Numerical investigation of Forced Convection and longitudinal Optimization for Finned Tube Heat Exchanger

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ABSTRACT : A numerical study has been carried out to investigate the heat transfer by laminar forced convection of nanofluid taking Titania (TiO2) and Alumina (Al2O3) as nanoparticles and the water as base fluid in a three dimensional plain and U-longitudinal finned tube heat exchanger. A Solid WORKS PREMIUM 2018 is used to draw the geometries of plain tube heat exchanger or U-longitudinal copper finned tube heat exchanger. The effect of various fin designs with Water concentrations is done using Fluent. Aim is to investigate the optimized fin design with better nano fluid percentage.

Keywords : Nano Fluid , Ansys , CFD , Heat Transfer , U Longitudinal Fin

I.INTRODUCTION

The study of improved heat transfer performance is referred to as heat transfer enhancement, augmentation, or intensification. In general, this means an increase in heat transfer coefficient.Taborek updated sketchy methods for double pipe heat exchangers especially for longitudinal finned tubes. Calculation methods are presented for plain double pipe units, as well as finned tube units. Equations for the mean temperature difference for units with flow in series-parallel are also given. Mir et al. carried out numerical simulation of studying laminar, forced convection heat transfer in the finned annulus for the case of fully developed incompressible flow. The simulation was corresponding to thermal boundary condition of uniform heat input per unit axial length with peripherally uniform temperature at any cross section. The results showed a good comparison with the literature results. Strand bergandDebendra compared the performance of hydraulic finned–tube heating units utilizingnanofluids with the performance of conventional heat transfer fluid of 60% ethylene glycol and 40% water by using mathematical model. Al_2 O_3and CuO nanoparticles dispersing in 60% EG solution were used. Finned–tube heating performance was enhanced by employing nanofluids. The increase of (11.6%) in finned tube heating output was predicted with 4% of Al_2 O_3and 60% EG.

Furthermore, the increase of (8.7%) was predicted with 4% CuO and 60% EG comparing of basefluid. Syed et al. performed numerical simulation of finned annulus in the steady and laminar convection in the thermal entry region, fully developed flow at uniform heat flux. Finite difference based marching procedure was used to compute the numerical solution of the energy equation. The numerical results showed the Nusselt's number has complex depending on the geometric variables like ratio of radii, fin height, and number of fins. The validation of the simulation was performed by comparison with open literature. Present work concerns of studying the performance of U–longitudinal finned tube heat exchanger and comparing it with smooth tube. Then, its performance with nanofluids. This is done after adding nanoparticles to basefluid. The effect of this new technology on estimated reduction in surface area of fins will be examined. Numerical simulation by ANSYS FLUENT 14 package is used to simulate the system and then using laminar flow with and without nanofluids.

II.MATHEMATICAL MODELLING AND NUMERICAL SIMULATION

Numerical simulation performs analysis of a system involving fluid flow, heat transfer and associated phenomena based on various disciplines of science. These are includes mathematics, computer engineering and physics to provide meaningful modeling of fluid flow. ANSYS FLUENT 14 package has been conducted for performing numerical simulation across the heat exchanger using three– dimensional model.

The solution of conservation continuity, momentum and energy equations is used to analyze the flow field inside the heat exchanger. A comparison of heat transfer for smooth, finned tube with or without nanofluids is carried out. A SOLID WORK PREMIUM 2012 is used to draw the geometries of this work which consist smooth tube heat exchanger and U–longitudinal finned tube heat exchanger with inlet and outlet portions. The outside flow is confined by insulating tube having inlet and outlet portions as shown in figure1. Computational domains in the present study are displayed as inlets and outlets of both hot side (water or nanofluids) in the inner tube, and air side in the annuli. Fins are built on the outside surface of the inner tube and the flow on both sides is counter flow.

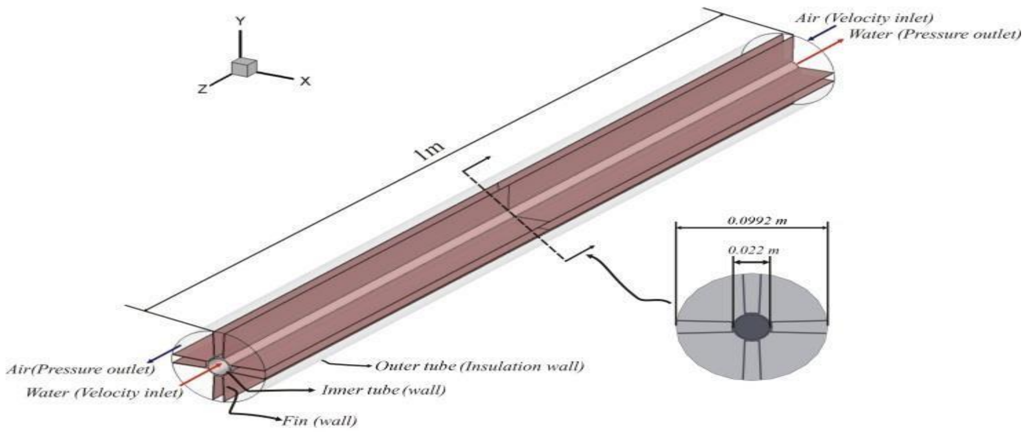


Figure 1. U-longitudinal finned tube heat exchanger.

The assumptions used for water, nanofluid and air during the present study are steady state, Newtonian fluid, incompressible, three dimensional, laminar flow in the inner side (water or nanofluid) and turbulent flow in the annuli side (air).Both fluids are forced convection heat transfer. Buoyancy effect is assumed to be negligible. Radiation heat transfer is not considered. The governing equations for continuity, momentum, and energy of laminar flow in an inner tube are:

Continuity Equation $$\frac{D\rho}{Dt} + \rho\frac{\partial U_i}{\partial x_i} = 0$$ Equation.......1

Momentum Equation $$\underbrace{\rho\frac{\partial U_j}{\partial t}}_{I} + \underbrace{\rho U_i\frac{\partial U_j}{\partial x_i}}_{II} = -\underbrace{\frac{\partial P}{\partial x_j}}_{III} - \underbrace{\frac{\partial \tau_{ij}}{\partial x_i}}_{IV} + \underbrace{\rho g_j}_{V}$$ Equation........2

Energy Equation $$\underbrace{\rho c_\mu\frac{\partial T}{\partial t}}_{I} + \underbrace{\rho c_\mu U_i\frac{\partial T}{\partial x_i}}_{II} = \underbrace{-P\frac{\partial U_i}{\partial x_i}}_{III} + \underbrace{\lambda\frac{\partial^2 T}{\partial x_i^2}}_{IV} - \underbrace{\tau_{ij}\frac{\partial U_j}{\partial x_i}}_{V}$$ Equation........3

where, (u, v, w) = velocitycomponent,T = temperature, k = thermal conductivity, Cp = specific heat,

μ = dynamic viscosity, and ρ = density.

III. Mesh generation

Unstructured mesh is used in the present study to discretize the computational domain into a finite number of control volumes by using the finite–volume scheme. The model was meshed by GAMBIT software. The refinement and generation of mesh system are very crucial to predict the heat transfer in sophisticated geometries. In this study triangular element type is employed for surface mesh and tetrahedron element type is used for three dimensional geometry. This is because it has priority in the sophisticated geometries. Figure 2 shows the mesh of present model. To estimate the performance of the present heat exchanger, some introductory requirements of the physical model are defined adequately as Reynolds number in the inlet was specified for inner and annuli sides during this study. On the other hand the temperature inlet of the inner tube is 60 °C while in annuli is 20°C.

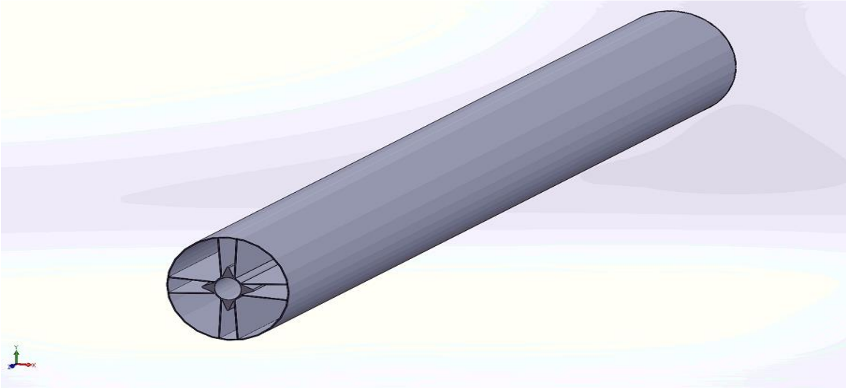


fig: 3.1 New Design Sugesstion for the Finned Tube Heat Exchanger.

The outlet domain is specified as pressure outlet for both sides. No slip boundary condition is specified in the wall of the inner tube. These conditions are used to bound fluid and solid region. It is worth mentioning that convenient numerical control and modeling techniques are very important to step up convergence and stability during the calculation. By adopting control–volume technique, FLUENT shifts the governing equations to algebraic equations that can be solved numerically. The control volume technique involves of integrating the governing equations inside each control volume, yielding discrete equations [8]. Simplifying of geometry which is avoided during this study to get the best degree of accuracy which may be influenced by reducing the resolution as long as the computer ability is capable to achieve the simulation accurately. For this study, an average of 11 million cells is used and it is the maximum number of iterations performed to get the solver terminates. 4000 iterations are needed in this study.

Boundary Condition

Parameter	Method
Viscous	Laminar
Energy	On
Air Inlet	Re=600-1900
Fluid inlet	0.5kg/s
Air inlet temp	333K
Fluid Inlet temp	296

IV.Result

(a) U tube With Re=600 (b) W tube With Re=600

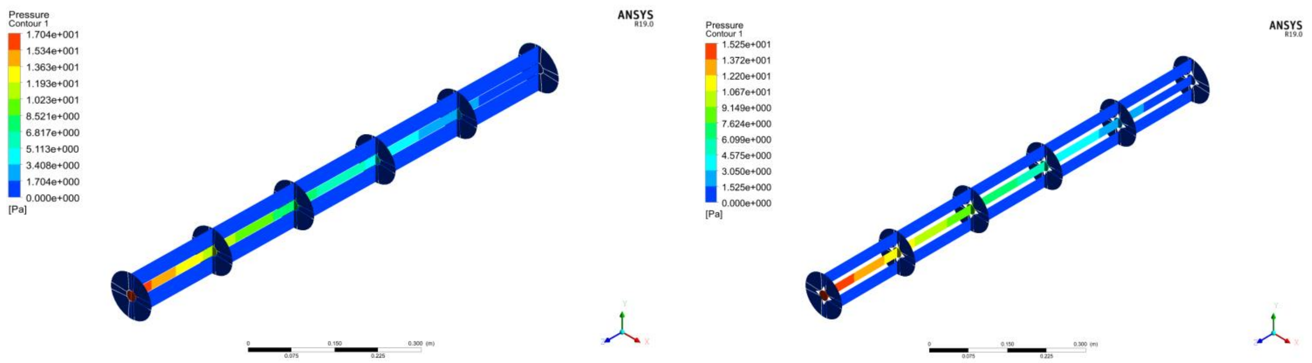


Figure 4.1 Pressure Contour for Re=600 with water in U tube and W tube

The above Figure represents the Pressure distribution of Water and Air in their Respective Region discussed in the Schematic Fig 3.1 Where Blue Color Show Minimum Pressure Area and The red color show Maxim Pressure from the Figure we can say that The pressure of the water is reached From 17 pascal to 1.7 pascal at inlet and outlet Respectively.

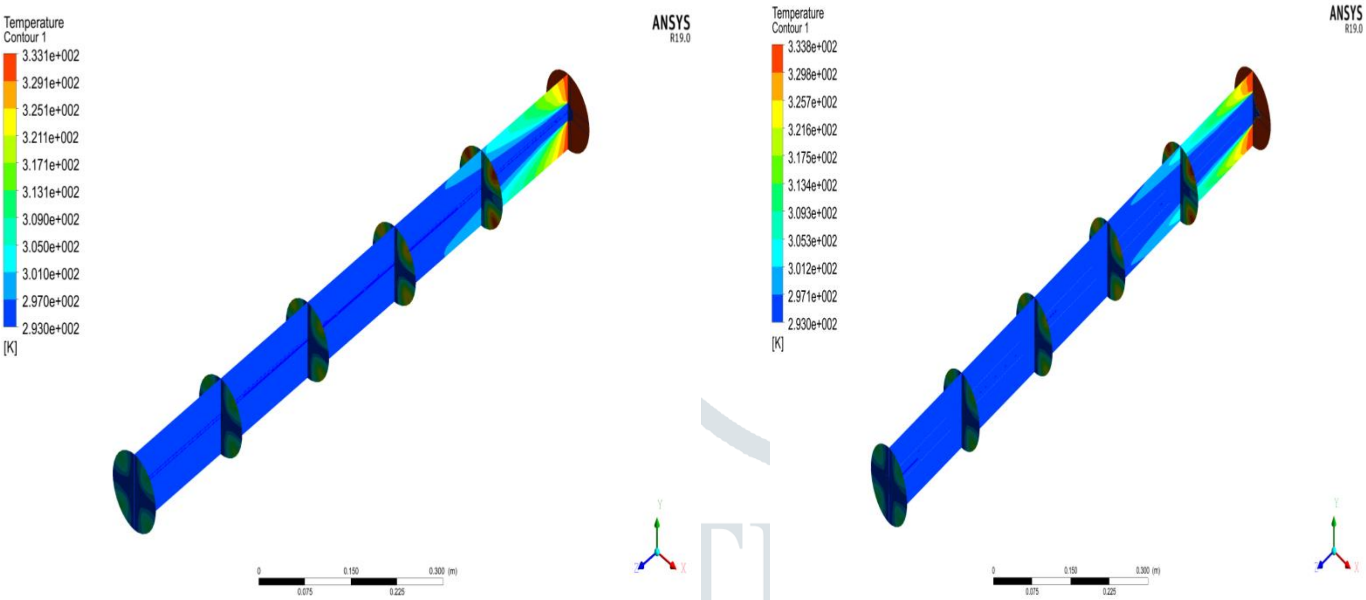


Figure 4.2 Temperature contour for Re=600 with water in U tube and W tube.

The above figure represents the Temperature distribution of Water and Air in their Respective region discussed in the Schematic Fig 3.1 where the blue color show minimum temperature area and The red color show maximum temperature from the figure we can say that the Temperature of the Air is reached from 333 Kelvin to 317 Kelvin at Inlet and outlet Respectively.

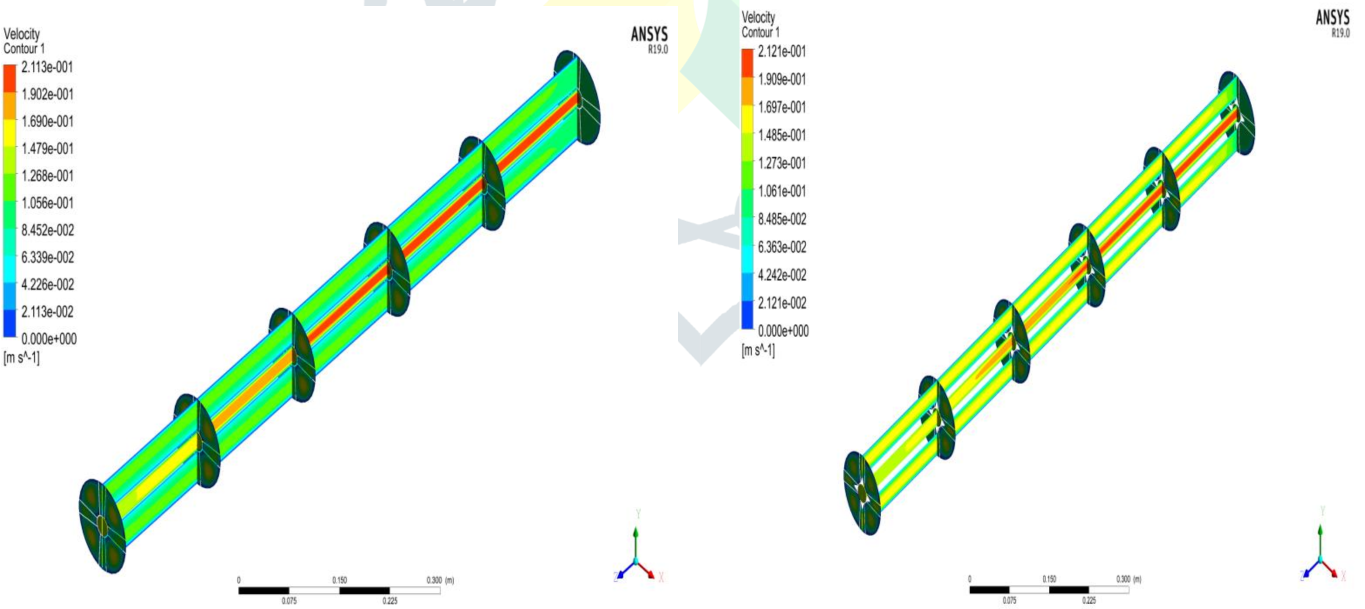


Figure 4.3 Velocity contour for Re=600 with water in U tube and W tube.

The above figure represents the velocity changes of water and Air in their respective region discussed in the schematic Fig. 3.1 Where blue color show minimum velocity area and the red color show maximum velocity from the figure we can that the velocity of the air is reached from 0.212 meters per second to 0.021 meters per second at inlet and outlet respectively.

(c) U tube with Re=900 (d)W tube withRe= 900

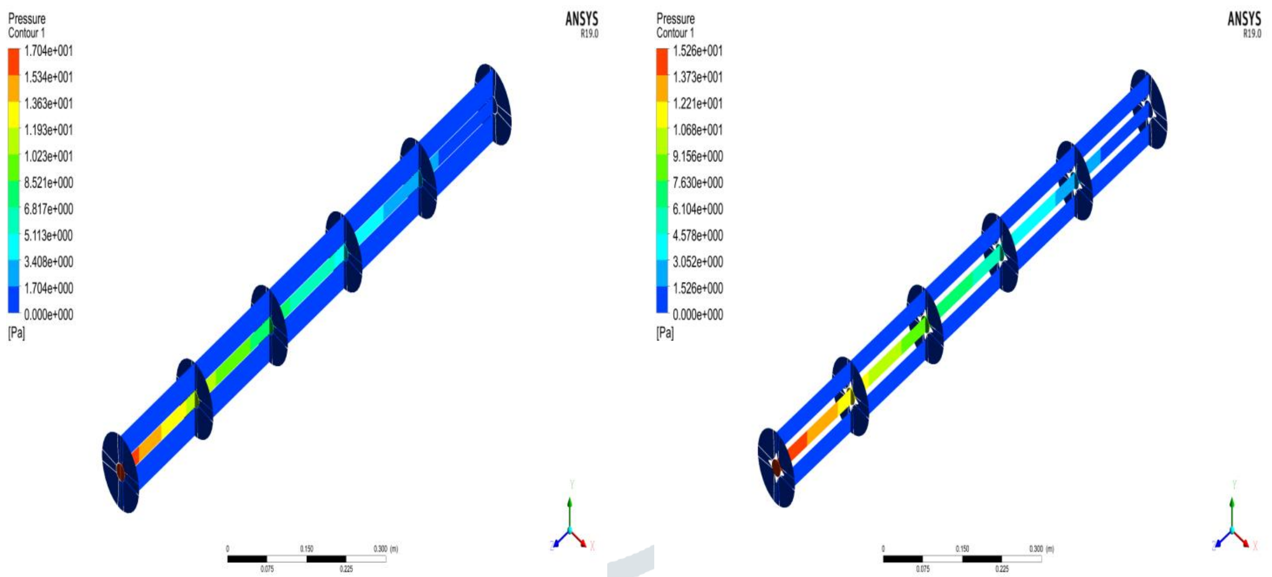


Figure 4.4 Pressure Contour for Re=900 with water in U tube and W tube

The above Figure represents the Pressure distribution of Water and Air in their Respective Region discussed in the Schematic Fig 3.1 Where Blue Color Show Minimum Pressure Area and The red color show Maxim Pressure from the Figure we can say that The pressure of the water is reached From 17 pascal to 1.7 pascal at inlet and outlet Respectively.

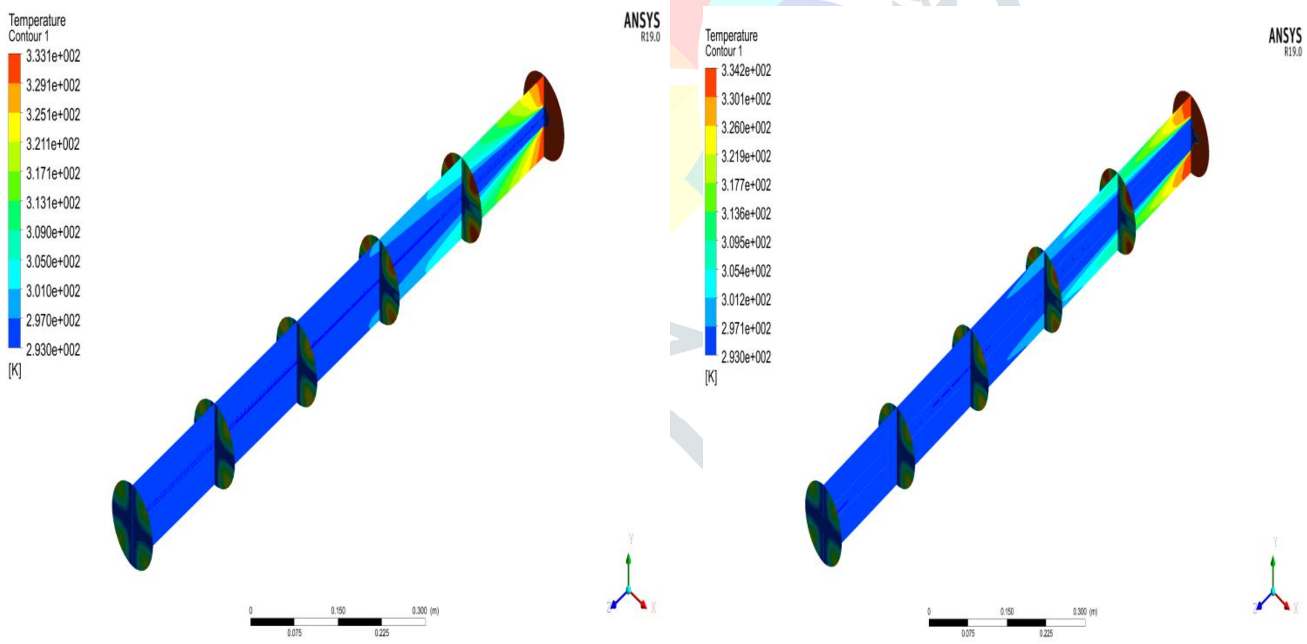


Figure 4.5 Temperature contour for Re=900 with water in U tube and W tube.

The above figure represents the Temperature distribution of Water and Air in their Respective region discussed in the Schematic Fig 3.1 where the blue color show minimum temperature area and The red color show maximum temperature from the figure we can say that the Temperature of the Air is reached from 333 Kelvin to 325 Kelvin at Inlet and outlet Respectively.

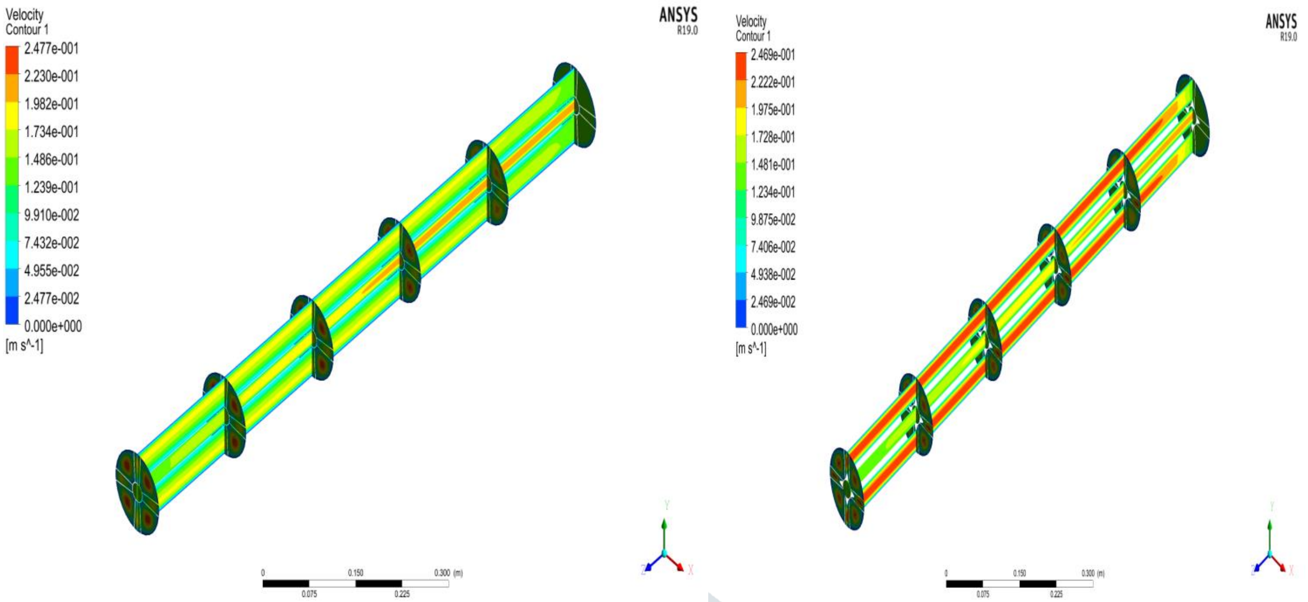


Figure 4.6 Velocity contour for Re=900 with water in U tube and W tube.

The above figure represents the velocity changes of water and Air in their respective region discussed in the schematic Fig. 3.1 Where blue color show minimum velocity area and the red color show maximum velocity from the figure we can that the velocity of the air is reached from 0.247 meters per second to 0.024 meters per second at inlet and outlet respectively.

(b) U tube with Re=1600

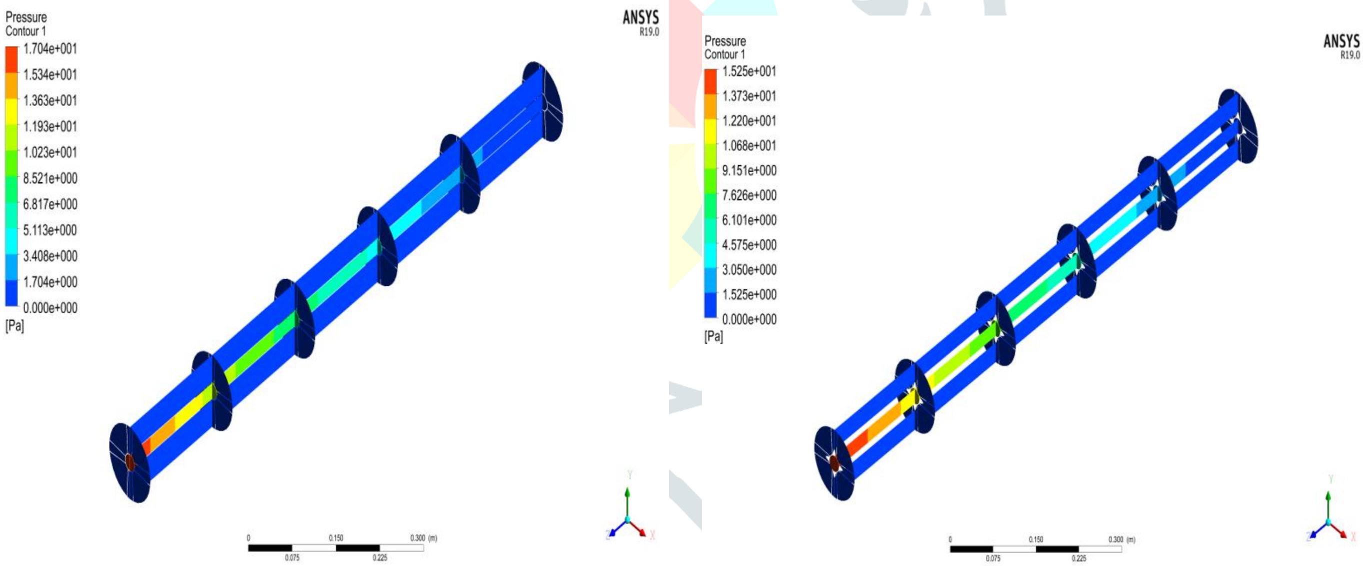


Figure 4.7 Pressure Contour for Re=1600 with water in U tube and W tube.

The above Figure represents the Pressure distribution of Water and Air in their Respective Region discussed in the Schematic Fig 3.1 Where Blue Color Show Minimum Pressure Area and The red color show Maxim Pressure from the Figure we can say that The pressure of the water is reached From 17 pascal to 1.71 pascal at inlet and outlet Respectively.

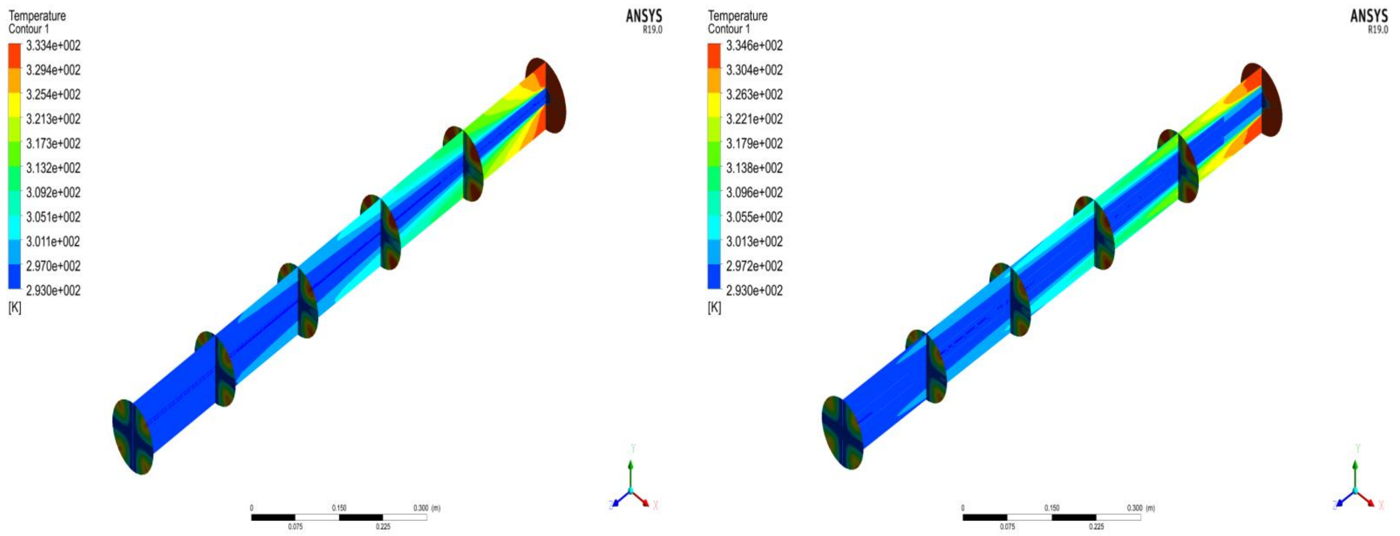


Figure 4.8 Temperature contour for Re=1600 with water in U tube and W tube.

The above figure represents the Temperature distribution of Water and Air in their Respective region discussed in the Schematic Fig 3.1 where the blue color show minimum temperature area and The red color show maximum temperature from the figure we can say that the Temperature of the Air is reached from 333 Kelvin to 325 Kelvin at Inlet and outlet Respectively.

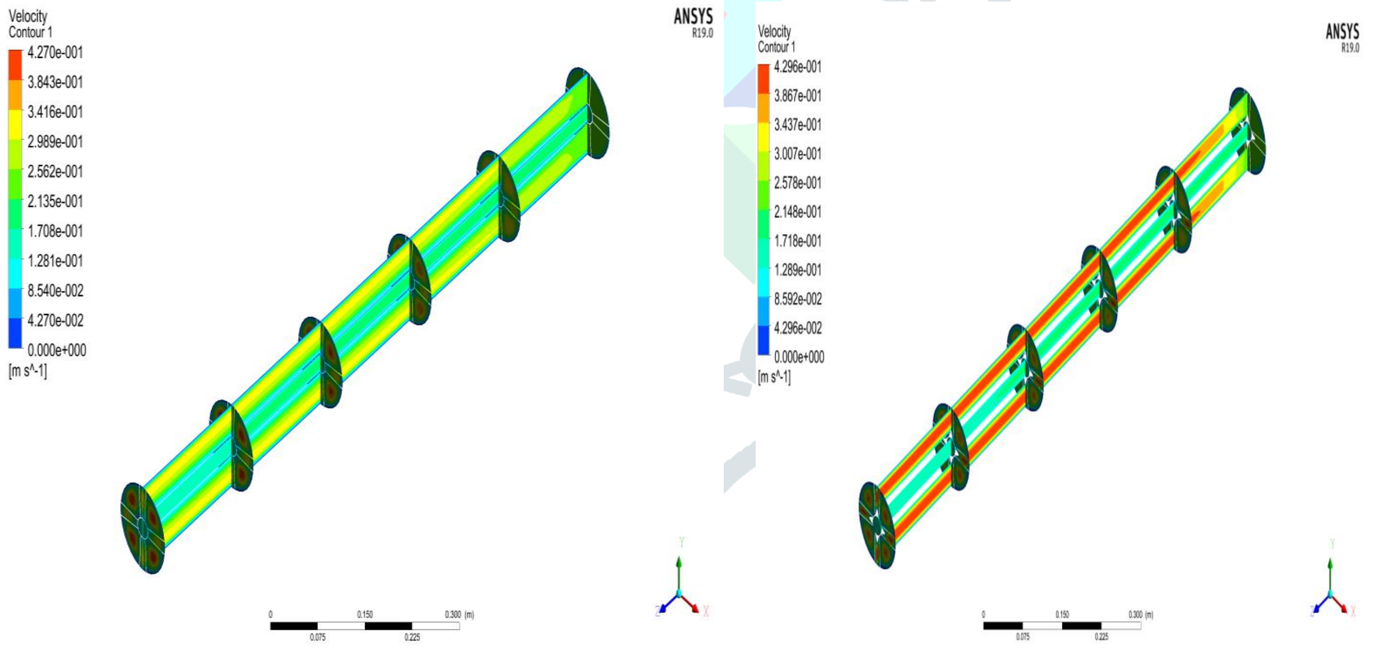


Figure 4.9 Velocity contour for Re=1600 with water in U tube and W tube.

The above figure represents the velocity changes of water and Air in their respective region discussed in the schematic Fig. 3.1 Where blue color show minimum velocity area and the red color show maximum velocity from the figure we can that the velocity of the air is reached from 0.427 meters per second to 0.298 meters per second at inlet and outlet respectively.

(c) U tube with Re=1900

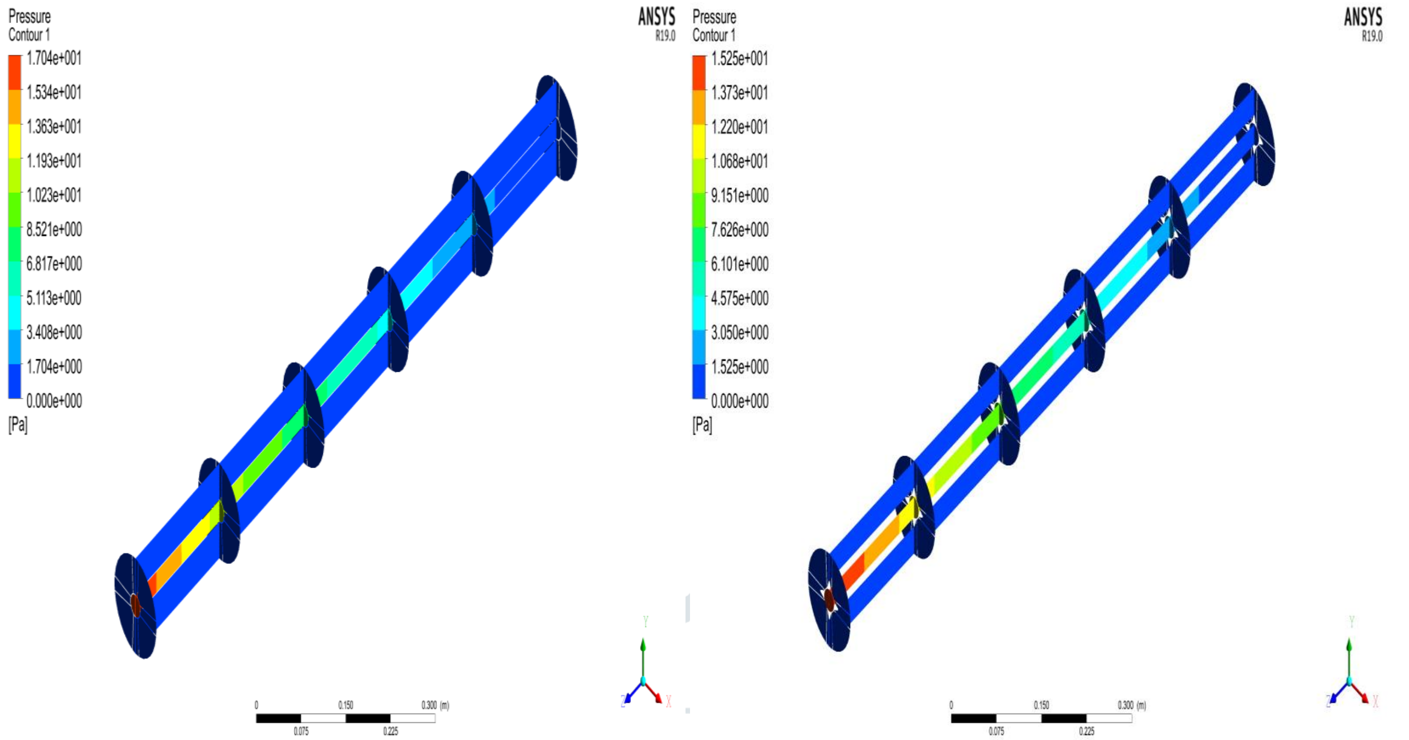


Figure 4.10 Pressure Contour for Re=1900 with water in U tube and W tube.

The above Figure represents the Pressure distribution of Water and Air in their Respective Region discussed in the Schematic Fig 3.1 Where Blue Color Show Minimum Pressure Area and The red color show Maxim Pressure from the Figure we can say that The pressure of the water is reached From 17 pascal to 1.7 pascal at inlet and outlet Respectively.

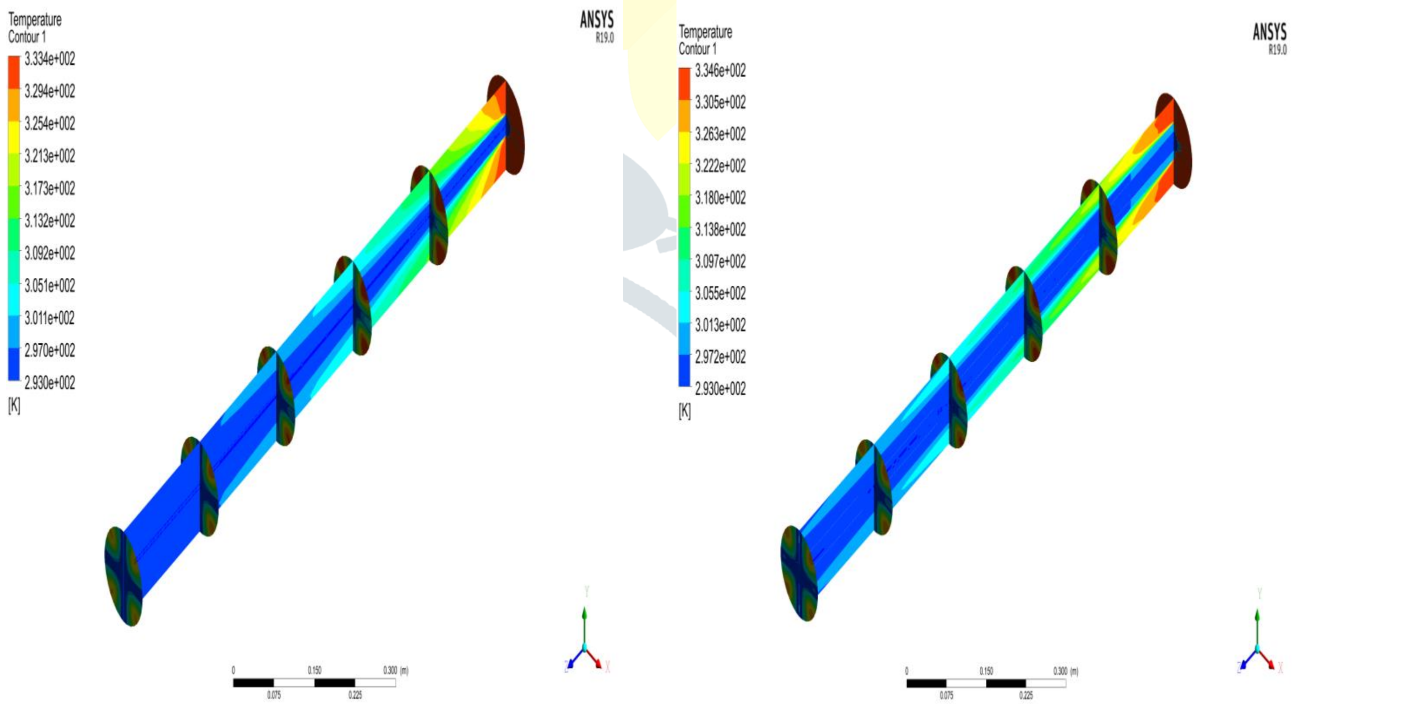


Figure 4.11 Temperature contour for Re=1900 with water in U tube and W tube.

The above figure represents the Temperature distribution of Water and Air in their Respective region discussed in the Schematic Fig 3.1 where the blue color show minimum temperature area and The red color show maximum temperature from the figure we can say that the Temperature of the Air is reached from 333 Kelvin to 325 Kelvin at Inlet and outlet Respectively.

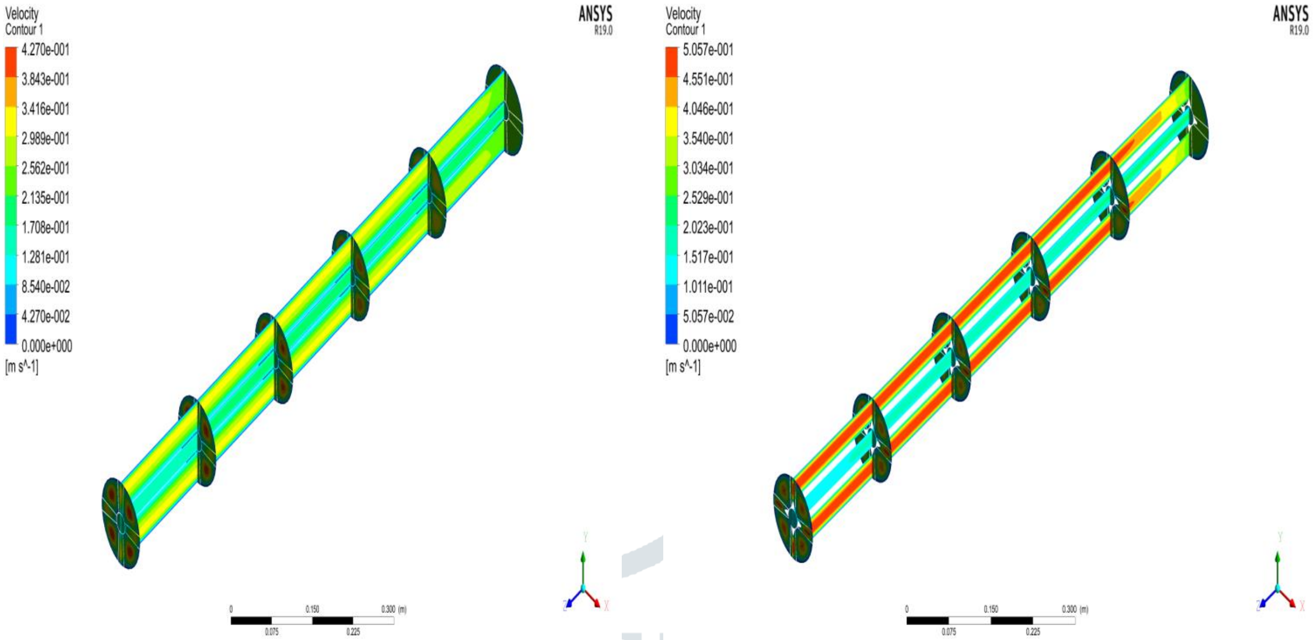
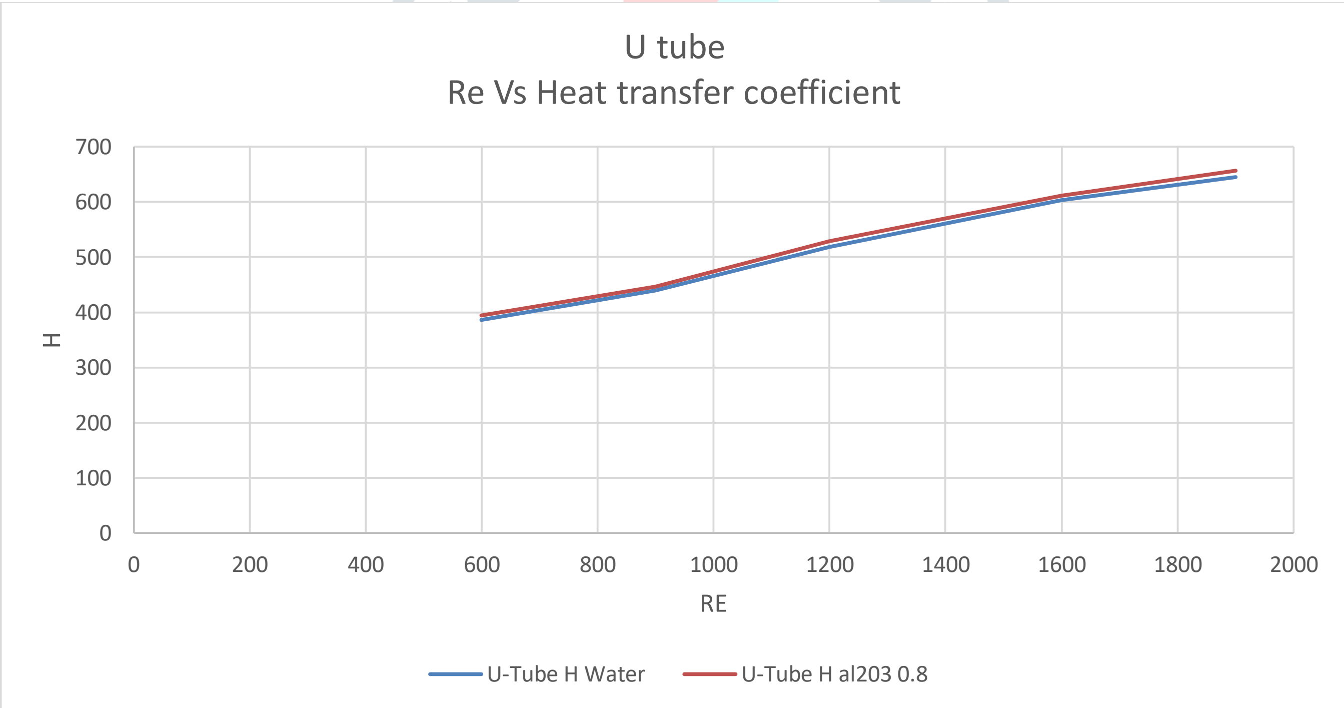


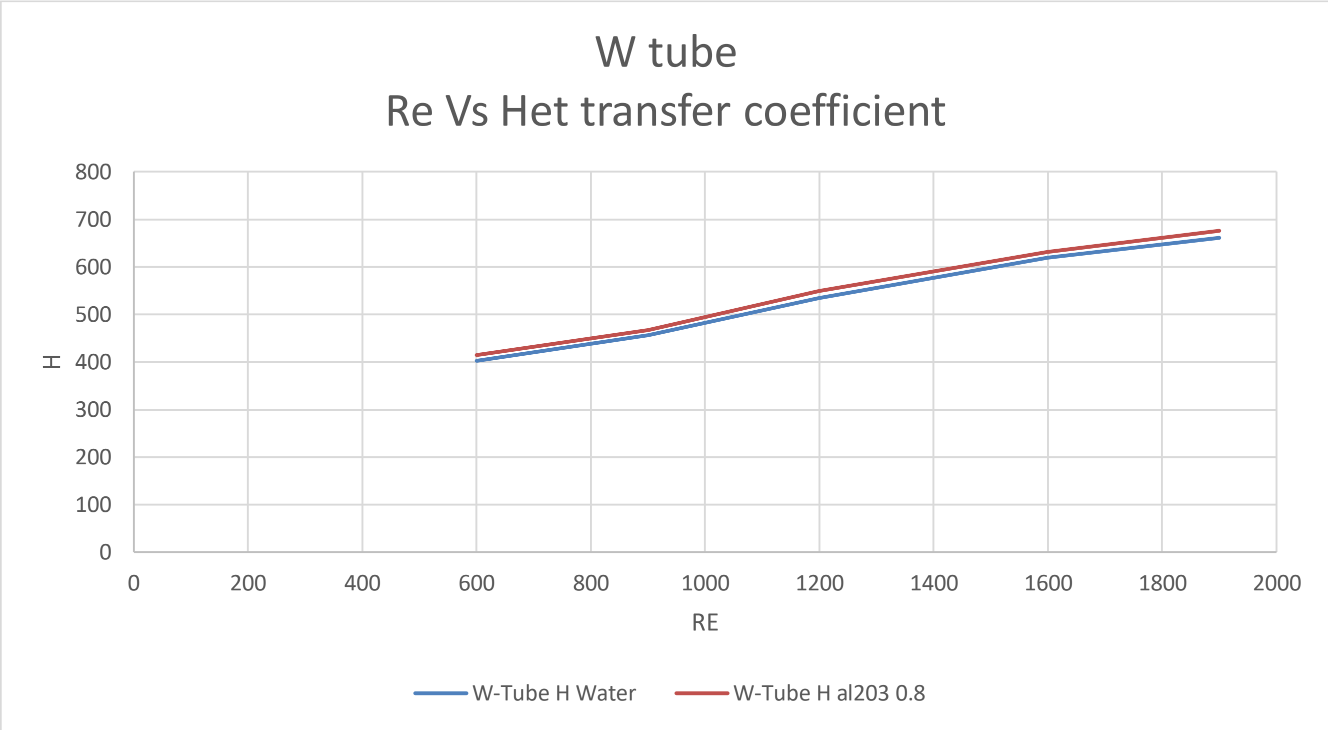
Figure 4.12 Velocity contour for Re=1900 with water in U tube and W tube.

The above figure represents the velocity changes of water and Air in their respective region discussed in the schematic Fig. 3.1 Where blue color show minimum velocity area and the red color show maximum velocity from the figure we can that the velocity of the air is reached from 0.427 meters per second to 0.213 meters per second at inlet and outlet respectively.



Plot 4.1 X-y Plot of u Fin and tube Re Vs H

The above plot represents the Heat transfer Coefficient of the U finned tube heat exchanger with Reynolds Number where from the plot we can say that Heat transfer coefficient is increasing with Reynolds number.



Plot 4.2 X-Y plot of W fin and tube with Nano Fluid and Water Re Vs H.

The above plot represents the Heat transfer Coefficient of the W finned tube heat exchanger with Reynolds Number where from the plot we can say that Heat transfer coefficient is increasing with Reynolds number.

Conclusion

In the Comparison of the Current Analysis the u tube is done in the previous literature where a better design is implemented in this thesis which gives a significant advantage in the heat eradication from air at dfferent speeds. The performance of the heat exchanger is increased at 7.5% of the nano Fluid Concentration. The w tube fin and tube heat exchanger is also useful in extending surfaces from the both ends and gives an advantage of increasing in the heat capacity where Heat transfer coefficient of u Fin is 660.75 w/m2k and W Fin is 676.786 W/m2k. Hence we can conclude that the increase in the heat transfer coefficient we can say at Re=1900 with w tube gives More efficiency

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