CFD Analysis of Twisted pipe heat exchanger using ANSYS

[1]Roshan Datt Kashyap, [2]Anoop Kumar, [3]Sudhuir Singh Rajput

[1]Research Scholar, [2]Assistant Professor, [3]Head of Department
[1]Mechanical Engineering,
[1]Raipur Institute of Technology, Raipur, Chhattisgarh, India.

Abstract: There are different methods to augment heat transfer like incorporating swirl-flow devices with different geometric arrangements which could create rotating flows. Geometric arrangements include use of coiled tubes, vortex generators and twisted tapes being used to increase heat transfer rate. These geometric configuration finds its application in various industrial components and heat exchangers, HVAC systems. This research investigates application of nano fluids Al_2O_3/water nano fluids in heat exchanger with dual twisted tapes using numerical method. The numerical investigation is conducted using techniques of Computational Fluid Dynamics. The CAD model is developed using Creo design software and the CFD simulation is conducted using ANSYS CFX. RNG K epsilon turbulence model is used for analysis which is more suited for flows involving swirl.

Keywords: ANSYS CFX, Nano fluids, heat transfer.

I. INTRODUCTION

In heat exchanger thermal energy of one fluid is transferred to another fluid. The heat transfer may take place through surface to fluid or between solid particles to fluid. The main criteria of heat transfer between fluids or from surface to fluid is thermal gradient or temperature difference between the two. Heat exchangers are used widely for heating and cooling operations of fluid involves. The process involves evaporation, condensation etc. Some other application of heat exchangers involve sterilization, pasteurization. The fluids in heat exchanger are separated by wall thus fluids don’t intermix.

II. LITERATURE REVIEW

Maiga et al. [1] numerically investigated effect of Al_2O_3/water nanofluid and Al_2O_3/ethylene glycol nanofluid in circular tube using single wall heat flux condition. Standard k-epsilon turbulence model was used for analysis and results shown enhancement in heat transfer with ethylene glycol based nanofluid.

Roy et al. [2] numerically analyzed radial cooling system using CuO/water nanfluid in both laminar and turbulent flow. The increase of heat transfer coefficient is evident with increase of volume fraction of nanoparticles.

Xuan et al. [3] proposed a warm Lattice Boltzmann demonstrate for stream and vitality transport reproduction of a Cu/water nanofluid. The distinctive component of this model is the speculation of molecule area at a progression of cross sections, exhibiting a Boltzmann appropriation inside these. Another applicable element is the temperature freedom as to molecule thickness dissemination. The model anticipated an improvement of the nanofluid Nusselt number over that of water alone.

Behzadmehr et al. [4] conducted CFD analysis of tube using nanofluid and parameters varied were velocity gradient under constant wall heat flux boundary condition. The data for numerical analysis was taken from experimental tests .

Pfautsch [5] conducted numerical analysis on plate heat exchanger using Al_2O_3/water nanofluid and Al_2O_3/ethylene glycol nanofluid. The analysis were performed using Finite Difference Method. Results showed that the laminar stream convection coefficient increments drastically with molecule estimate decrease and volume part increment. For all around scattered particles in water the greatest improvement was anticipated to be 130%, though for ethylene glycol the upgrade was fundamentally higher (275%).

Mohammed et al. [6] conducted numerical investigation on micro channel heat exchanger using four different nano particles of Al_2O_3, SiO2, Ag and TiO2 at laminar flow conditions. Under steady state flow conditions Al_2O_3 water nanofluid show better heat transfer characteristics while with increase in Reynolds number leads to increase in pumping power.

III. PROPOSED WORK

The objective of this research is to investigate the application of nano fluids Al_2O_3/water nano fluids in heat exchanger with dual twisted tapes. The nano particle percentage taken for CFD analysis is 1% and 2% respectively for Al_2O_3. The Nusselt number obtained for Al_2O_3/water nano fluids is compared with base fluid water. The CAD model of twisted tape heat exchanger is developed in Creo design software and CFD analysis is conducted in ANSYS CFX software.

IV. METHODOLOGY

CAD model of heat exchanger is developed using various configuration of twisted tapes. Three different geometries having parameters Y_0/Y 1.5, Y_0/Y 2, and Y_0/Y 2.5 are developed as shown in fig 1, fig 2 and fig 3 respectively.

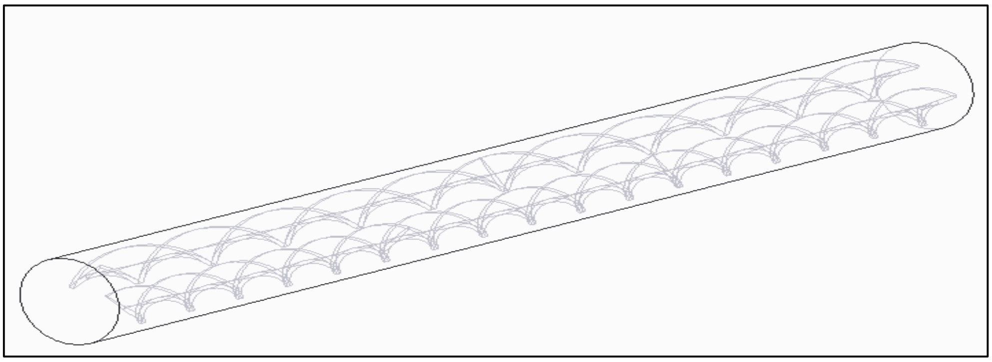

Fig. 1 Wireframe CAD model of heat exchanger using twisted tapes (Y_0/Y 1.5)

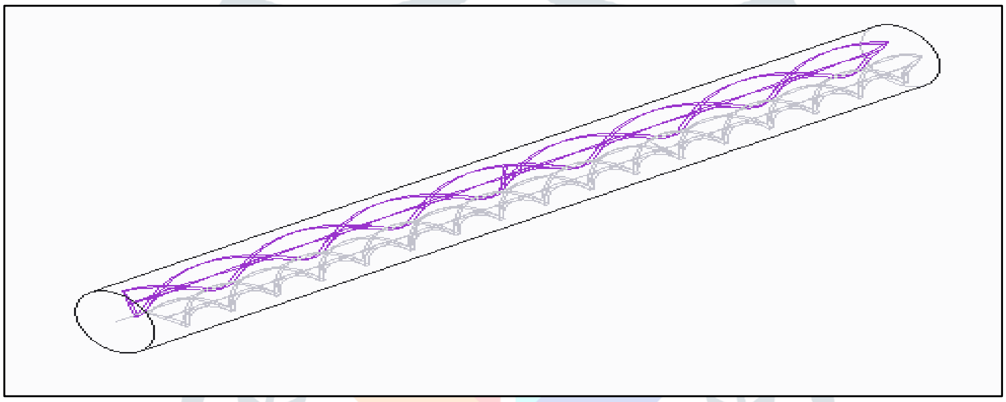

Fig. 2 Wireframe CAD model of heat exchanger using twisted tapes (Y_0/Y 2)

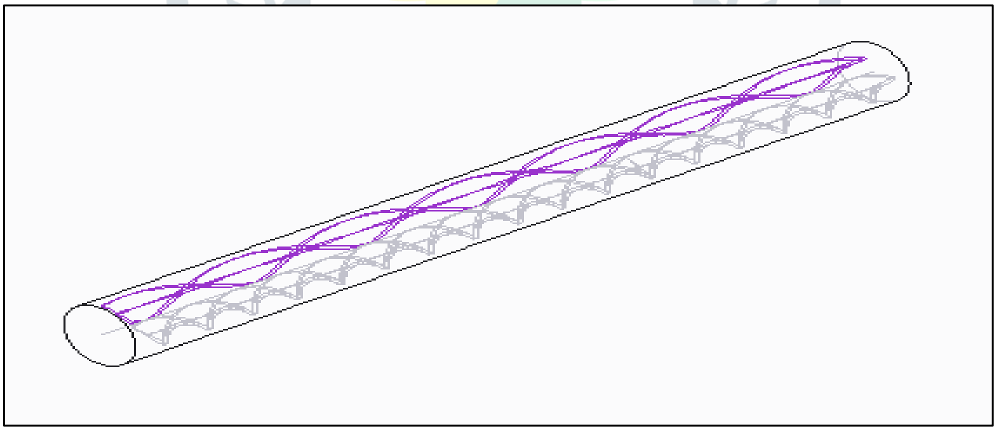

Fig. 3 Wireframe CAD model of heat exchanger using twisted tapes (Y_0/Y 2.5)

The fluid is assumed to be incompressible with constant property and the flow is laminar and in steady state condition. A mass flow rate of 0.05 to 1.58 kg/s is applied to the inlet boundary of the periodic module. The fluid enters with uniform temperature of 300 K and different inlet uniform velocities V in are applied. At the outlet of the computational Model a relative average pressure equalling zero was defined. A constant temperature Tw = 340 K is specified for the wall (tube). The first step involves importing CAD model in ANSYS workbench using import tool and geometry cleanup is performed using various tools

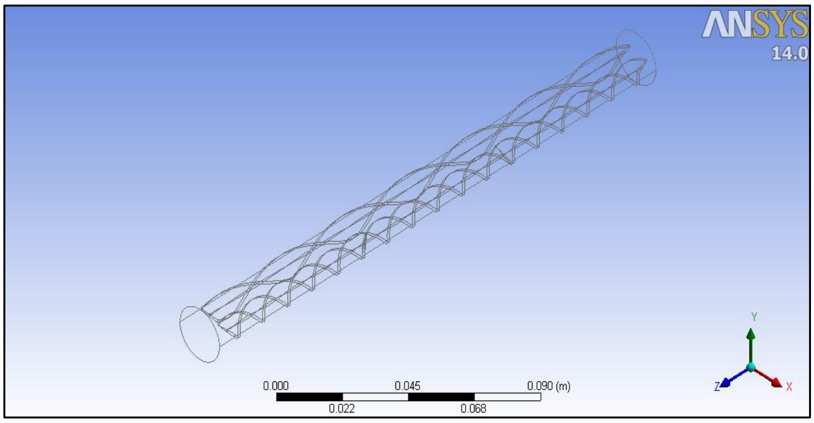

Fig. 4: Imported CAD model in ANSYS

The model is meshed using brick elements and with given parameters and appropriate mesh density. The mesh size is set to fine and inflation to normal with relevance set to 100. Transition is set to slow and smoothing medium and span angle fine.

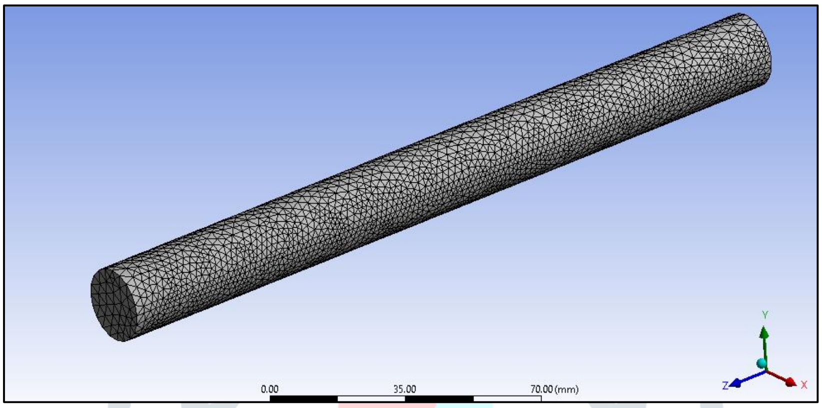

Fig. 5: Meshed model in ANSYS and parameter setting

In the third step boundary conditions are applied. Here fluid properties are assigned. An inlet boundary conditions with varying Reynolds number 6798,8175,9554,10935,12136,14620,16002 are applied. The Reynolds number is based on inner tube diameter is given by:

Re = ρUD/μ

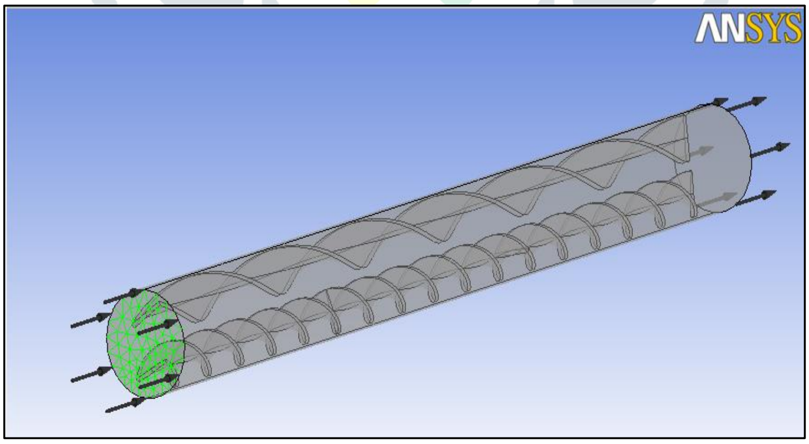

Fig. 6: Inlet boundary conditions

The inlet boundary conditions are defined on left surface with varying velocities as shown in fig 7 and turbulence intensity is medium to 5% whereas for outlet right surface is selected and relative pressure is set to zero.

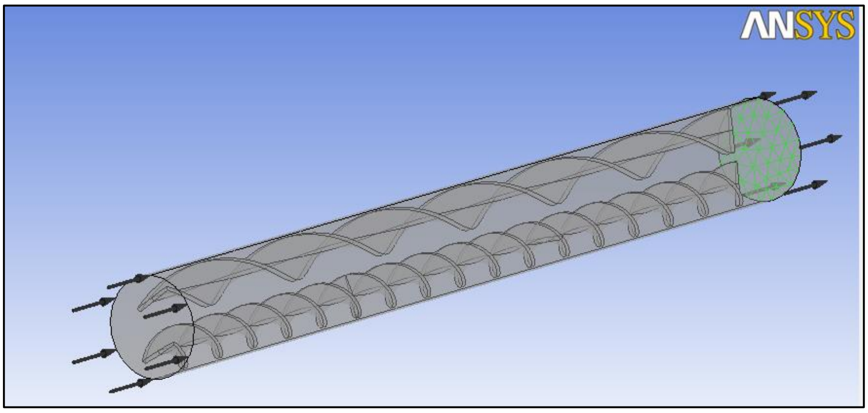

Fig. 7: Outlet boundary conditions

The modeled cases were solved using ANSYS software. A Segregated, implicit solver option was used to solve the governing equations. The first order upwind discrimination scheme was employed for the terms in energy, momentum, and laminar flow parameters. A standard pressure interpolation scheme and SIMPLER pressure velocity coupling were implemented.

V. RESULTS AND DISCUSSION

Initial analysis of heat exchanger using water as fluid is conducted and temperature distribution, pressure plot are plotted below.

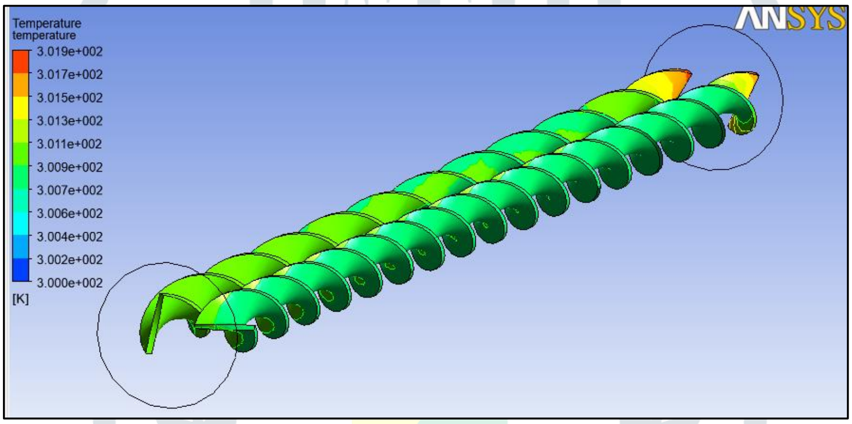

Fig. 8 Temperature contour for Y_0/Y 1.5

The temperature plot shown above shows increased temperature towards end of twisted tapes. The figure 8 above is for geometric configuration of Y_0/Y 1.5. Although the temperature distribution across twisted tapes is not much evident, noticeable temperature difference is observed in fluid outlet.

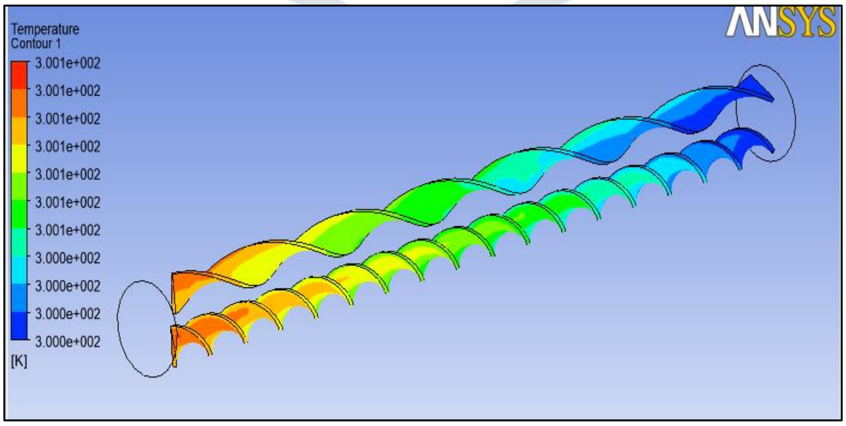

Fig. 9 Temperature contour for Y_0/Y 2

The temperature plot shown in figure 9 above shows temperature variation for geometric configuration of Y_0/Y 2. The temperature at inlet is lower and temperature at outlet is higher for twisted tapes.

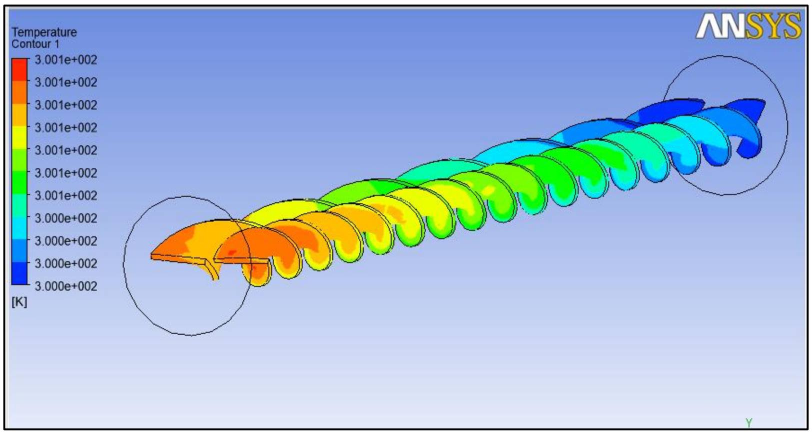

Fig. 10 Temperature contour for Y_0/Y 2.5

The temperature plot shown in figure 10 above shows temperature variation for geometric configuration of Y_0/Y 2.5. The temperature at inlet is lower and temperature at outlet is higher for twisted tapes.

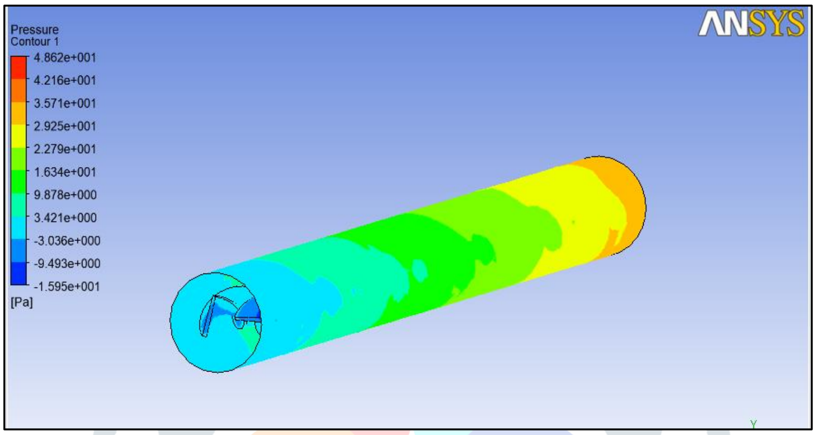

Fig. 11 Pressure contour for Y_0/Y 1.5

The pressure plot of heat exchanger for geometric configuration Y_0/Y 1.5 is shown in figure 11 above. The maximum pressure is at inlet portion with value of 48.12Pa and reduces on moving towards outlet.

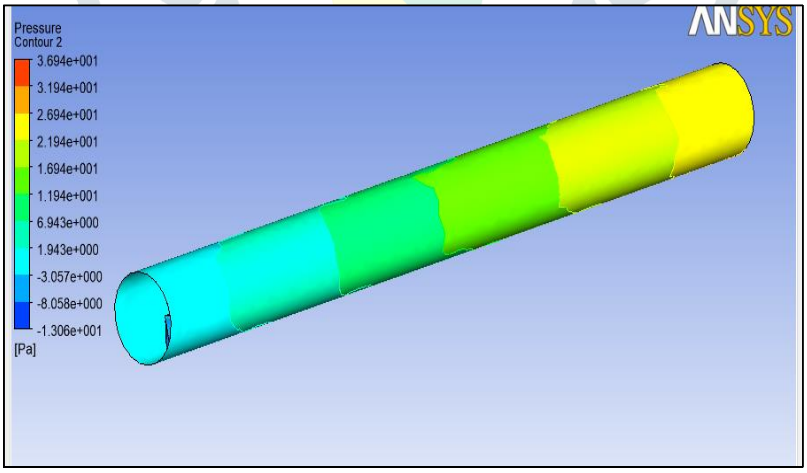

Fig. 12 Pressure contour for Y_0/Y 2

The pressure plot of heat exchanger for geometric configuration Y_0/Y 2 is shown in figure 12 above. The maximum pressure is at inlet portion with value of 36.84Pa and reduces on moving towards outlet. Similarly, pressure plot for geometric configuration Y_0/Y 2.5 is shown below shows maximum pressure at inlet and on moving towards outlet pressure decreases as shown in figure 13 below.

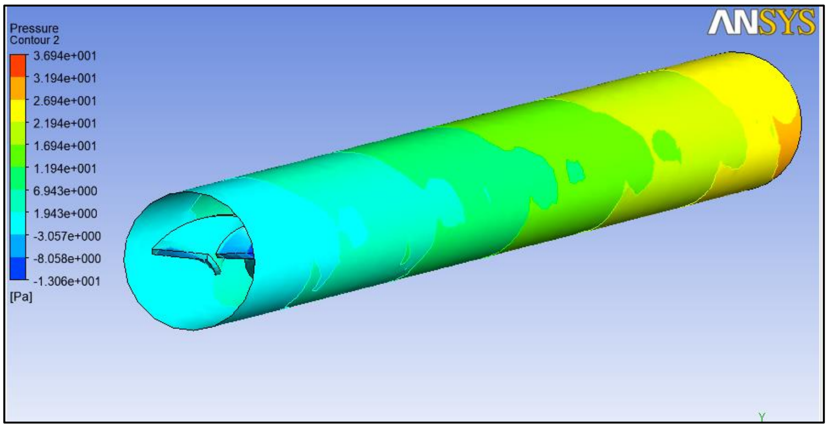

Fig. 13 Pressure contour for Y_0/Y 2.5

Nusselt number calculation for Yo/Y 1.5 at 6798 Reynolds number

Nu = h D/k

Where h is calculated from CFD software i.e. 1357.4 W/m^2 K

D is hydraulic diameter i.e. 19mm

K is thermal conductivity if fluid i.e. .606 W/mK

For Reynolds number 6798

Nu = 1357.4 * .019/.606 = 42.51

Nusselt number calculation for Yo/Y 2 at 6798 Reynolds number

Nu = h D/k

Where h is calculated from CFD software i.e. 1300.02 W/m^2 K

D is hydraulic diameter i.e. 19mm

K is thermal conductivity if fluid i.e. .606 W/mK

For Reynolds number 6798

Nu = 1300.02 * .019/.606 = 40.71

Nusselt number calculation for Yo/Y 2.5 at 6798 Reynolds number

Nu = h D/k

Where h is calculated from CFD software i.e. 1300.02 W/m^2 K

D is hydraulic diameter i.e. 19mm

K is thermal conductivity if fluid i.e. .606 W/mK

For Reynolds number 6798

Nu = 1035.62 * .019/.606 = 32.42

Table 1: Nusselt number comparison using water as fluid

Reynolds Number	Nusselt number Yo/Y 1.5	Nusselt number Yo/Y 2	Nusselt number Yo/Y 2.5
6798	42.51	40.71	32.42
8175	49.59	49.62	38.29
9554	56.87	58.98	44.25
10935	64.53	68.54	50.36
12316	73.54	78.24	56.58
14620	89.08	94.47	67.15

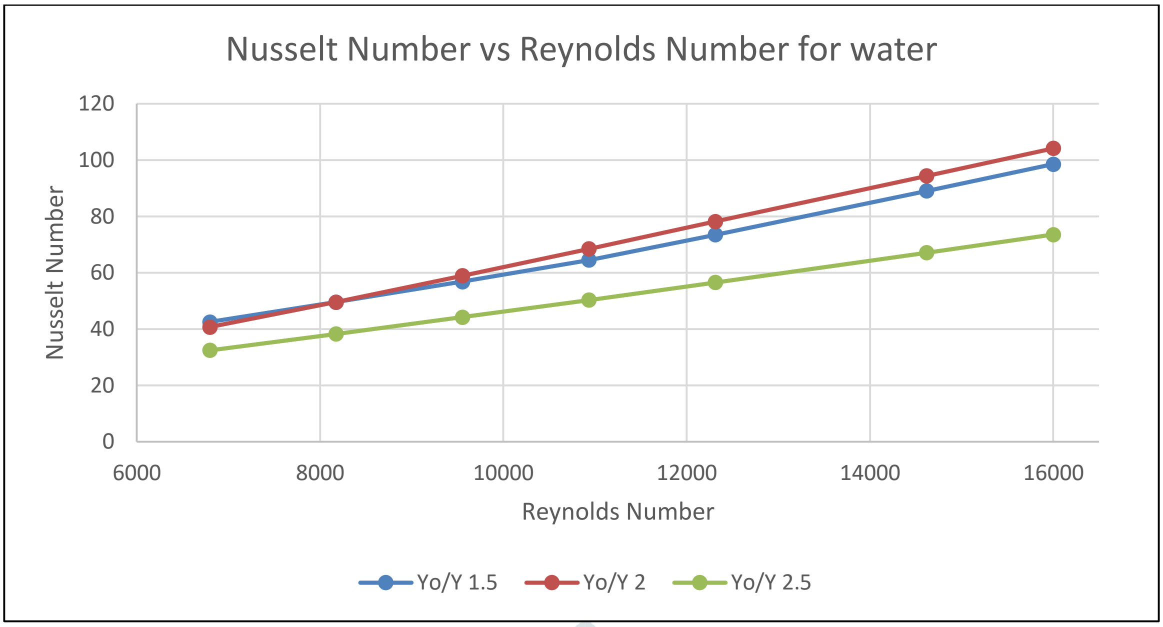

Fig. 14 Nusselt number comparison for Y_0/Y 1.5, Y_0/Y 2, Y_0/Y 2.5 using water

As can be seen from graph above the Nusselt number increases with increase in Reynolds number for the geometric ratios of Y_0/Y, the Nusselt number is higher for Y_0/Y 2 as compared to Y_0/Y 1.5 and Y_0/Y 2.5 which means that while using water as fluid the twisted tapes with Y_0/Y 2 shows better heat transfer coefficient and higher Nusselt number. Similar analysis are conducted using nano fluids Al_2O_3/water and CuO/water nano fluids to determine Nusselt number and friction factor for three design configurations i.e. Y_0/Y 2 , Y_0/Y 1.5 and Y_0/Y 2.5.

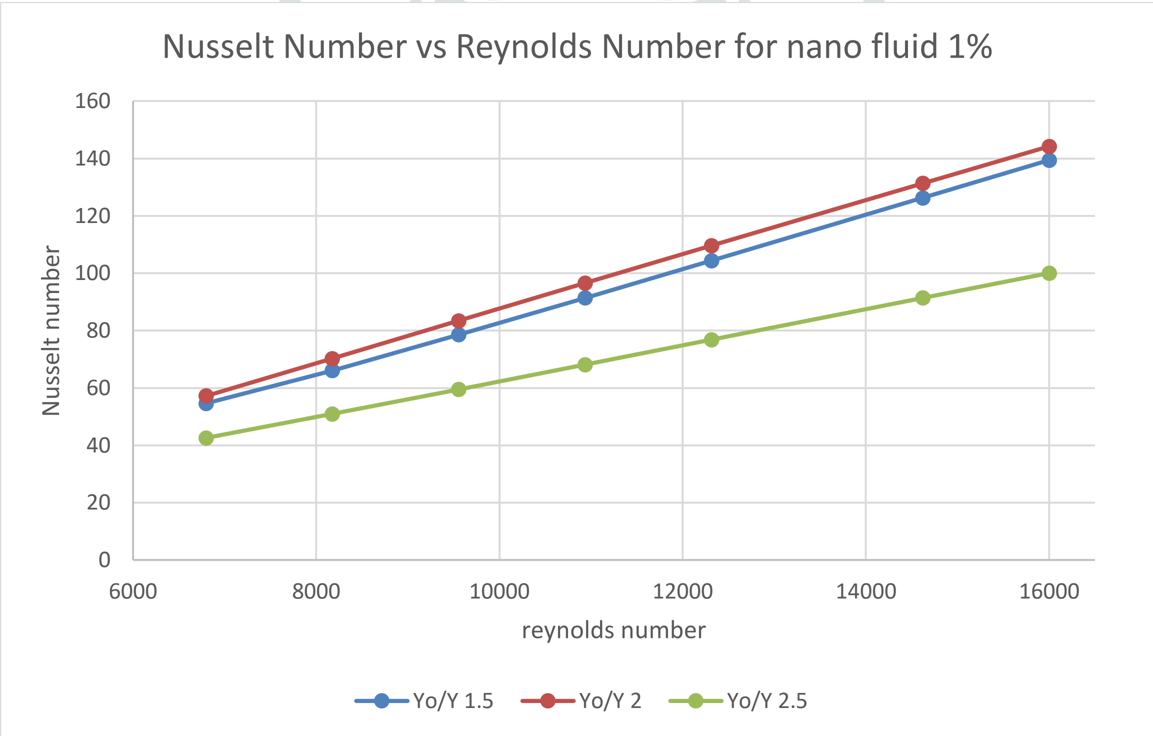

Fig. 15 Nusselt number comparison for Y_0/Y 1.5, Y_0/Y 2, Y_0/Y 2.5 using using Al_2O_3(1%)- water nano fluid

As can be seen from figure 15 above the Nusselt number increases with increase in Reynolds number for the geometric ratios of Y_0/Y, the Nusselt number is higher for Y_0/Y 2 as compared to Y_0/Y 1.5 and Y_0/Y 2.5 which means that while using water as fluid the twisted tapes with Y_0/Y 2 shows better heat transfer coefficient and higher Nusselt number.

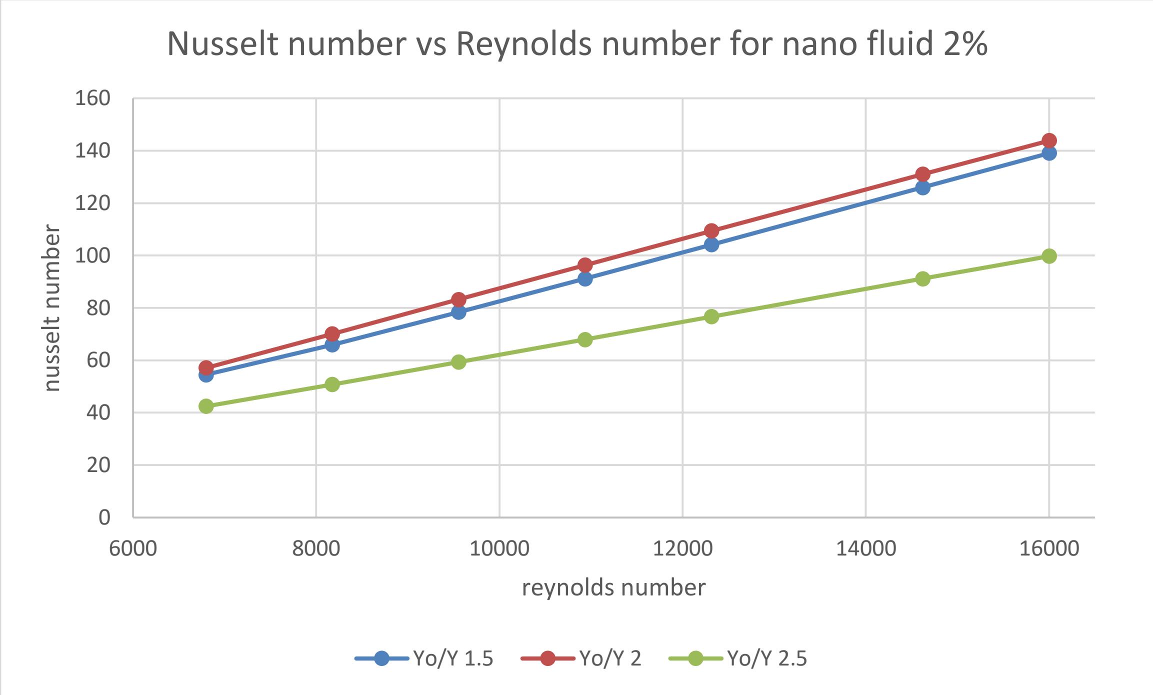

Fig. 17 Nusselt number comparison for Y_0/Y 1.5, Y_0/Y 2, Y_0/Y 2.5 using using Al_2O_3(2%)- water nano fluid

As can be seen from figure 17 above the Nusselt number increases with increase in Reynolds number for the geometric ratios of Y_0/Y, the Nusselt number is higher for Y_0/Y 2 as compared to Y_0/Y 1.5 and Y_0/Y 2.5 which means that while using water as fluid the twisted tapes with Y_0/Y 2 shows better heat transfer coefficient and higher Nusselt number.

VI. CONCLUSION

The CFD analysis is conducted on heat exchanger tube with twisted tapes for 3 different design configurations i.e. Y_0/Y 2 , Y_0/Y 1.5 and Y_0/Y 2.5. RNG k-epsilon turbulence model gave reasonable fluid flow predictions for the complex geometry involving twisted tapes. The findings have shown that an increase of 13.26 % of heat transfer is found with 1% nano fluid compared to base fluid concentration at lower Reynolds number. An increase of 14.03 % of heat transfer is found with 2% nano fluid compared to base fluid concentration at lower Reynolds number. An increase of 19.68 % of heat transfer is found with 3% nano fluid compared to base fluid concentration at lower Reynolds number. Nusselt number increases with increase in Reynolds number for the geometric ratios of Y_0/Y, the Nusselt number is higher for Y_0/Y 2 as compared to Y_0/Y 1.5 and Y_0/Y 2.5 which means that while using water as fluid the twisted tapes with Y_0/Y 2 shows better heat transfer coefficient and higher Nusselt number.

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