Experimental Research & Numerical Analysis in Heat Recovery Generator

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Abstract - *A boiler is a container in which a fluid is heated until it changes into vapor or a high-temperature liquid. Heat is supplied in boilers through convection, radiation and conduction. There are two types of boilers: fire tube boilers and water tube boilers. Here, we analyzed a water tube boiler. It is very essential to optimize and study the heat transferring mechanism and their characteristics to study & also control the various thermal losses. In this work internal flow analysis of a super heater is done to study the heat transfer characteristics of super heater using a Computational Fluid Dynamics (ANSYS- FLUENT) package. The CFD analysis provided fluid velocity, temperature, pressure, and wall fluxes, and especially we have concentrated on the inlet to outlet of the super heater of a boiler pressure drop. The Computational Fluid Dynamics (CFD) approach used here to solve many boiler problems such as pressure drop, parametric study and heat losses of super-heater analysis helped to study the possibilities of improve the heat transfer properties.*

***Key Words*: CFD, Wall fluxes.**

1. INTRODUCTION

The boiler is the device of a power plant that generates steam by burning available fuels used for power generation. The super heater can work as the heart of any boiler system. Continuous supply of the desired amount of steam at the rated pressure and temperature is the main work of it. Super-heater is the heat exchanger in which heat is transferred from furnace gas to the steam, Because of the improper heat transfer between furnace gas & steam leads to problems of heating. It reduced performance, repetitive failures in boiler component are common problem related to any type of boiler system. Super heater tube damage is very common issue in boilers. In this work we have done CFD analysis of super heater flow to study thermal parameter, to study and investigate the enhancement in heat transfer characteristics. Temperature distribution in the water tube boiler performs various efficiency testing and simulation of thermal flow inside in sugar factory boiler, The analysis of the temperature distribution for any location inside the domain is conducted by setting the constant temperature and varying parameters such as mass flow rate of steam (kg/s), steam inlet temperature and depth of scale formation. The commercial CFD software used to control volume based technique to convert the various governing equations, which are solved numerically using the implicit method. The temperature distribution in the boiler tube is affected by the many variables such as mass flow rate of steam (kg/s), steam temperature, feed water pressure & temperature. If we increase the mass flow rate of steam through the boiler tube, then there will be a decrease in temperature on the inner tube wall. Computer simulation is used to understand the thermal flow in the boiler, solve operational problems, and search for optimal solutions. The thermal flow behaves inside the boiler was studied to make the study of heat transfer characteristics and minimize the all thermal losses. The work study performs a detailed simulation of combustion and thermal flow behaviour inside the sugar factory boiler. Actual Working Conditions

Fig.1.1 Actual photograph of Steam drums of a super heater

Fig.1.2 Actual photograph Super heater tubes of a boiler

The existing super heater of a boiler is manufactured by Walchandnagar Industries Ltd. and assembled by Hi-Tech Engineering Corporations for the Shrinath Mhaskoba Sakhar karkhana Pvt. Ltd. Patethan Tal: Daund, Dist:Pune-412104. This plant has capacity of 70 Tons/hr. In this sugar factory there are two types of superheating coils primary coils and secondary coils. Heated water and steam from the heating pipe is enters in the steam drum as shown in fig 1 and there is separator in the steam drum so that water and steam is separated, below 300 °c steam is reheat and the only above 300°c steam flows in the super heater pipe this steam temperature again increased by due to heating of flue gases in the boiler drum .In sugar factory there are total 45 number of same super heating tubes present at the separator drum arrangement. The capacity is 70 Tons/hr steam is flow through the super heater tubes. Same steam flow rate gets divided in 45 numbers of tubes, so we have consider single tube for the analysis.

2. OBJECTIVE OF WORKS

The objectives of work are as listed below.

1. Studying the speed, pressure, and temperature distribution of the super heater that helps to identify the reasons for heat loss and determine the reduced heat transfer properties through CFD simulations.To validate the practical result with CFD result.

2. Parametric study to identify feasible and practical solutions to improve heat transfer performance in a super heater by modifying various parameters in the system such as geometry, boundary conditions, mass flow rate of the super heater, diameter of the coil, temperature of the inlet, thermal flow, etc.

3. LITERATURE REVIEW

The purpose of this work is to provide an in-depth analysis of super heater tube defects and improvements suggested by various authors to enhance the heat transfer properties. The losses reported and quantified are also included. This chapter will help to explore the different aspects of the heat transfer and the fluid flow of the super heater section. Therefore, this chapter focuses on the model and analysis of the super heater to analyze and study the thermal flow of the boiler to solve the operational issues.

Saripalli and Masoud (1-2) presented a detailed description of thermal-flow, combustion, and possible causes of super heater tube rupture in the boiler. Exhaust gas temperature is in line with the real results of the infrared thermography inspection. This study helps industry in improving boiler efficiency, reducing emissions, preventing super heater tube rupture, and understanding the thermal flow transport within the boiler. The CFD scheme applied for provides a comprehensive picture of what is going on inside the boiler. In most cases, the problems can be identified and a solution can be developed. A CFD analysis provides fluid flow rate, pressure, temperature and species concentration across the entire domain of the solution. During the analysis, boundary conditions (e.g. flow rate, inlet velocity) can be changed to see their impact on thermal-flow pattern or species concentration distribution. Several ideas were developed from this study to increase boiler efficiency and reduce the thermal stress problem caused by the super heater tubes.

Jayakumar[3] reported that heat transfer in a helical coil is higher than that in a corresponding straight pipe. It was observed that the variation of local Nusselt number along the length and circumference at the wall of a helical pipe. Movement of fluid particle in the helical pipe has been observed. CFD simulations are carried out for vertically oriented helical coil by varying coil parameters such as (i) pitch circle diameter (PCD), (ii) tube pitch & (iii) pipe diameter and their influence on heat transfer has study. Many researchers have identified that a complex flow pattern exist inside a helical pipe due to which the enhancement in heat transfer is find out. Transition from laminar to turbulent flow takes place at a Reynolds number higher than that for a straight pipe. Critical Reynolds Number and curvature ratio given bellow. A plot of 〖Re〗cr for the curvature ratio from 0.01 to 0.25 is given in Fig.2.1 In the lower range of curvature ratios (1 < 0.05), all of the correlations provide approximately the same value for 〖Re〗cr. The periodic behavior of Nusselt number at top and bottom sides of the cross-sections along the length of the pipe.The values of Nusselt number at the inner, outer, top and bottom along the periphery at given cross- section in the developing section. Fig.2.2 gives the variation of Nusselt number around the periphery at various cross-sections, along the length of the helical pipe. In this analysis, a helical coil with a pipe of inner diameter (2r) 20mmand pitch circle diameter of 300mm was considered. Analyses were carried out by changing the coil pitch. Coil with pitch of (i) 0mm, (ii) 15mm, (iii) 30mm, (iv) 45mm and (v) 60mm were analyzed. When the coil pitch is zero, local Nusselt numbers at the bottom and top points on cross of the periphery are almost the same. The magnitude of difference between the local Nusselt numbers at the bottom and top at any given corresponding cross-section thus increases with increase in pitch. However, variation of local Nu for the coils with pitch of 45 and 60mm are identical. Nusselt number on the outer side of the coil is found to be the higher among all other points at a specified cross-section, while that at the inner side of the coil is the lowest. However, the average Nusselt number is not affected by the coil pitch.

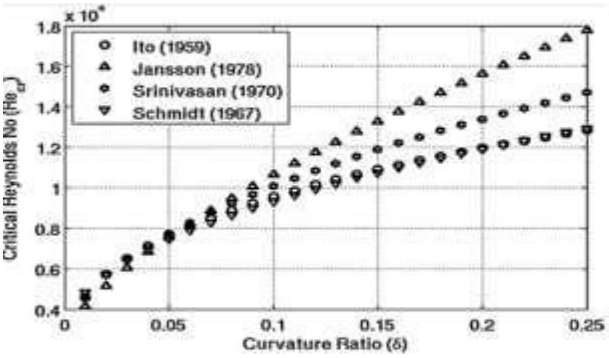

Figure 3.1 Critical Reynolds number predicted by various correlations [3]

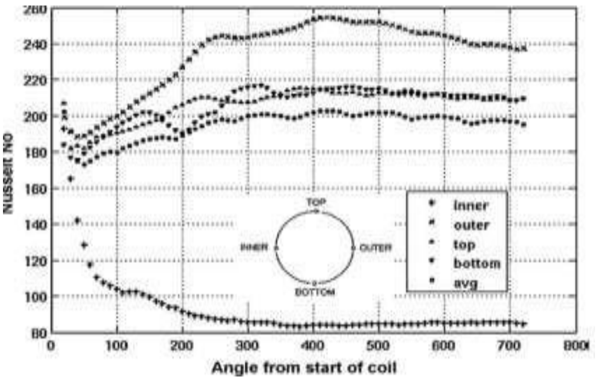

Figure 3.2 Variation of Nu along the length coil [3]

Shajikumar [5] presented an investigation on tube temperature distribution in a water tube boiler, performs detailed efficiency testing and simulation of thermal flow inside an industrial boiler. The simulations were carried out using commercial available CFD software. Figure 2.3 shows that temperature varies along the radial distance.

The analysis of the temperature distribution for every location inside the domain is conducted by setting constant heat fluxes, and varying parameters such as mass flow rate of steam, steam inlet temperature and scale thickness.

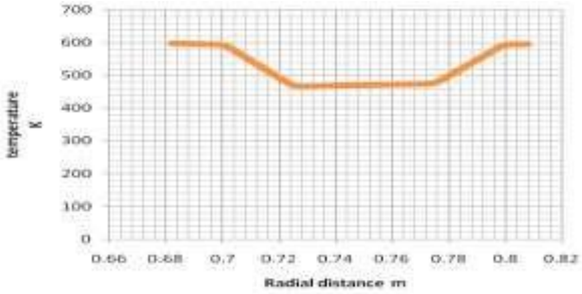

Figure 3.3 Temperature vs axial distance [5]

The distribution of the temperature in the boiler tube depends on many factors such as the mass flow rate of the steam, the steam temperature, the feed water temperature and the pressure. As the mass flow rate increases, the temperature in the internal tube wall decreases. This behavior is due to the non-proportional release of heat from the flue gas to the steam. The ability to absorb the heat from higher mass flow rate of flue gas is faster than the ability to absorb steam at higher mass flow rate. As a result, the temperature of the flue gas must increase in order for the heat balance to be achieved. The inlet temperature of the steam influences the thermal efficiency of the thermal power plant. Higher steam inlet temperature will increase thermal efficiency and higher operating temperature will also increase scale growth.

According to Begem[6], boiler tube failures are the main cause of today's plant and have a negative impact on overall plant performance. The heat transfer analysis used was to apply surface heat flux to the tube's inner wall surface, which will either provide heat or remove heat in the process. Then, the vector option was activated and a vector plot of heat flow was shown. Due to the thermal fluctuation caused by slag and change in operating conditions, alternating stresses were also created. The boiler tubes were cracked and the plant needs to overhaul for maintenance purposes because of the leak generated by the cracks. The analysis was based on a pre-dominant simulation, which mainly focused on the underlying cause of boiler tube failure exposed to operating conditions. The heat transfer was applied to the inner wall of the tube, which will either supply or remove heat in. There are several types of failure modes that a boiler tube may experience. These modes include stress corrosion cracking (Pitting), water side corrosion (Corrosion), fatigue failure (Fatigue), overheating (Overcrowding), dissimilar metal welding fatigue (Mechanical Fatigue), and erosion (Erosion). In this study, the failure modes and the end cracks of the boiler tube due to dissimilar metal welding were analyzed. Therefore, data was collected and analyzed to identify the cause of the failure and to suggest a solution. The use of suggestion can prevent the crack occurrence in boiler tube. It can also delay the process because of thermal properties. Preventing the crack will reduce the frequency of maintenance and therefore the cost of the operation will decrease.

In this work, Bingzhi LI[7] presented a sub model to calculate the structure of the slag flow. This sub model is used to reduce the heat transfer in the case of super heater tubes. The deposition formed on the super heater tube may also cause the corrosion of the tube material. In the Kraft recovery boiler furnace, alkali rich deposits are molten and flow down the super heater tubes. In this work, the sub model is applied to the CFD model of super heater tube section. In particular, it is used to calculate the slag structure on two tube bends of one of the initial groups of tube banks of the first flue gas exposed to the furnace. The slag model takes into account the deposition by inertia impaction and supposes all the depositing particles are fully molten and steam temperature in the super heater constant. The slag model provides thickness distribution and surface temperature distribution of the owing deposion layer.

Khanorkar (10) presented a CFD analysis of vertical tube. Vertical copper tube with constant cross section area is used to represent the medium through which water convection occurs. In this work, natural convection flow is studied and analyzed through vertical pipe. The physical parameters of the tube such as diameter, length, and heat flux influence the outlet flow parameters such as velocity and temperature. The constant heat flux is a boundary condition provided on the entire surface of the tube. In this study, the outlet temperature and the outlet velocity increase as the tube length increases but decrease as the diameter of the pipe increases. The outlet temperature increases but the velocity decreases as shown in Fig. 3.4.

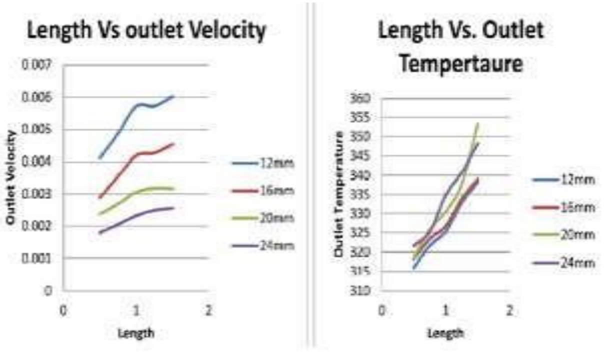

Figure 3.4 Results between length vs. outlet velocity and length vs. outlet temperature [10]

4. EXPERIMENTATION

4.1 Actual working parameter

Working Fluid - Steam
Inlet mass flow rate - 0.4320 kg/sec
Inlet Temperature - 573 K
Outlet Pressure - 40 Kg /cm2
Constant Wall Temperature – 873 K
Specific heat of steam-(Cp) – 2916.19 J / Kg-K
Thermal conductivity of Steam (K) - 0.05194 W/Kg-k
Density of Steam (ρ) – 18.46 Kg/m^3
Dynamic viscosity of steam (μ) – 1.985 x 10^5
Total Length of Super heater pipe – 28.07 m
Inner diameter of super heater pipe – 0.041 m
Number of Super heater pipe from the steam drum – 45
Total surface Heat Flux – 89200 W / m^2
Total heating surface Area of Super Heater – 198 m^2

4.2 Computational Details

To determine turbulent flow in a boiler's super heater pipe, K-ε model is used in the study. In this study, the final volume modeling was performed by Fluent simulation (Fluent 14.0). The velocity and the pressure field are connected using semi implicit method (SIMPLE algorithm) for the pressure linked equation.

4.2.1 Continuity equation

$$\frac{D\rho}{D\tau} + \rho\nabla.V = 0 \quad \text{..............................}(2)$$

4.2.2 Momentum equation

X component

$$\rho\frac{Du}{Dt} = \frac{\partial\rho}{\partial x} + \frac{\partial\tau xx}{\partial x} + \frac{\partial\tau yx}{\partial y} + \frac{\partial\tau zx}{\partial z} + \rho fx \quad \dots\dots\dots\dots(3)$$

Y component

$$\rho\frac{Dv}{Dt} = \frac{\partial\rho}{\partial y} + \frac{\partial\tau xy}{\partial x} + \frac{\partial\tau yy}{\partial y} + \frac{\partial\tau zy}{\partial z} + \rho fy \quad \dots\dots\dots\dots(4)$$

Z component

$$\rho\frac{Dw}{Dt} = \frac{\partial\rho}{\partial z} + \frac{\partial\tau xz}{\partial z} + \frac{\partial\tau yz}{\partial y} + \frac{\partial\tau zz}{\partial z} + \rho fz \quad \dots\dots\dots\dots(5)$$

4.2.3 Energy equation

$$\rho\frac{D}{D\tau}\left(e + \frac{v^2}{2}\right) + \rho q + \frac{\partial}{\partial x}\left(k\frac{\partial\tau}{\partial x}\right) + \frac{\partial}{\partial y}\left(k\frac{\partial\tau}{\partial y}\right) + \frac{\partial}{\partial z}\left(k\frac{\partial\tau}{\partial z}\right) - \frac{\partial}{\partial x}(up) - \frac{\partial}{\partial y}(vp) - \frac{\partial}{\partial z}(wp) + \frac{\partial(u\tau xx)}{\partial x} + \frac{\partial(u\tau yx)}{\partial y} + \frac{\partial(u\tau zx)}{\partial z} + \frac{\partial(v\tau xx)}{\partial x} + \frac{\partial(v\tau yx)}{\partial y} + \frac{\partial(v\tau zx)}{\partial z} + \frac{\partial(w\tau xx)}{\partial x} + \frac{\partial(w\tau yx)}{\partial y} + \frac{\partial(w\tau zx)}{\partial z} + \rho f.V \quad \dots\dots\dots\dots\dots(6)$$

4.3 Assumptions in the study

The numerical simulations used in this study are based on certain assumptions that have been made by other researchers while conducting super heater flow analyses. The following are the assumptions that have been used in the current work. The fluid is considered to be non-compressible with constant thermodynamic properties. The flow is considered to be 3D, turbulent, steady, non-rotating due to the working fluid being steam. The super heater tube wall is assumed to have a constant temperature. No-slip velocities are applied at the walls. At the inlet, a uniform mass flow rate is set. The pressure outlet condition at the outlet is assumed. The turbulence intensity level for the flow is 1.00%.

4.4. Experimental to numerical Conversion

Fig 4.3 illustrates how the experimental geometry is converted to a numerical model. In the numerical model, only the flow is simulated. The external sections, walls, etc. as in the experimental set up, have not been drawn because it is not necessary for numerical study. Therefore, here we are simulating the flow within the super heater.

Fig.4.1 Experimental Model

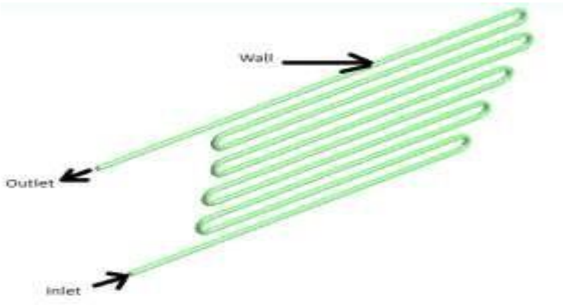

Fig.4.2 Numerical Model in this study

Here experimental model is converted in to numerical model by utilizing flow governing equations.

4.5 Boundary conditions

The numerical simulations in this study have been performed based on some assumptions of other researcher while study the super heater flow analysis. Following are some of the assumptions on which the current work is based.

a) The fluid is assumed to be incompressible with constant thermo-physical properties and the flow is assumed to be 3 dimensional, turbulent, steady and non-rotating. The working fluid is steam.

b) Constant temperature is prescribed on the wall of super heater tube.

c) No-slip velocity conditions are applied at all walls.

d) A uniform mass flow rate and temperature are set at the inlet

e) A pressure outlet condition is assume at the outlet.

f) A turbulence intensity level of 1% is assumed for the flow.

4.6 Mesh Conversions Study

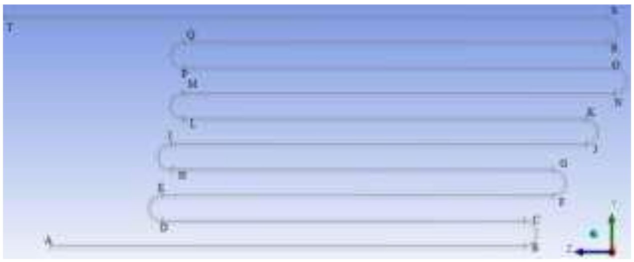

Fig:4.3 Numerical Model of Super Heater for conversions study

In this section, we split the geometry into nighteen parts to analyze the different thermal parameters in the various parts of a super heater pipe, as shown in the Fig, the fluid flow between the inlet and the outlet. In this section, we draw the line inside the center of the super heater geometry, measure the temperature and the pressure at the different parts of super heater pipe, measure the pressure and temperature, and draw the curves for section ST.

4.6.1 Various plots for all grids

To make sure that the numerical result is correct and valid, a thorough check of the grid dependency of the numerical solutions was done by taking into account 4 grid systems with high number of grid points 64932cells 63900 cells 50048 cells 42080 cells for simulating super heater tube. The plotted pressure, temperature at center line of super heater tube surface Nusselt number, skin friction coefficient for super-heater wall of these 4 grid systems.

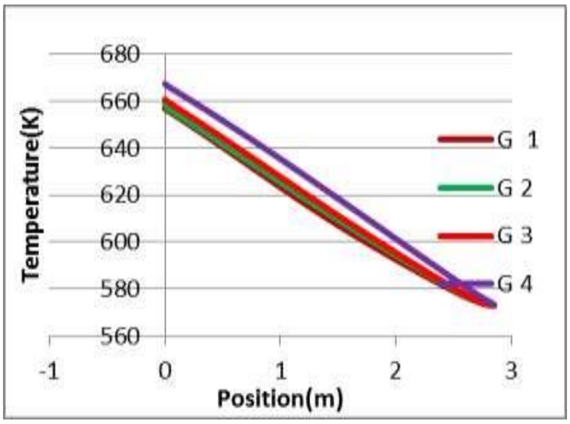

Fig.4.4 Temperature Plots for all grids of Super heater Section AB.

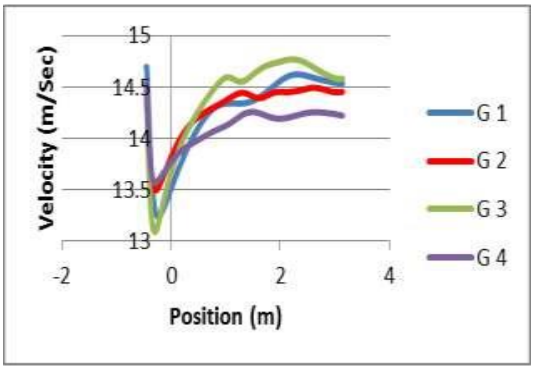

Fig.4.5 Velocity Plots for all grids of Super heater Section ST

Figure 4.5 illustrates how the velocity changes at the bending part of the super heater. If a fluid moves with a straight pipe which curves after a few points, the bending of the super heater causes the fluid particles to move in a different direction.

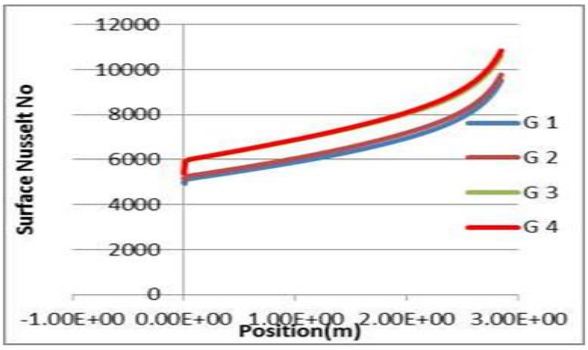

Fig.4.6 Surface Nusselt number for all grids of a super heater Section AB

The surface nusselt number is decrease along the length of the super-heater and grid 3 and grid 4 show the same result shown in the fig 4.6.

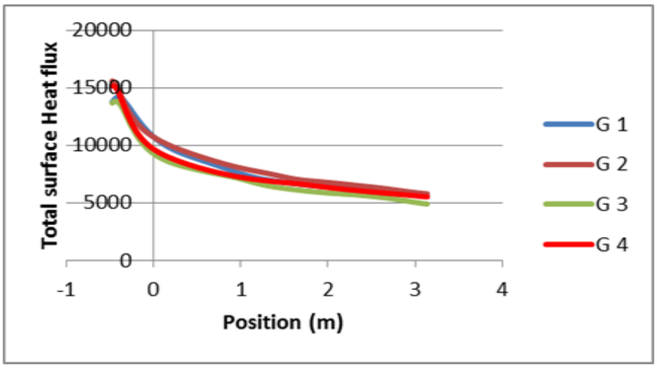

Fig 4.7 Total surface heat flux for all grids of a super heater Section ST

The total surface heat flux decreases along the length of the super-heater, and its magnitude is minimal at section ST of the super heater wall. The normal deviation of the temperature and pressure, the surface number of the surface, the total surface heat flux, and the skin friction coefficient are as follows: · 50048 – 63900 cells – 42080 (Grid 2, Grid 3, and Grid 4) To save computer resources and maintain a balance between computational efficiency and prediction accuracy, we have selected the grid of 50048 cells for the simulations. These simulations have been performed on a computer with a 2.3 GHz frequency and 2 GB core memory.

4.7 Convergence History

The convergence criterion kept for continuity, momentum, k and equations and energy equation are 10^{-6}. The Solution is converged at 164 iterations and got following results. 5000 iterations are given at start of the solution and solution converges at 164 numbers iterations. Parameters like temperature, velocity at outlet and surface nusselt number and skin friction coefficient monitors are set in fluent monitor setup.

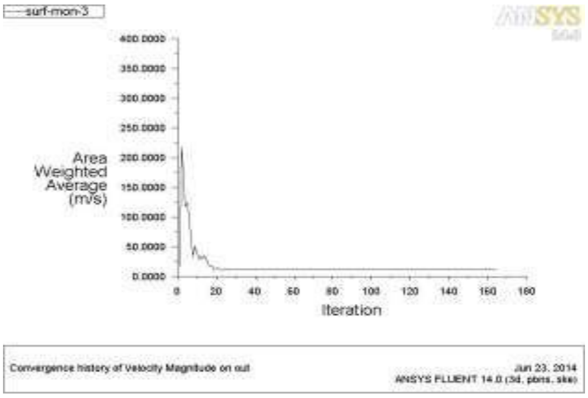

Fig. 4.8 Conversions history of velocity at outlet of super heater

The velocity variations also occur at the super heater outlet where it increases by 10 iterations and then decreases by 20 iterations until it reaches 164 iterations as shown in Fig. 4.8.

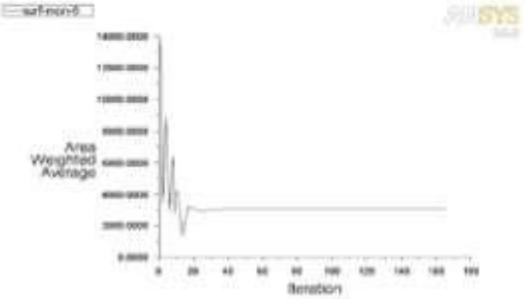

Fig. 4.9 Convergence history of Nusselt number along the wall of super heater

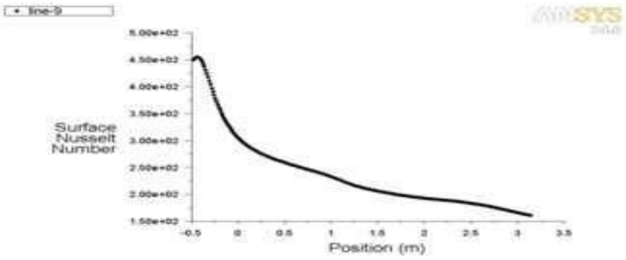

Fig. 4.10 Conversions History of skin friction coefficient along the wall of super heater

In Fig. 4.10, the surface Nusselt number increases first up to 20 iterations and then decreases to 20 iterations. After 20 iterations, the skin friction coefficient increases again up to 20 iterations. The skin friction coefficient decreases after iteration 40 and increases to 164 iterations. Figure 4.10

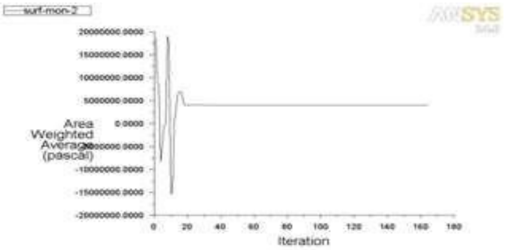

Fig.3.11 Conversion history of pressure inlet of super heater pipe

From the figure 4.11 it is observed that pressure at inlet of super heater is fluctuate from iteration 1 to iteration 20 after 20 iterations it remains constant

5. RESULTS AND DISCUSSION

5.1. Various curves for super heater

Here various curves are plotted on the line drawn inside the geometry of the super heater to study thermal flow inside super heater.

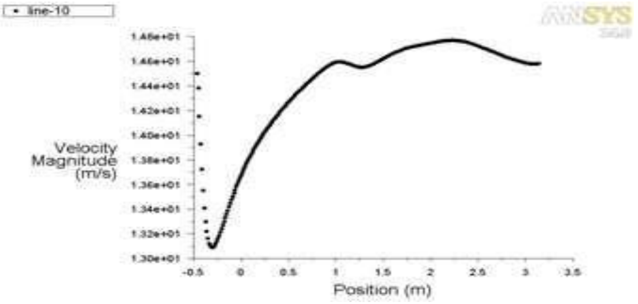

Fig. 5.1 Velocity plot for Super heater Section ST

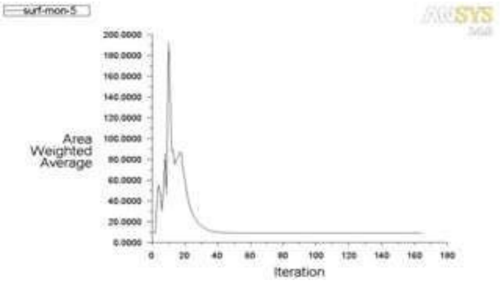

Fig. 5.2 Wall skin friction coefficient plot for Super heater section ST

Figure 5.2 shows that velocity increases along super heater length and then slightly decreases along super heater length. Velocity is highest at the bending part of super heater pipes. Due to the curvature, there will be a negative pressure gradient with the increase in pressure. Therefore, velocity decreases near convex wall and increases on the outside side of pipe. Skin friction coefficient is also high at super heater bending section and decreases along super heater wall as shown in Figure 5.3.

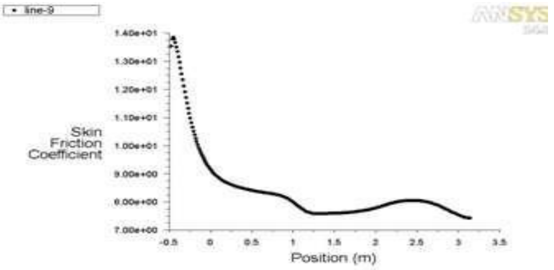

Fig. 5.3 Surface Nusselt number plot for Super heater section ST

The nusselt (surface temperature) decreases from the inlet to the outlet of the super heater wall. The nusselt is minimal at the super heater at the outlet of the wall. As shown in Figure 5.4 and Figure 5.5, temperature increases with the super heater section ST. Temperature increases along the super heater section of ST from 865°C to 868°C. The highest temperature occurs at the super heater outlet at 868 °C.

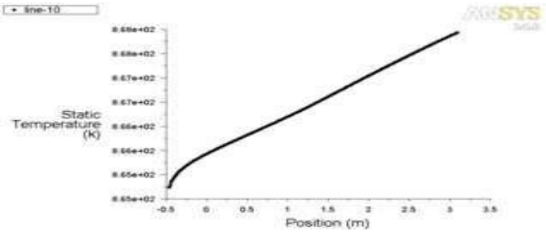

Fig. 5.4 Temperature plot for super heater section ST

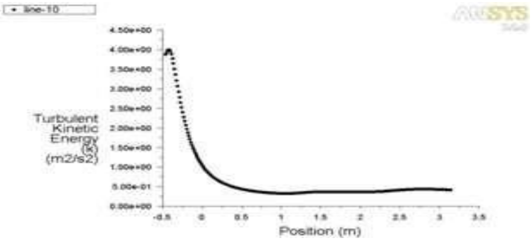

Fig. 5.5 Turbulent kinetic energy plot for super heater section ST

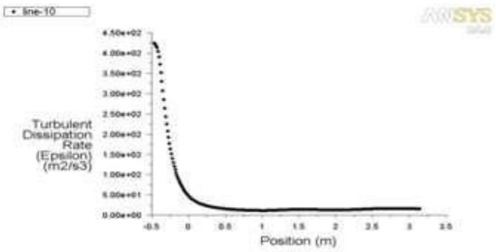

Fig. 5.6 Turbulent dissipation rate plot for super heater section ST

Figure 5.5, figure 5.6 shows that turbulent kinetic Energy, turbulent dissipation rate decreases along the length of super heater section ST. Turbulent kinetic energy and turbulent dissipation rate is maximum at the bending section of super heater.

6. VARIOUS CONTOURS FOR SUPER HEATER

Here various contours are plotted for a super heater to study and understand the thermal flow in the pipe to resolve the operational problems. From figure it is observed that temperature near the U-tube bend found more than another part of the super heater. Temperature in the super heater section ST, SR, QR and PQ shows the same temperature. Temperature is decreases along the length of super heater. This fluctuation of temperature may cause the boiler tube leakage. As the super-heater is the heat exchanger it increases the temperature of the steam flowing inside the tube and so the temperature of steam increases from inlet to outlet due to the super heater wall is heated by flue gas around 600 ° Celsius. At certain region sudden temp variation leads to the thermal embrittlement. This may leads to fatigue and cracks near the joint of the tube resulting into change in shape and cracks near the corners.

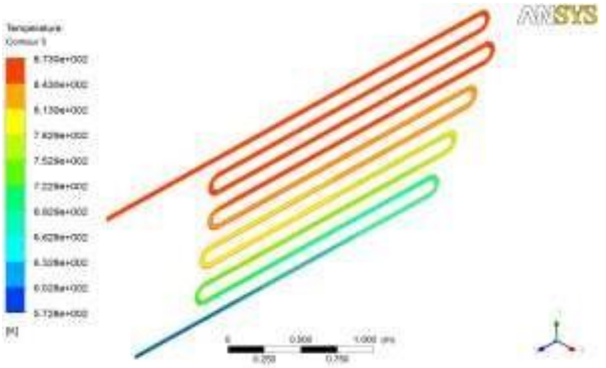

Fig.6.1 contour of temperature along the interior of super heater

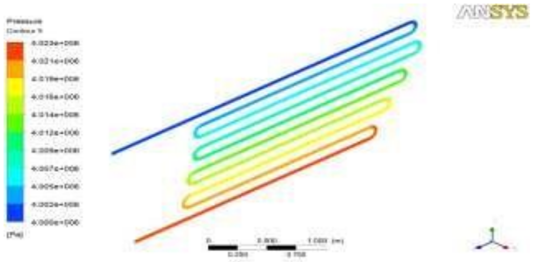

Fig.6.2 contour of pressure along the interior of the super heater

Fig. 6.1 show that pressure is decreases along the length of super heater, maximum pressure occurs at inlet and minimum pressure at outlet. The pressure drop in various bent geometries. The pressure drop is more significant due to flow separation at the inner wall in elbows as compared to bends.

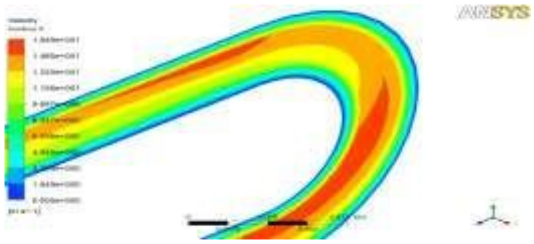

Fig.6.3 Contour of velocity along the bending interior of super heater

From the figure 6.4 and figure 6.5 it is observed that the velocity fluctuation takes place at the U-bending section. The sudden increment and decrement of the velocity takes place at the bending part of the super heater. Maximum velocity observed at the bending of a super heater. A boundary layer is formed as the fluid enters the pipe where the viscous forces are confined while the core is in viscid, like in a straight pipe. The secondary flow generated by the curvature is therefore moving the slower fluid from the boundary layer inwards and the faster fluid at the outwards. The inflow condition greatly affects the initial development of the flow with non-uniformity in wall shear stress, i.e. the shear is largest at the inner wall before the maximum moves to the outer wall, appearing at two times larger distance for the first inlet condition than for the second one.

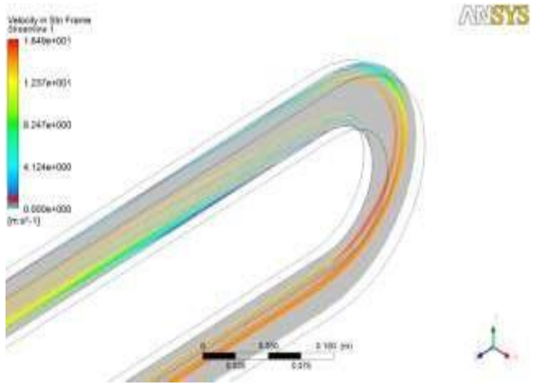

Fig.6.4. Contour of velocity streamline along the bending interior of super heater

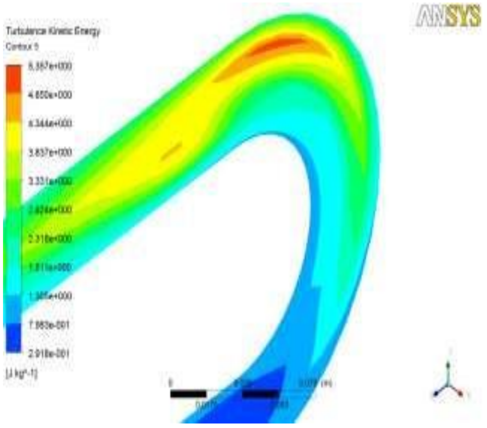

Fig.6.5 Contour of turbulent kinetic energy along bending interior of super heater

7. VARIOUS PLOTS OF SUPER HEATER FOR PARAMETRIC STUDY

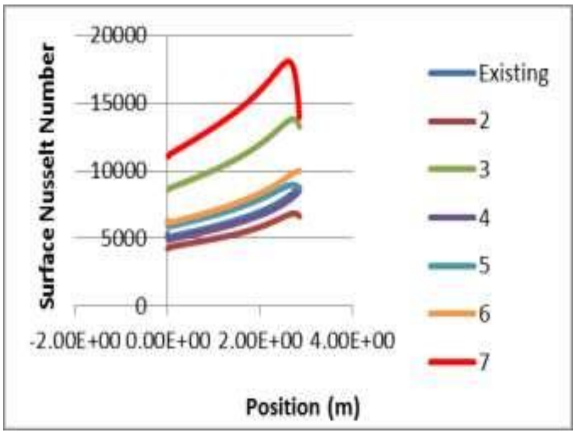

Fig.7.1 Nusselt number comparisons along the wall of super heater section AB

From the figures 7.1 is found that if the mass flow rate of steam increases then nusselt number increases. If the total number of tubes of super heater decreases then mass flow rate and nusselt number increase. If the diameter of super heater tube increases then nusselt number also increases.

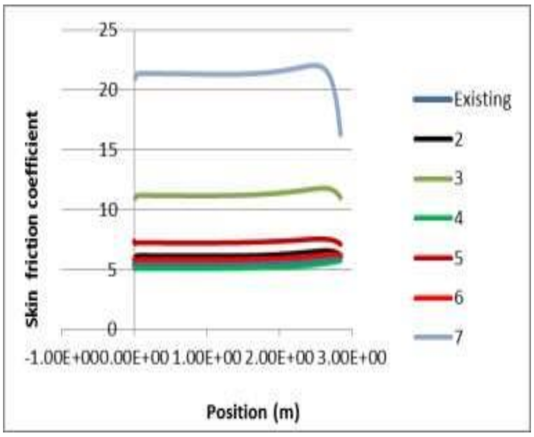

Fig.7.2 Skin friction coefficient comparisons along the wall of super heater section AB

If the diameter of super heater decreases then skin friction coefficient along the wall of super heater increase due to this pressure drop also increased at the bending section of super heater. If the mass flow rate of steam decreases then skin friction coefficient along the wall of super heater decrease as shown in the figure 6.2. The diameter of super heater tube increases, the heat transfer also increase.

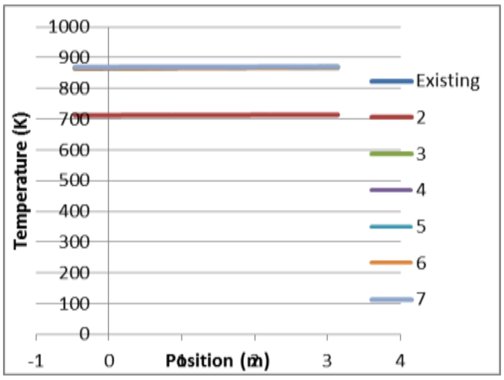

Fig.7.3 Temperature comparisons of a super heater at ST

It is evident that the mass flow rate strongly affects the temperature distribution of the water tube boiler. From figure 7.3 is found that the increase of mass flow rate of steam through the boiler tube causes the decrease in temperature in the inner tube wall. This behavior occurs because of the heat release from flue gas to steam is not proportional as the ability to absorb heat from flue gas for higher mass flow rate is faster. If mass flow rate of steam is increased consequence of it, temperature of flue gas must be increased to make heat balance in equilibrium condition. The higher steam inlet temp increases thermal efficiency but operating boiler with higher temperature has some disadvantages (i.e. to make steam inlet temp higher, more time is required, and also strength of tube materials should be considered as higher temperature will degrade the strength of material and thermal conductivity).

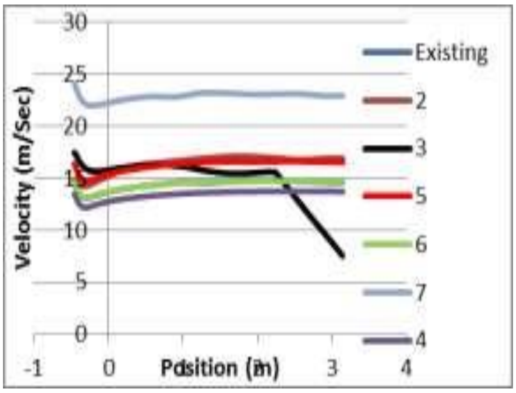

Fig.7.4 Velocity comparisons of a super heater section ST

Velocity of steam is depends on diameter of the super heater pipe. From figure 6.4 it cleared that if diameter the super heater tube increased then velocity of a steam decreases. Also cleared that velocity of steam is maximum at lower diameter of super heater pipe.

8. Conclusion

The results and the study concluded that the heat transfer along the length of the super heater pipe and temperature range is also the same at sections OP,QR and ST. Therefore, it is possible to reduce the super heater length to avoid thermal losses and financial losses. When mass flow rate of the steam in the super heater is decreased, the temperature of the steam inside the super heater tube increases. When total number of the super heater pipes are decreased by 5, the mass flow rate in the tube increases, resulting in an increase in the average nusselt number. This increases the heat transfer and temperature decreases, which helps to prevent overheating of the super heater. When the mass flow rate increases, the pressure drop increases and the average nussselt number decreases. This increases the turbulent kinetic energy at the bending interior.

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