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IJIEMR Transactions, online available on 19 May 2017. Link :
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Volume o6, Issue 03, Pages: 126 - 146.

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HEAT TRANSFER ENHANCEMENT OF NANO FLUIDS IN A CONCENTRIC TUBE HEAT EXCAHNGER WITH INSERTS

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Abstract

The present work includes the results of CFD analysis of enhancement of turbulent flow heat transfer in a horizontal concentric circular tube with different inserts (Cylinder, rectangular and trapezoidal), with nanofluids (Al_2O_3, SIO_2, CUO) as working fluid. Working fluid (nano fluid) flows through the inner tube with boundary conditions -inlet velocity=0.9942m/s and inlet temperature=348k and auxiliary fluid (water) flows through the outer tube with boundary conditions – inlet velocity=1.8842 m/s and inlet temperature=283k The Reynolds number ranged from 6000 to 14000. Geometry of tube having inner diameter 0.27 m and length of the tube is 0.6100 m. The horizontal concentric tube in the presence of different inserts: Geometry description of cylinder: pitch=0.050m, core rod diameter =0.002m, diameter of cylinder =0.020m, thickness of cylinder=0.003m.Geometry description of trapezoidal: pitch=50mm, core rod diameter =0.002m, bottom length=0.020m, top length=0.010m, height=0.010m.Geometry description of Rectangle : pitch=0.05mm, core rod diameter =0.002m, breath=0.010m, length =0.017m, thickness of rectangle =0.002m).In this study, an attempt has been made to analyze the effect of parallel-flow on the total heat transfer from a concentric tube heat exchanger. The temperature contours, velocity vectors, surface nusselt number, total heat transfer rate from the wall of the tube was calculated and plotted using ANSYS 15.0. Copper was chosen as the metal for the construction of concentric tube heat exchanger. Finally we compared results by using tool of package of ANSYS-15.0 version 15.0 versions to compare the construction, performance, and economics of tube inserts with plain concentric tube heat exchanger. Geometries for plain tube and tube with different inserts is developed by using CRIO (3d-dimensional) with and exported to ANSYS-15.0 version15.0 version, then suitable boundary conditions are applied to these models and solved energy momentum and turbulence equations and results obtained are discussed.

Key Words: Different inserts (Cylinder, diamond and trapezoidal), turbulent flow, pressure drop, augmentation. ANSYS-FLUENT 15.0.

1. INTRODUCTION

1.1 INTRODUCTION

Heat exchange between flowing fluids is one of the most important physical process of concern, and a variety of heat exchangers are used in different type of installations, as in process industries, compact heat exchangers nuclear power plant, HVACs, food processing, refrigeration, etc. The purpose of constructing a heat exchanger is to get an efficient method of heat transfer from one fluid to another, by direct contact or by indirect contact. The heat transfer occurs by three principles: conduction, convection and radiation. In a heat exchanger the heat transfer through radiation is not taken into account as it is negligible in comparison to conduction and convection. Conduction takes place when the heat from the high temperature fluid flows through the surrounding solid wall. The conductive heat transfer can be maximized by selecting a minimum thickness of wall of a highly conductive material. But convection is plays the major role in the performance of a heat exchanger. Forced convection in a heat exchanger transfers the heat from one moving stream to another stream through the wall of the pipe. The cooler fluid removes heat from the hotter fluid as it flows along or across it. Heat exchanger is a device used for the process of heat exchange between the two fluids that are at different temperatures. The heat exchange process in heat exchangers can be described by the principles of evaporation or condensation, conduction, radiation and convection. Heat exchangers are useful in many engineering processes like those in air conditioning systems and refrigeration, food processing systems, chemical reactions, and power systems.

2. DESCRIPTION

2.1 CAD DESIGN TOOL (CREO)

Creo is a family or suite of design software supporting product design for discrete manufacturers and is developed by PTC. PTC Creo is a scalable, interoperable suite of product design software that delivers fast time to value. It helps teams create, analyze, view

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and leverage product designs downstream utilizing 2D CAD, 3D CAD, parametric & direct modeling. PTC Creo Parametric provides the broadest range of powerful yet flexible 3D CAD capabilities to accelerate the product development process. By automating tasks such as creating engineering drawings, we are able to avoid errors and save significant time. The software also lets us perform analysis, create renderings and animations, and optimize productivity across a full range of other mechanical design tasks, including a check for how well our design conforms to best practices. PTC Creo Parametric enables us to design higher-quality products faster and allows us to communicate more efficiently with manufacturing, suppliers.

3D Model of Concentric Tube Heatexchanger with dierent Inserts:

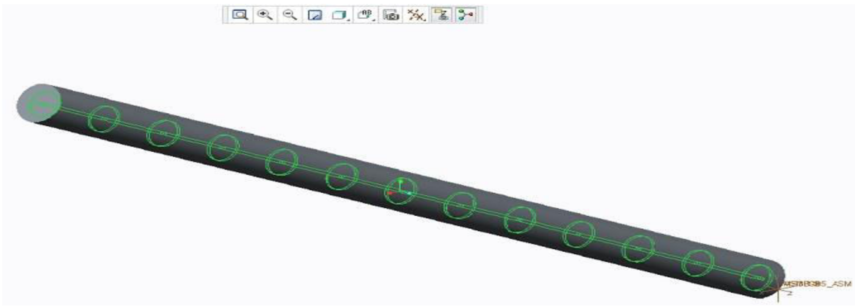

Fig1: Concentric tube heat-exchanger with circular inserts.

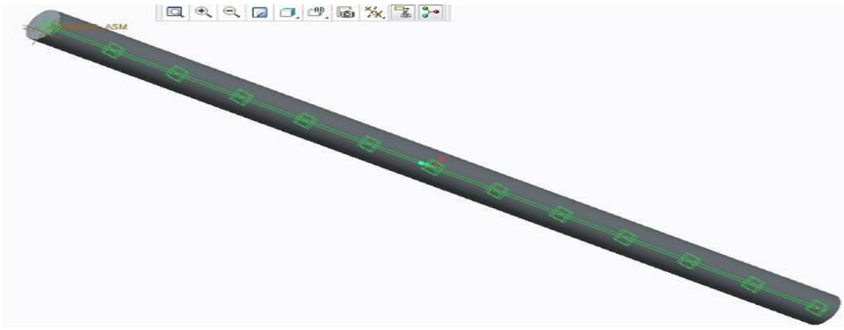

Fig2: Concentric tube heat-exchanger with rectangular inserts.

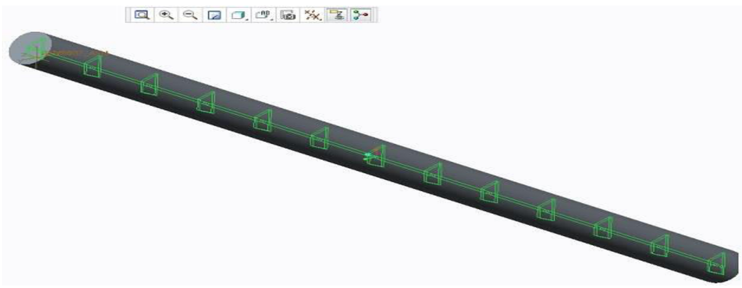

Fig3: Concentric tube heat-exchanger with trapezoidal inserts.

2.2 CFD ANALYSIS

For all engineers and students coming to finite element analysis or to ANSYS software for the first time, this powerful hands-on guide develops a detailed and confident understanding of using ANSYS's powerful engineering analysis tools. The best way to learn complex systems is by means of hands-on experience.

Computational fluid dynamics (CFD) study of the system starts with the construction of desired geometry and mesh for modeling the dominion. Generally, geometry is simplified for the CFD studies. Meshing is the discretization of the domain into small volumes where the equations are solved by the help of iterative methods. Modeling starts with the describing of the boundary and initial conditions for the dominion and leads to modeling of the entire system. Finally, it is followed by the analysis of the results, discussions and conclusions.

2.2..1 Geometry:

Concentric tube Heat exchanger with different inserts is built in the Creo design module. It is a parallel-flow heat exchanger. First, the fluid flow (fluent) module from the workbench is selected. The design modeler opens as a new window as the geometry is double clicked. Click on import file and browse the respective file and say ok.

Table 1 Naming of various parts of the body with state type

Part number	Part Of The Model	State Type
1	inner _ fluid	Fluid
2	inner _ pipe	Solid
3	outer _ fluid	Fluid
4	outer _ pipe	Solid
5	fins	Solid

2.2.2 Mesh:

Initially a relatively coarser mesh is generated. This mesh contains mixed cells (Tetra and Hexahedral cells) having both triangular and quadrilateral faces at the boundaries. Care is taken to use structured hexahedral cells as much as possible. It is meant to reduce numerical diffusion as much as possible by structuring the mesh in a well manner, particularly near the wall region. Later on, a fine mesh is generated. For

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this fine mesh, the edges and regions of high temperature and pressure gradients are finely meshed.

	Concentric tube with circular inserts	Concentric tube with rectangular inserts	Concentric tube with trapezoidal inserts
Relevance centre	Fine Meshing	Fine Meshing	Fine Meshing
Smoothing	Medium	Medium	Medium
Size of the element	8.9266e-02 mm to 17.8530 mm	8.9266e-02 mm to 17.8530 mm	8.9266e-02 mm to 17.8530 mm
Pinch tolerance	8.034e-002mm	8.034e-002mm	8.034e-002mm
No. of Nodes	120656	118749	118398
No. of Elements	498873	493962	491602

Table: Details of "Mesh Parameters"

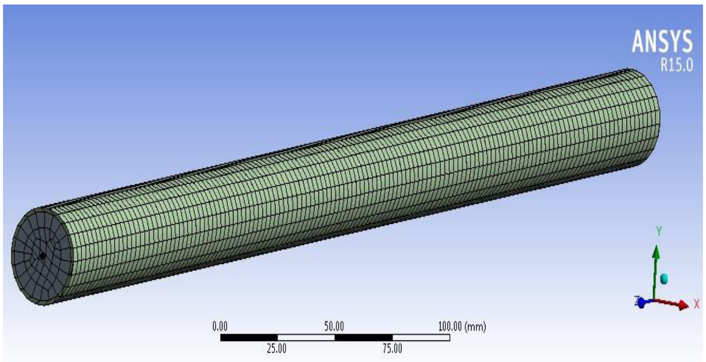

Figure 4 Mesh

2.2.3 Named Selection

The different surfaces of the solid are named as per required inlets and outlets for inner and outer fluids. The outer wall is named as insulation surface.

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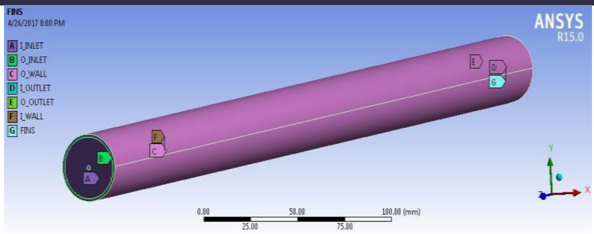

Fig5 : Named Selections of concentric tube heat exchanger

Save project again at this point and close the window. Refresh and update project on the workbench. Now open the setup. The ANSYS Fluent Launcher will open in a window. Set dimension as 3D, option as Double Precision, processing as Serial type and hit OK. The Fluent window will open.

2.3 Solution:

2.3.1 Problem Setup

In solution setup under general settings the mesh is checked by selecting the same dimensional units assigned to model and quality is obtained. The solver type is changed to Pressure Based type, the velocity formulation is changed to absolute and time is changed from transient state to steady state. Gravity is defined as y = -9.81 m/s^2

2.3.6 Reference Values

The inner inlet is selected from the drop down list of "compute from".

The values are:

I. Area = 1 m^2
II. Density = 998.2 kg/m^3
III. Length = 39.37008 inch
IV. Temperature = 348 K
V. Velocity = 0.9942 m/s
VI. Viscosity = 0.001003 kg/m-s
VII. Ratio of specific heats = 1.4

Solution Methods

The solution methods are specified as follows:

Pressure-Velocity Coupling Scheme = Simple

Spatial Discretization:

I. Gradient = Green Gauss Cell Based.
II. Pressure = Second Order.
III. Momentum = Second Order Upwind.
IV. Turbulent Kinetic Energy = Second Order Upwind.
V. Turbulent Dissipation Rate = Second Order Upwind.

Solution Control and Initialization

Under relaxation factors the parameters are:

I. Pressure = 0.3 Pascal.
II. Density = 1 kg/m^3.
III. Body forces = 1 kg/m^2s^2.
IV. Momentum = 0.7 kg-m/s.
V. Turbulent kinetic energy = 0.8 m^2/s^2.

Then the solution initialization method is set to Standard Initialization whereas the reference frame is set to Relative cell zone. The inner inlet is selected from the compute from drop down list and the solution is initialized.

3. RESULT

Each case was run using higher order residual schemes for each governing equations. It was ensured that residuals dropped to at least 10^{-6} for each case. Nusselt number and friction factor calculated for the plain tube and plain tube with different insert for 6000<Re<14000.

Table: The net mass flow rate and total heat transfer rate for different configurations with different nano fluids.

	Heat exchanger with circular inserts			Heat exchanger with Rectangular inserts			Heat exchanger with Trapezoidal inserts		
	Al_2O_3 & Water	CUO & Water	SIO_2 & Water	Al_2O_3 & Water	CUO & Water	SIO_2 & Water	Al_2O_3 & Water	CUO & Water	SIO_2 & Water

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Pressure (Pa)	2.12e+03	3.65e+03	2.06e+03	2.25e+03	3.69e+03	2.06e+03	2.25e+03	3.68e+03	2..06e+03
Temperature(K)	3.48e+02	3.48e+02	3.49e+02	3.78e+02	3.49e+02	3.64e+02	3.48e+02	3.48e+02	3.48e+02
Enthalpy	1.21e+05	1.20e+05	4.88e+04	1.17e+05	1.21e+05	5.08e+04	1.24e+05	1..24e+05	4.81e+04
Entropy	1.15e-04	5.27e+02	3.03e+02	5.17e+02	5.31e+02	3.09e+02	5.39e+02	5.38e+02	3.01e+02
Friction Coefficient	7.63e-03	2.22e+01	2.22e+01	2.19e+01	2.19e+01	2.19e+01	2.23e+01	2.22e+01	2.22e+01
Wall Shear Stress	1.36e+01	1.36e+01	1.36e+01	1.34e+01	1.34e+01	1.34e+01	1.37e+01	1.36e+01	1.36e+01
Prandtl Number (Pr)	1.30	1.31	1.28	1.09	1.11	1.07	1.20	1.19	1.13
Reynolds Number (Re	4.18e+13	8.72e+13	3.22e+13	5.00e+13	8.74e+13	3.23e+13	4.99e+13	8.69e+13	3.23e+13

The results for these cases are shown below.

3.1 Contours

The temperature, pressure and velocity distribution along the concentric tube heat exchanger with different inserts can be seen through the contours.

Concentric tube heat exchanger with circular inserts by using nano fluid (Al_2O_3)

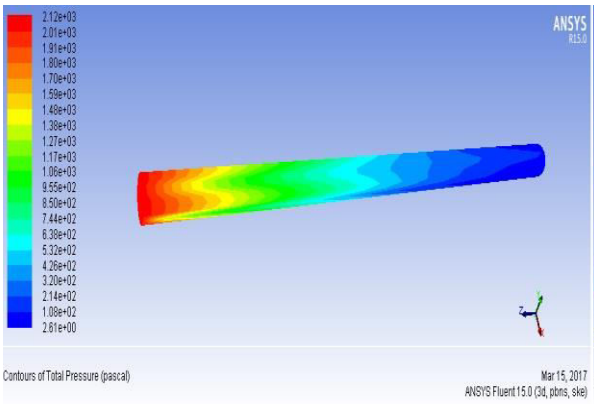


Fig6: Contour of Total Pressure

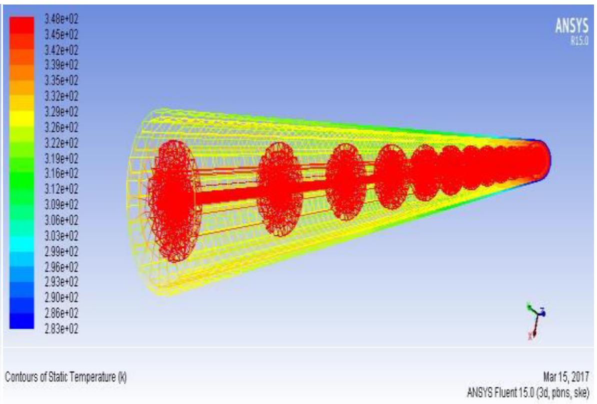


Fig7: Contour of Static Temperature

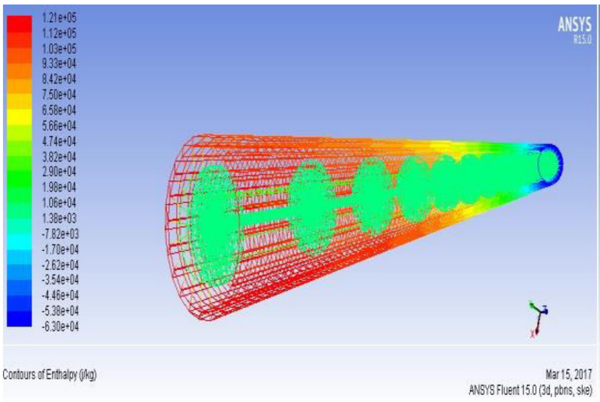


Fig8: Contour of Enthalpy

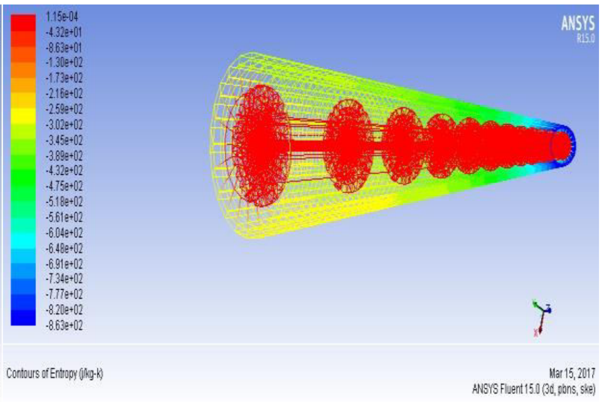


Fig 9: Contour of Entropy

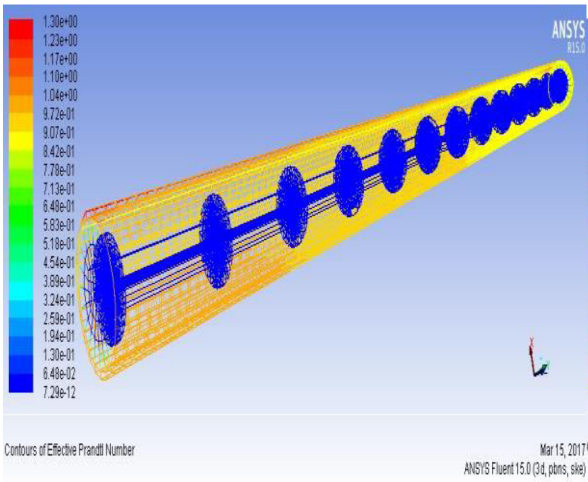


Fig 10: Contour of Prandtl Number

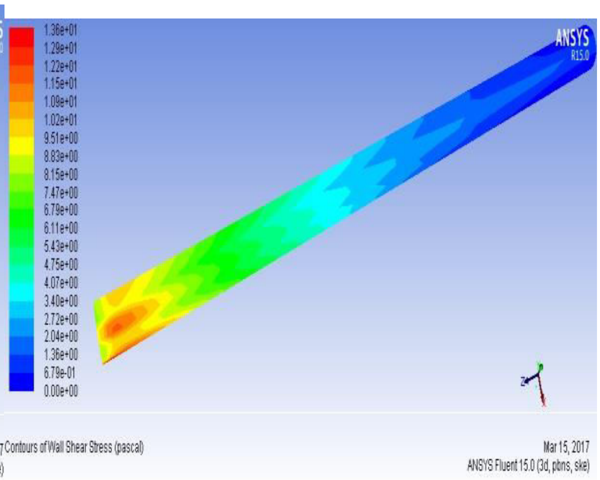
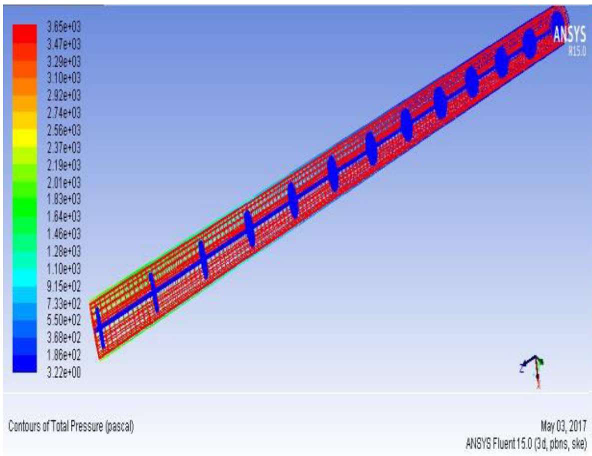


Fig 11: Contour of Wall Shear Stress



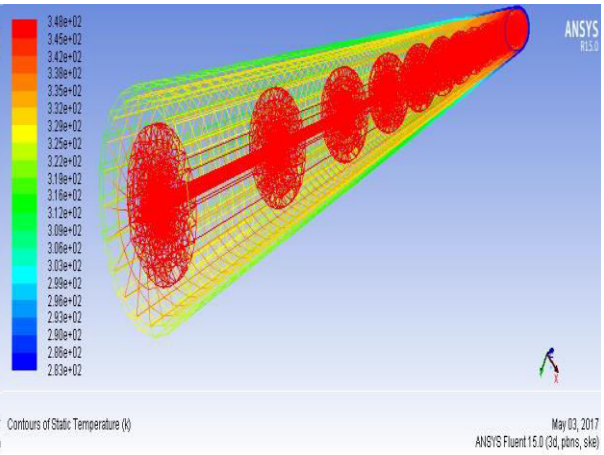
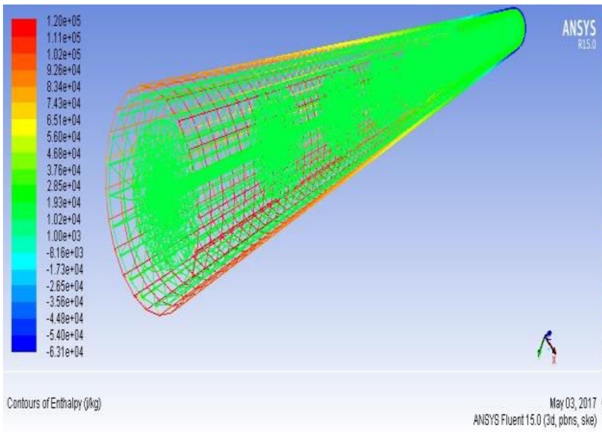


Fig 12: Contour of Total Pressure

Fig 13 : Contour of Static Temperature



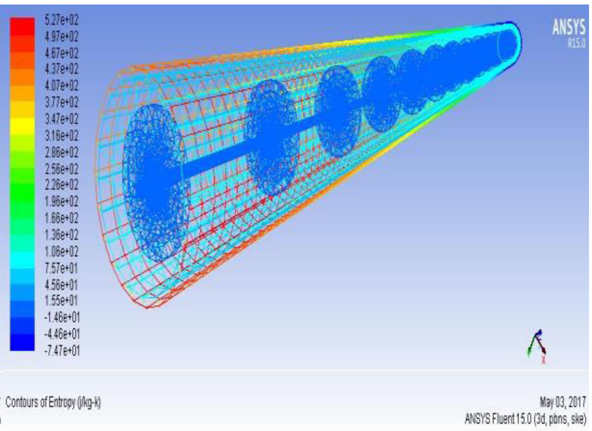
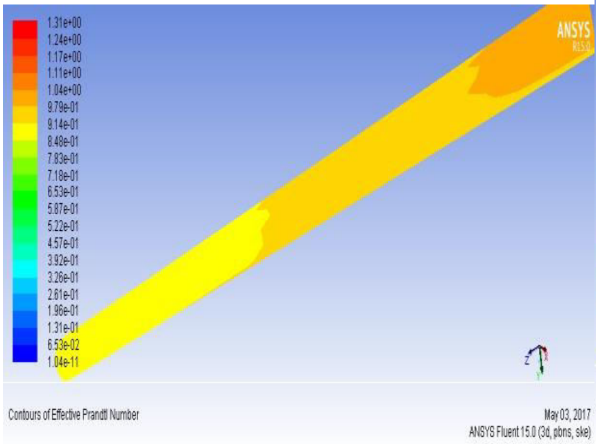


Fig 14: Contour of Enthalpy

Fig 15: Contour of Entropy



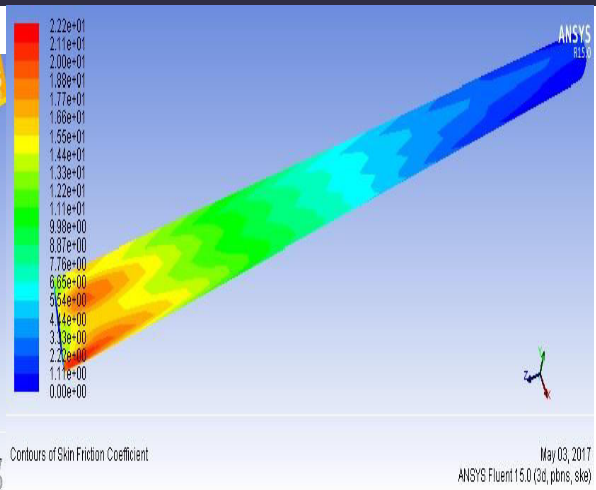
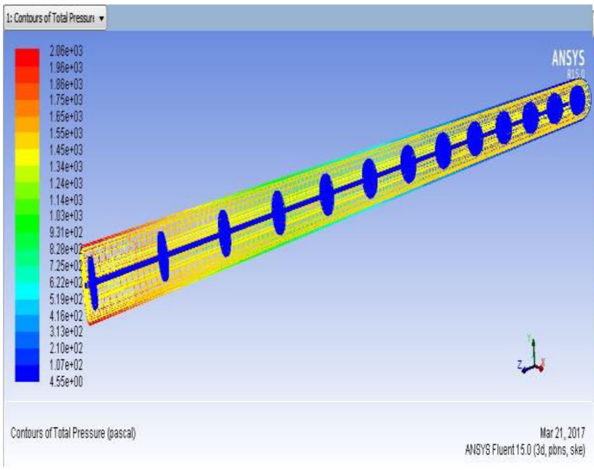


Fig 16: Contour of Prandtl Number

Fig 17: Contour of Wall Shear Stress

Concentric tube heat exchanger with circular inserts by using nano fluid (SIO_2)



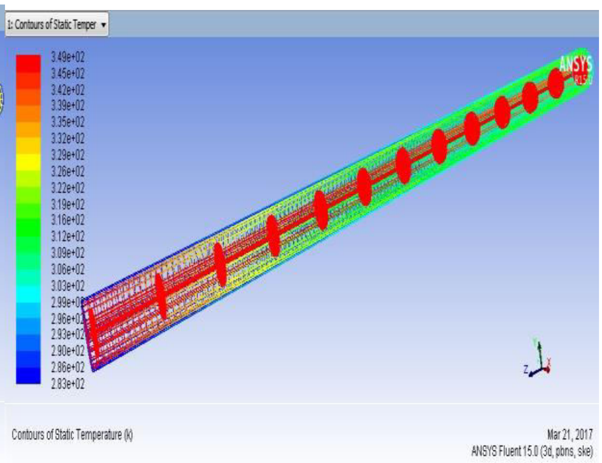
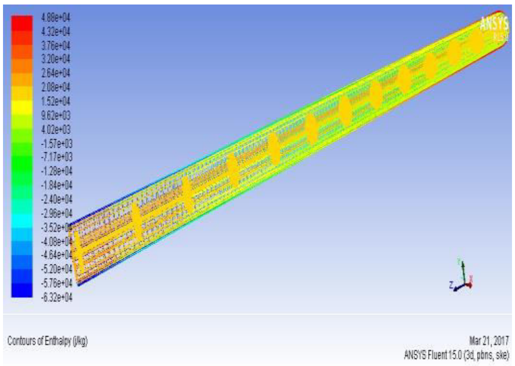


Fig 18 : Contour of Total Pressure

Fig 19: Contour of Static
Temperature



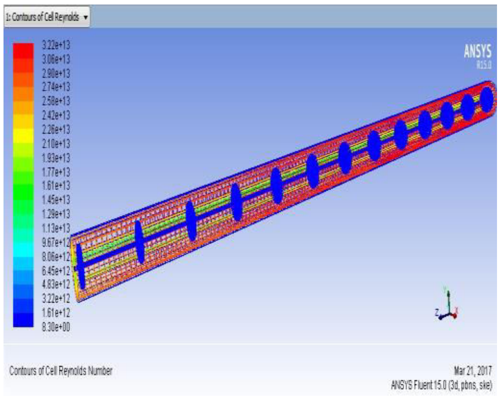


Fig 20 Contourof Enthalpy

F 21Contour of Cell Reynolds Number

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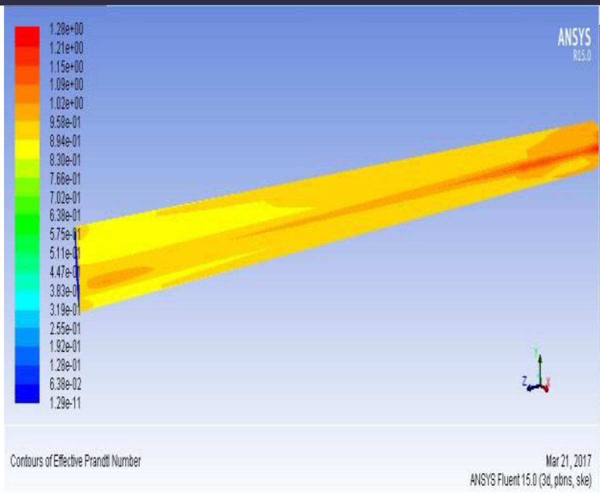


Fig 22: Contour of Prandtl Number

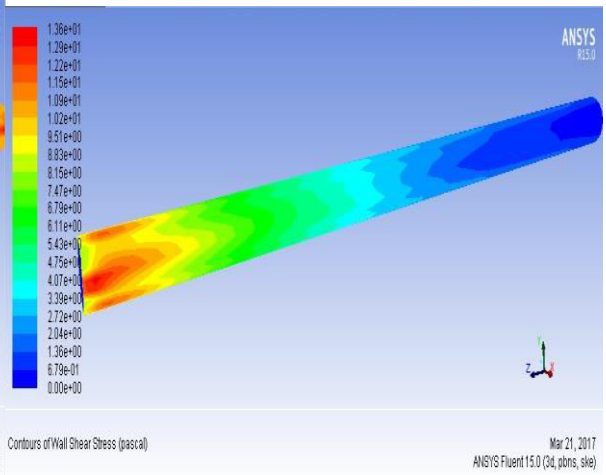


Fig 23: Contour of Wall Shear Stress

Concentric tube heat exchanger with rectangular inserts by using nano fluid (Al_2O_3)

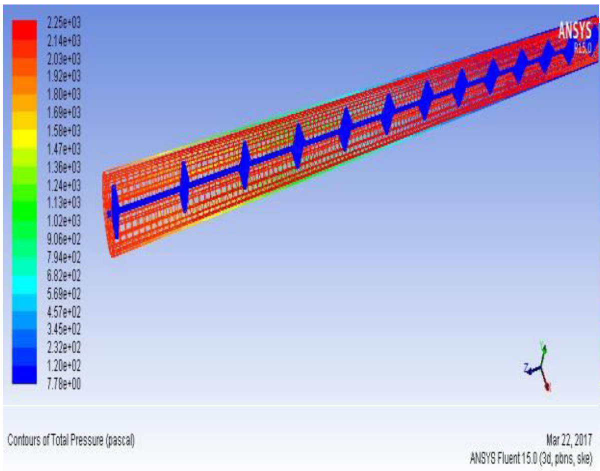


Fig 24 : Contour of Total Pressure

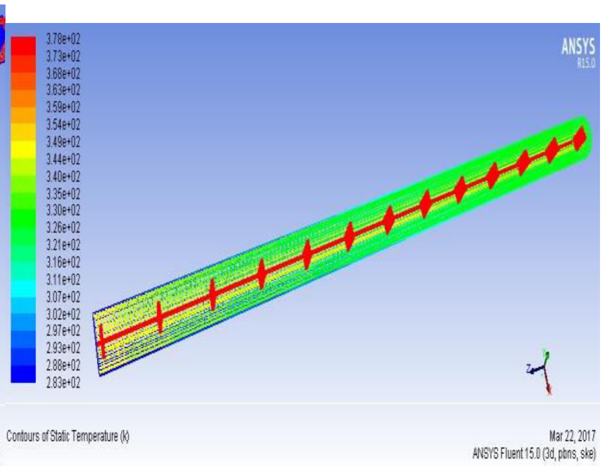
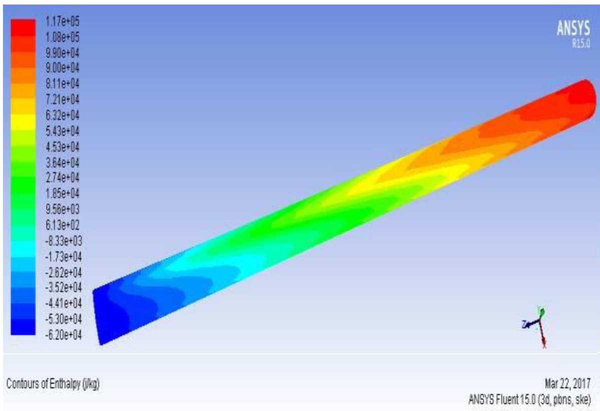


Fig 25 : Contour of Static Temperature



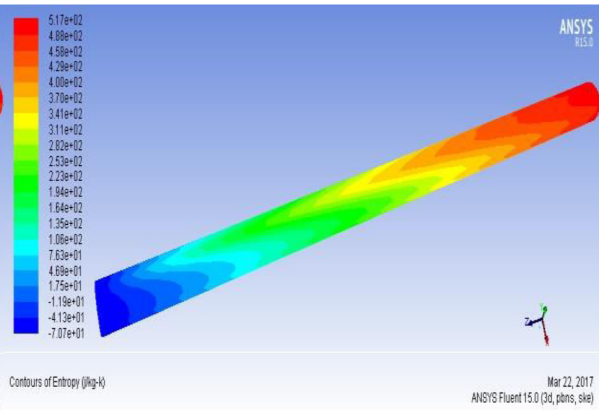


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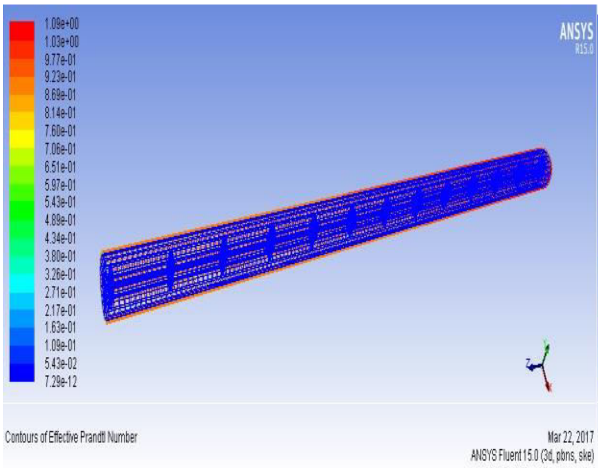
Fig 26 : Contour of Enthalpy

Fig 27: Contour of Entropy



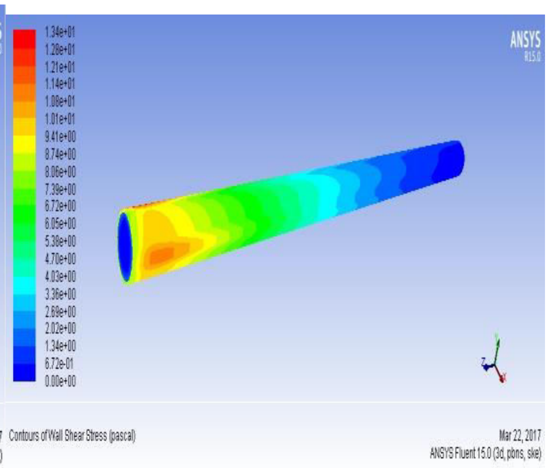
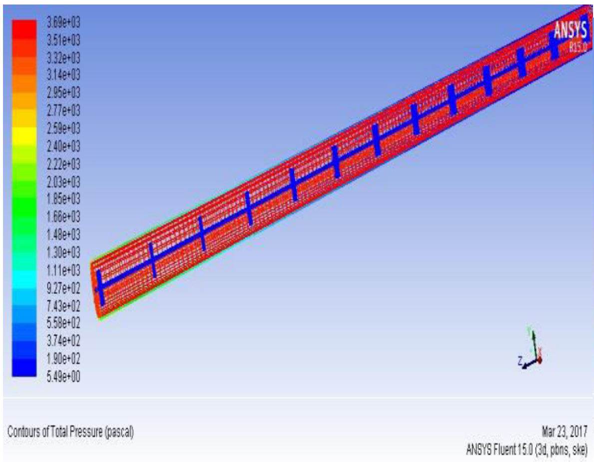


Fig 28: Contour of Prandtl Number

Fig 29: Contour of Wall Shear Stress

Concentric tube heat exchanger with rectangular inserts by using nano fluid (CUO)



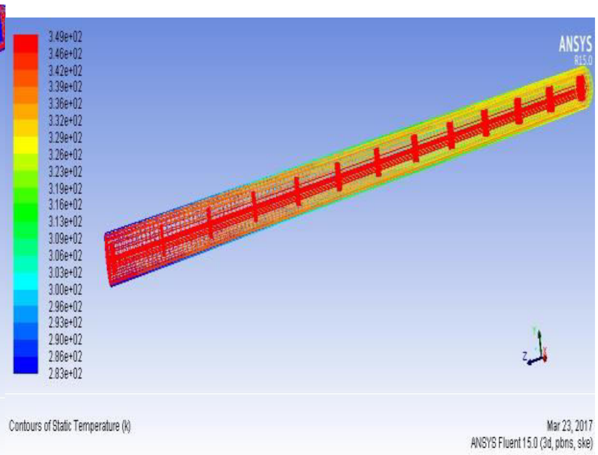
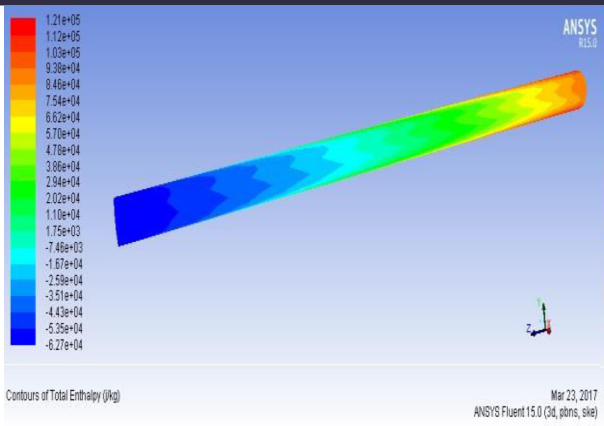


Fig 30: Contour of Total Pressure

Fig 31: Contour of Static Temperature



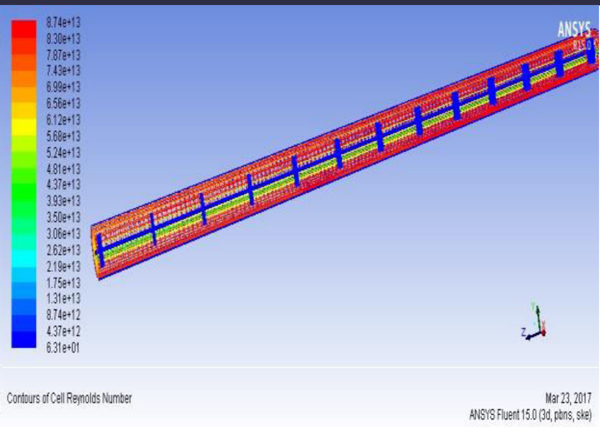


Fig 3`1: Contour of Enthalpy Fig 32: Contour of Cell Reynolds Number

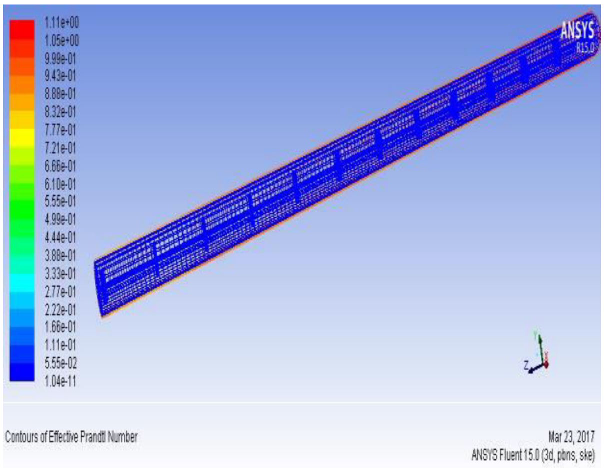
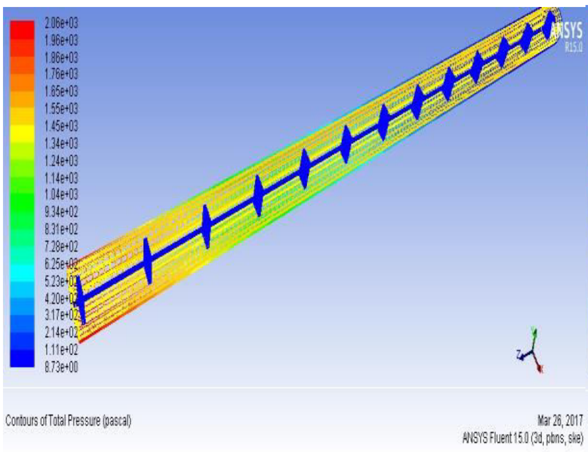


Fig 33: Contour of Prandtl Number

Concentric tube heat exchanger with rectangular inserts by using nano fluid (SIO_2)



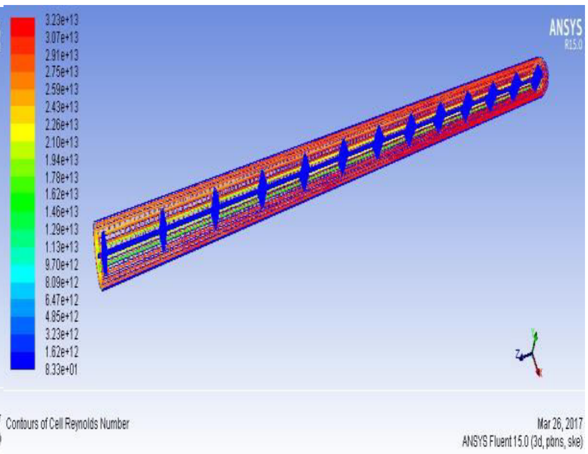


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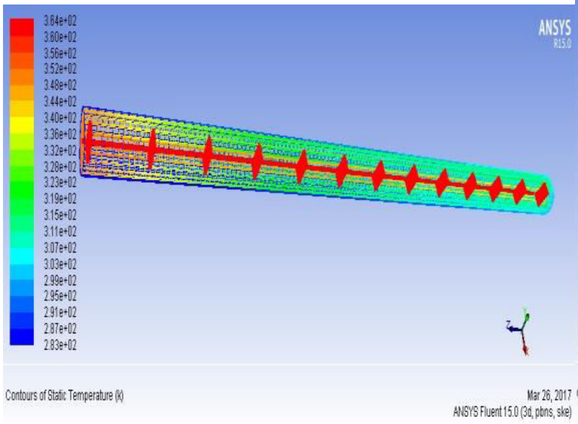
Fig 34 : Contour of Total Pressure

Fig 35: Contour of Reynolds Number



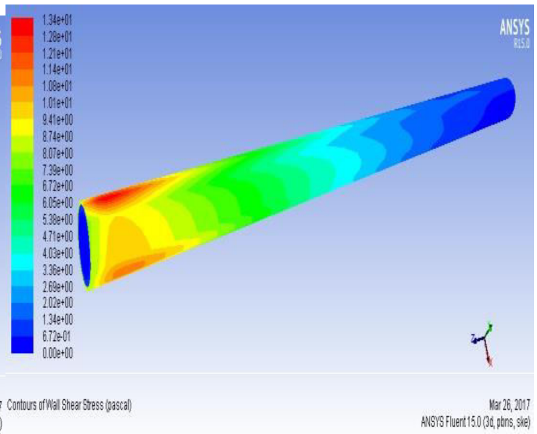
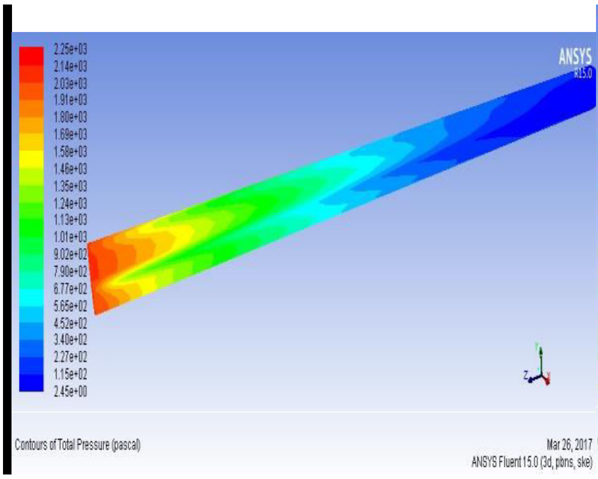


Fig 36: Contour o Static Temperature

Fig 37: Contour of Wall Shear Stress

Concentric tube heat exchanger with trapezoidal inserts by using nano fluid (Al_2O_3)



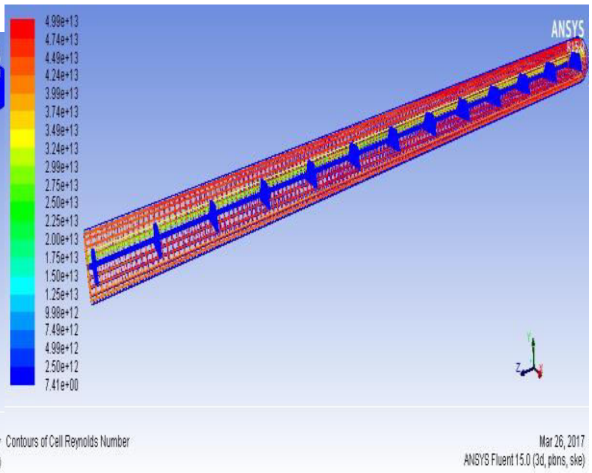


Fig 38: Contour of Total Pressure

Fig 39: Contour of Reynolds Number

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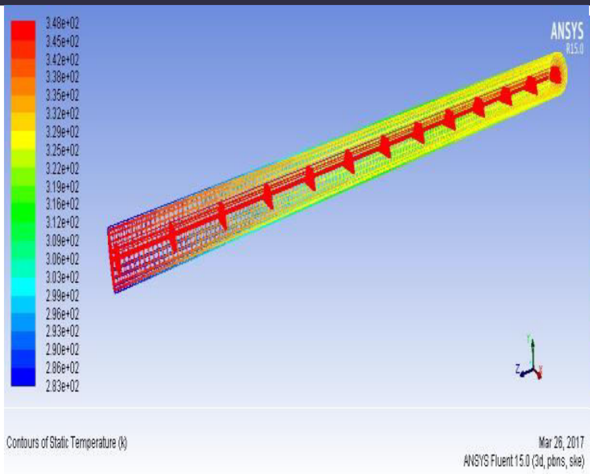

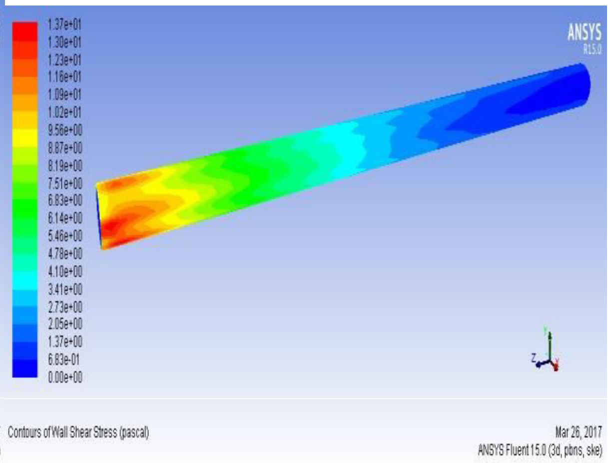

Fig 40: Contour of Static Temperature

Fig 41: Contour of Wall Shear Stress

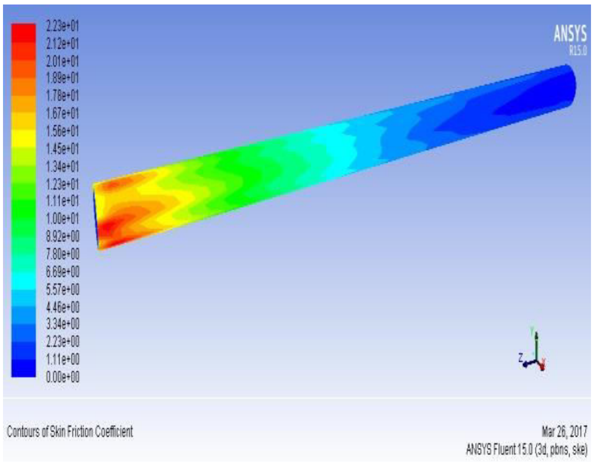

Fig 42: Contour of friction Coefficient

Concentric tube heat exchanger with trapezoidal inserts by using nano fluid (CUO)

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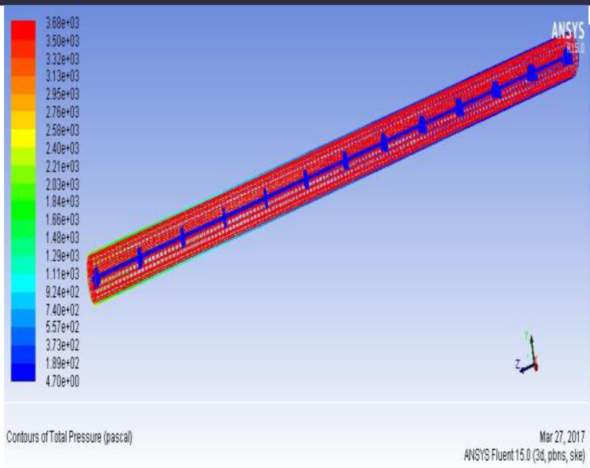


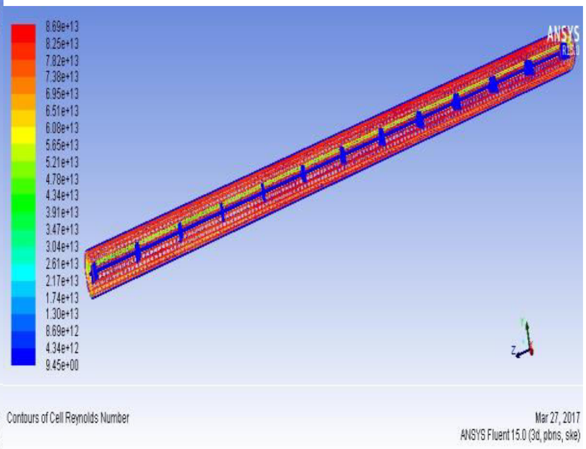
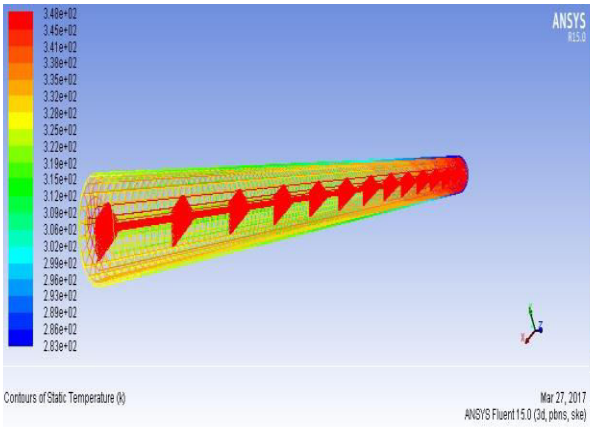


Fig 43: Contour of total Pressure

Fig 44: Contour of Reynolds Number



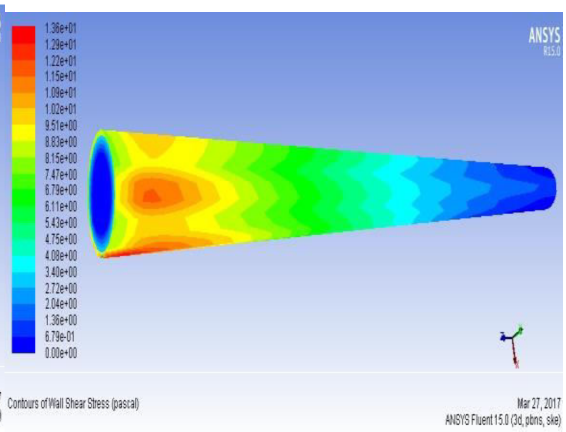
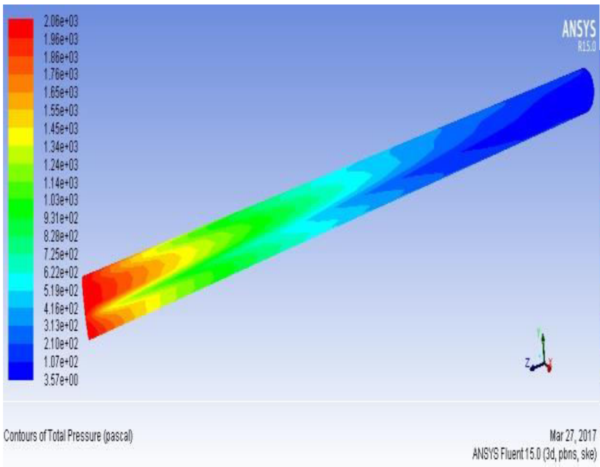


Fig 45: Contour of Static Temperature

Fig 46: Contours of Wall Shear

Concentric tube heat exchanger with trapezoidal inserts by using nano fluid (SIO_2)



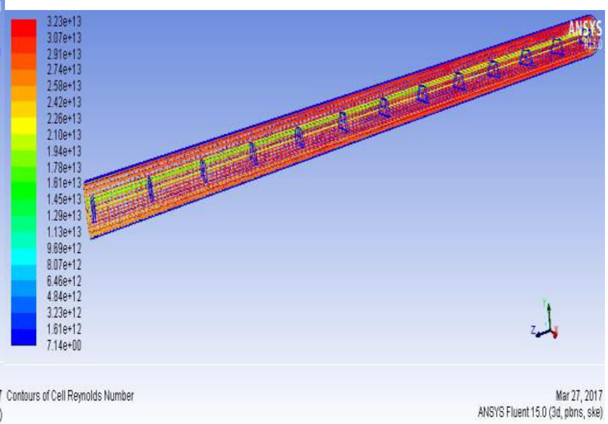


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Fig 47 : Contour of Total Pressure

Fig 48: Contour of Reynolds Number

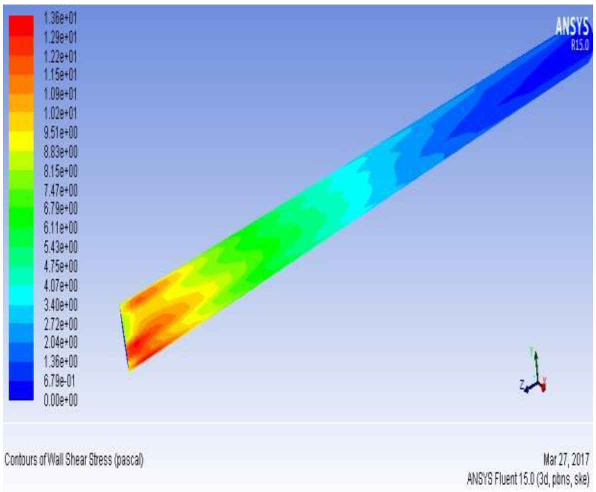

Fig 49: Contour of Wall Shear Stress

4. CONCLUSION

A CFD package (ANSYS FLUENT 15.0) was used for the numerical study of heat transfer characteristics of a concentric double pipe heat exchanger for parallel flow. The CFD results that are obtained from ANSYS-FLUENT 15.0 for different configurations of concentric tube heat exchanger with different inserts (circular, rectangular, trapezoidal) where compared within the error limits. The study showed that there is not much difference in the heat transfer performances for concentric tube heat exchanger with different inserts with parallel-flow configuration. The simulation was carried out for water to nano-fluids (Al_2O_3, CuO and SiO2) heat transfer characteristics and different inlet temperatures were studied. Net heat transfer rate and net mass flow rate is maximum for concentric tube heat exchanger with trapezoidal insert and CuO and water as primary and auxiliary fluids.

Characteristics of the fluid flow were also studied for the constant temperature and constant wall heat flux conditions. From the velocity vector plot it was found that the fluid particles were undergoing an oscillatory motion inside both the pipes.

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