exchangers is to maintain their operational effectiveness. The efficiency of the steam power plant can be further increased by increasing the surface area of feed water heater tube. However, the costs associated with either increasing the heat transfer surfaces of existing heaters, or adding additional heaters for efficiency purposes only is prohibitive due to the small incremental reductions in heat rate that would be obtained.

In the present work, the low pressure closed feed water heater comprising condensing section is modeled and simulated for analysis of feed water heater. A thorough search of the current literature revealed that there were no previous studies on optimizing the feed water heater efficiency by increasing the inlet temperature. Indigenous finite element analysis (FEA) has been carried out for optimizing the operating parameters of the feed water heater tubes in steam power plants and the results are discussed.

2. MODELING OF FEED WATER HEATER SYSTEM

A typical power plant is as shown in Fig 1, There are 3 incoming flow pipes to the lower pressure (LP1) heater shell, one carrying bleed steam (branch 1), the second one distillate from upstream lower pressure (LP2) heaters (branch 2) and condensate steam from extracting pump (branch 3). The only exit branch is at the bottom of LP1, directly to the distillate Pump, designated branch 4.

The geometrical modeling has been done with the measured data available in a typical low pressure power plant (LP) feed water heater. LP feed water heater 1 comprises of a condensing section, in contrast with LP2 and LP3 which has an additional drain sub cooling zone.

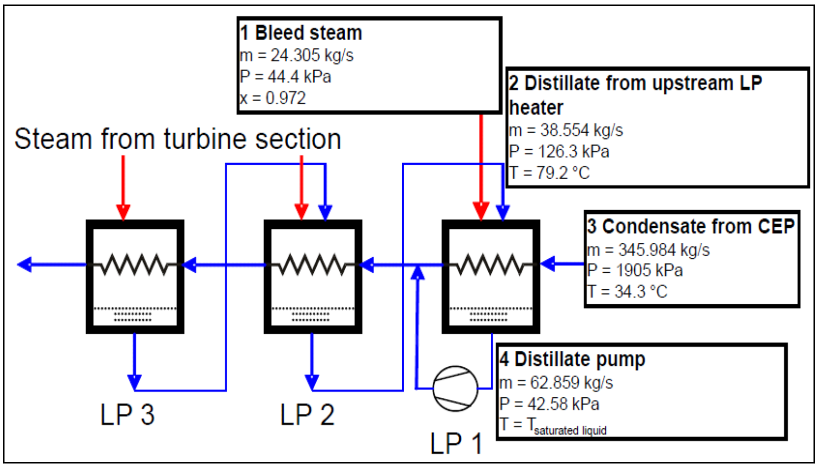

Fig 1: Initial Parameters of Low Pressure Feed Water Heater.

2.1 Geometric Modeling

One dimensional geometry of the feed water heater is generated and it forms the basis for the analysis in Flownex as shown in Fig. 2.

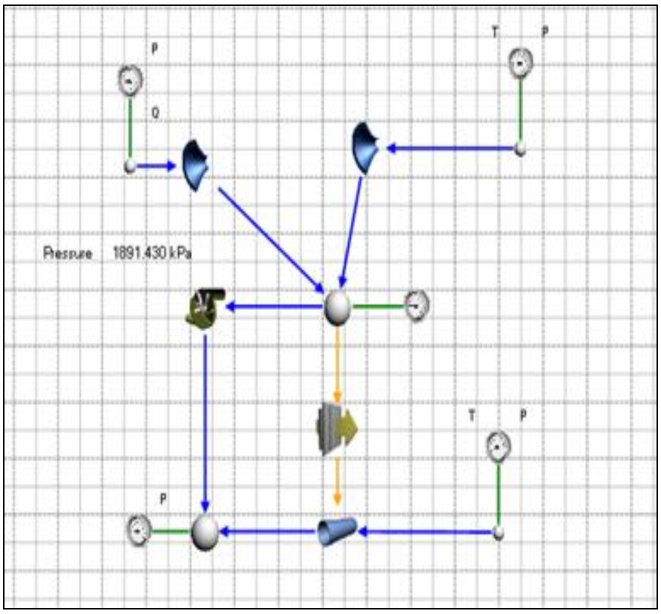

Fig 2: One Dimensional Geometric Model of Feed Water Heater System.

2.2 LP Feed Water Heater Modeling

The volume considered is 30m^3, Vessel diameter = 2m, extraction pump parameters are inlet pressure = 42.58kPa and outlet pressure = 1891.43kPa.

2.2.1 Bled Steam Inflow Valve and Distillate Inflow Valve

The bled steam parameters are inlet pressure = 44.4kPa, quality = 0.972, total mass flow = 24.305kg/s. The distillate inflow parameters are inlet pressure = 126.3kPa, temperature = 79.2^{0}C and mass flow = 38.554kg/s.

2.2.2 Feed water heater tube

The Boundary Condition for feed water tube are inlet pressure =1905kPa and inlet temperature = 34.3^{0}C. The specifications are wall thickness = 0.75mm, length = 14.13m, diameter = 0.0254m, roughness = 40µm, number of increments = 5, number in parallel = 692 and K forward = 0.

2.2.3 Heat Transfer Element

The Properties of heat transfer element are heat transfer coefficient = 14000W/m^2K, material thickness = 0.75mm, mass flow through the feed water tubes = 345.984kg/s.

3. SIMULATION

The steady state analysis of low pressure feed water heater is carried out by using Flownex Solver. The complete analysis was carried out to simulate flow of water and temperature distribution over length of the tube. For steady state analysis in Flownex first run the Designer by ensuring that the designer is converged then run a steady state solution. On the main canvas, select the Snap window. Select "New Snap" and Save the Snap. A "Snap" can be explained by means of a figurative photograph of the component values of a feed water heater.

Then by varying the values in the network or do transient simulations, where certain inputs or boundary conditions are varied in the network, inlet tube temperature of feed water heater is varied and the corresponding steam drum pressure, steam drum level and outlet tube temperature are analyzed. When loading the saved "Snap", the original values as saved in the "Snap" will be reloaded into the network.

Transient simulations enable the user to change simulation inputs in order to determine the simulated system's response over a period of time. In order to set up and solve the network for "Steady State" condition, the pressure and quality on nodes with level tracking (feed water heater drum level) are kept constant. In the transient simulation condition the pressure and quality boundary conditions on the nodes with level tracking are not considered in order to allow the pressure and level of these nodes to change.

It is important to ensure that the "energy source" and "mass source" on the nodes with level tracking are approximately equal to zero; otherwise the network does not have energy and mass balance in the steady state. By running a "transient" simulation the problem is solved and simulations are plotted. Simulation is done to analyze the variations of steam drum pressure, outlet tube temperature and steam drum level with respect to time for different inlet tube temperature.

4. RESULTS

The objective of the present study is to simulate a LP feed water heater in power plant systems and to understand the fluid dynamics of feed water heater in transient operation. Further it was decided to compare with the other by changing the inlet temperature. Keeping the above in the mind, the following CFD computations were carried out to study the simulations of the feed water heater were captured in different running modes as shown in Fig 3 to 11.

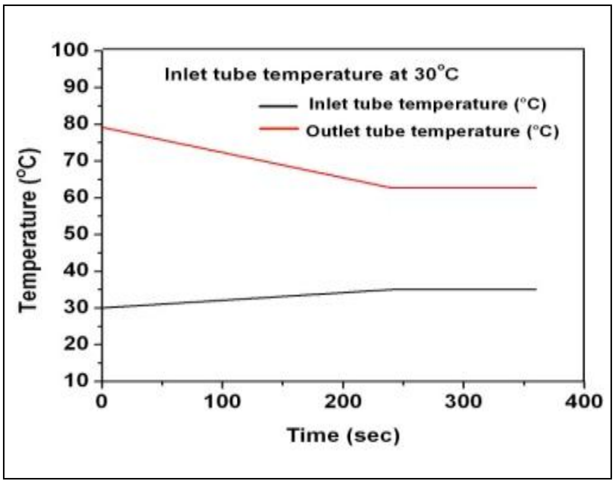

Fig 3: Temperature v/s Time of Inlet Temperature at 30^0C.

From Fig 3, Fig 4 and Fig 5, it can be observed that, when the temperature of the inlet tube is 30^0C, the outlet tube temperature is 79^0C. The time taken to attain saturation is 250s and after saturation, the outlet tube temperature is 62.705^0C at a boiler drum pressure of 42.580kPa and the boiler drum level reached a height of 0.150m.

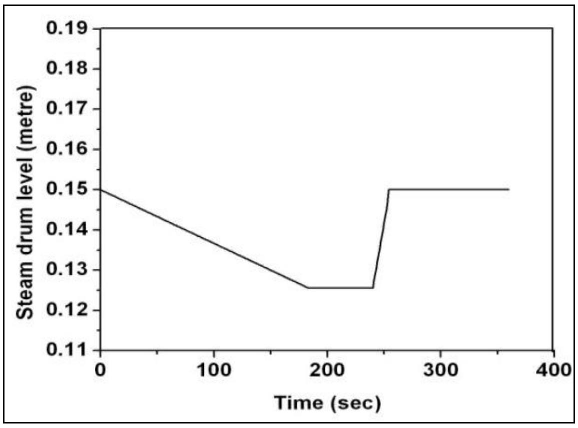

Fig 4: Level v/s Time of Inlet Temperature at 30^0C.

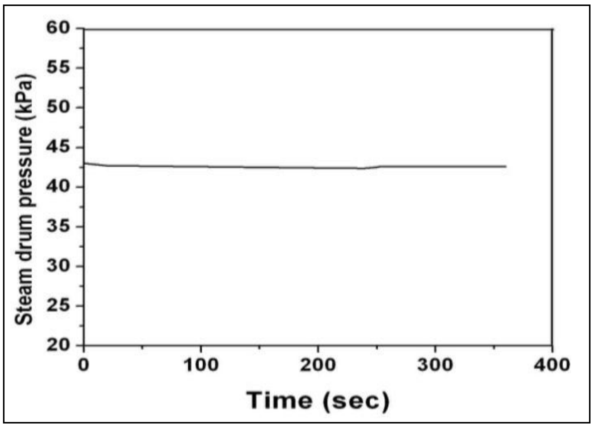

Fig 5: Pressure v/s Time of Inlet Temperature at 30^0C.

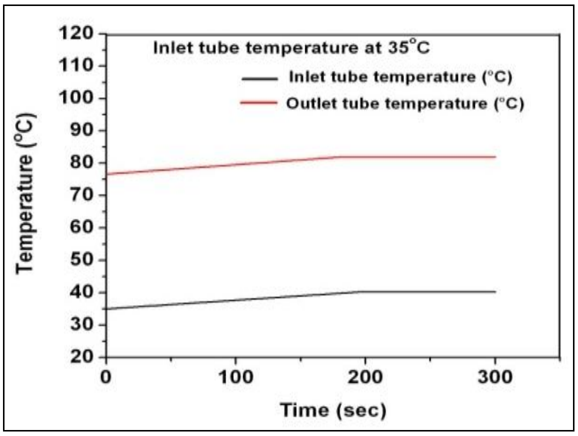

Fig 2: Temperature v/s Time of Inlet Temperature at 35^0C.

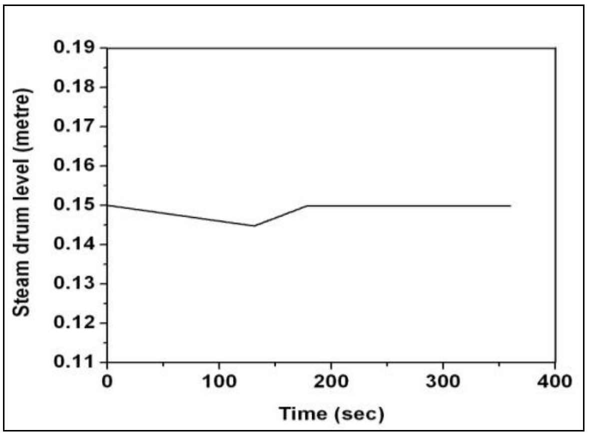

Fig 7: Level v/s Time of inlet temperature at 35^0C.

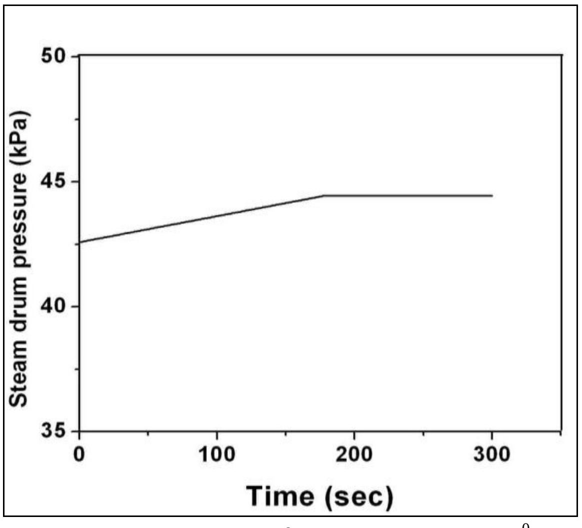

Fig 8: Pressure v/s Time of Inlet Temperature at 35^0C.

From Fig 6, Fig 7 and Fig 8, it can be observed that, when the temperature of the inlet tube is 35^0C, the outlet tube temperature is 76^0C. The time taken to attain saturation is 200s and after saturation, the outlet tube temperature is 80^0C at a boiler drum pressure of 44.438kPa and the boiler drum level reached a height of 0.150m.

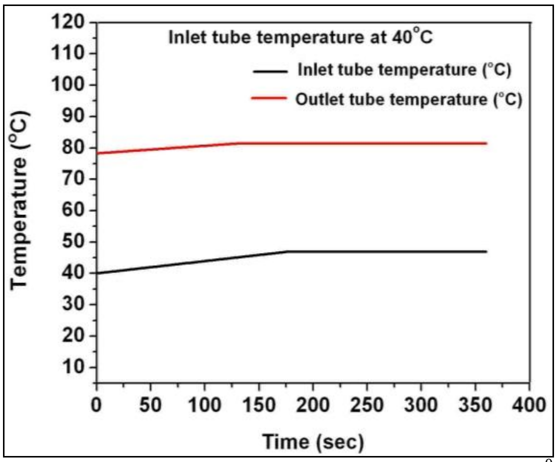

Fig 9: Temperature v/s Time of Inlet Temperature at 40^{0}C.

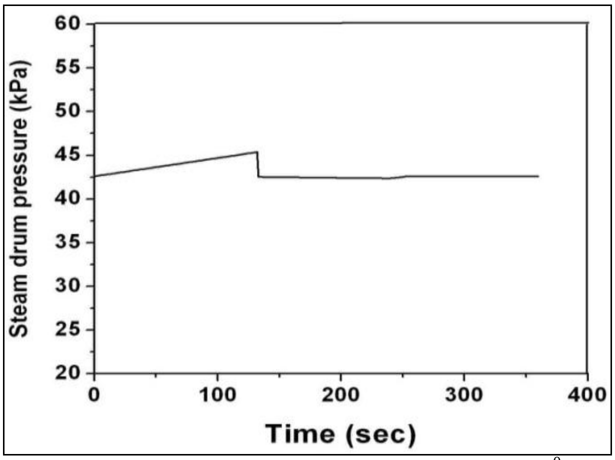

Fig 10: Pressure v/s Time of Inlet Temperature at 40^{0}C.

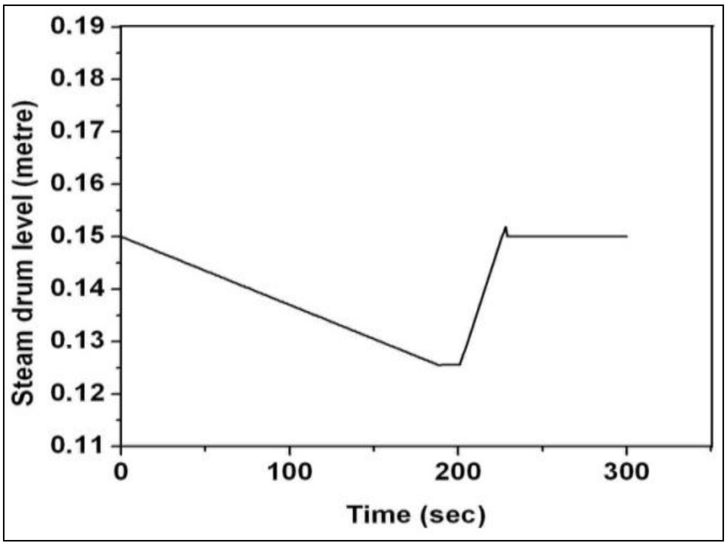

Fig 11: Level v/s Time of Inlet Temperature at 40^{0}C.

From Fig 9, Fig 10 and Fig 11, it can be observed that, when the temperature of the inlet tube is 40^{0}C, the outlet tube temperature is 78.5^{0}C. The time taken to attain saturation is 175s and after saturation, the outlet tube temperature is 80^{0}C at a boiler drum pressure of 42.5kPa and the boiler drum level reached a height of 0.150m.

5. DISCUSSION

Sl. No	Inlet Tube Temperature, (^{0}C)	Outlet Tube Temperature, (^{0}C)	Steam Drum Pressure, (kPa)	Steam Drum Level, (m)
1	30	62.705	42.580	0.150
2	35	80	44.438	0.150
3	40	80	42.50	0.150

Table 1: Variation of outlet tube temperature, steam drum pressure and steam drum level at different inlet tube temperature.

From the analysis of the graph and table it is observed that the outlet tube temperature of low pressure feed water heater increases with increase in inlet tube temperature. This increase in the outlet tube temperature of low pressure feed water heater is up to 35^{0}C of inlet tube temperature. With further increase in inlet temperature the outlet temperature practically remains constant. Similarly for 30^{0}C inlet tube temperature there is a decrease in tube outlet temperature.

From Table 1, it can be observed that at a temperature of 35^{0}C of the inlet tube a maximum pressure of 44.438kPa is reached. Below and beyond that temperature there is no appreciable change in steam drum pressure. With increase in inlet temperature from 30^0C on wards, the outlet temperature increases and reaches a maximum value of 80^0C for inlet temperature of 35^0C. Further increase in inlet temperature, the outlet temperature practically remains constant. Outlet tube temperature, steam drums pressure and steam drum levels varies with inlet tube temperature for the initial period (0 to 4 minutes) and die out to reach steady state.

6. CONCLUSION

The objective of the work is to simulate the LP feed water heater and understand the flow events involved during the power plant systems in transient operation using an available CFD platform Flownex SE. From the literature and present study it is seen that CFD contributes to significant understanding of one-dimensional flow inside the feed water drum and also provide detailed information, where measurements are difficult to make by experiments alone.

LP feed water heater simulation by CFD calculation increasingly gains the ability to support both the efficient optimization of a given feed water heater concept and feasibility studies of completely new concepts and Flownex SE is an effective tool for feed water heater Simulation. Hence convergence for the better results compared to other feed water heater model are more in this model.

The Low pressure feed water heater simulation results presented shows different aspects of the flow captured and are found to be in good agreement with fundamental concepts indicating the validation of the processes captured. For the employed configuration, inlet temperature of 35^0C optimizes the outlet tube temperature. For the range of inlet tube temperature, steam drum pressure and steam drum level practically remained constant.

The process takes 2-4 minutes to reach steady state. The captured images are in a sequence matching to the realistic LP feed water heater and hence can be stated that the available CFD platform Flownex SE is thus an efficient tool to simulate feed water heaters.

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