INTERNATIONAL JOURNAL OF SCIENTIFIC RESEARCH IN ENGINEERING AND MANAGEMENT (IJSREM)
VOLUME: 07 ISSUE: 01 | JANUARY - 2023 IMPACT FACTOR: 7.185 ISSN: 2582-3930

CFD ANALYSIS OF TRIANGULAR, SQAURE AND CIRCULAR SHAPED HELICAL COIL HEAT EXCHANGER BY USING TITANIUM OXIDE NANOFLUID.

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ABSTRACT

Helical coils are eminent coiled tubes which have been used in diversity of solicitations e.g. heat recovery, air-conditioning and preservation schemes, chemical reactors and dairy practices. Helical coil heat exchanger is the recent improvement of heat exchangers, to accomplish the industrial demand. A Helical coil are necessary for various heat exchangers, nuclear reactors and in chemical engineering, for of large quantity of heat is conveying in a slight space with high heat transmission rates and slight habitation time distributions even it suffers through a disadvantage of larger pressure drop. For this, my proposed work on CFD to analyze the helical coil by using ANSYS 18.2. Generation of 3D CAD model of copper helical tube of different shapes keeping PCD 60 mm, pitch 25 and length of 500 mm by using SOLIDWORKS and exporting to the IGES format and then import in ANSYS fluent 18.2.

Keywords: Helical Coil, Nano-fluid, Heat Exchanger, CFD, Pressure Drop, Temperature Distribution.

INTRODUCTION

In the era of growing population of world, per capita income along with demand for fresh and processed food and drinks is increasing enormously resulting in critical need in effective process technologies to produce them. Right nowadays, half of the world‘s inhabitant‘s lives in a town or city and this can be expected to be 9 billion people on the planet by 2050. Processed nutrients and liquid refreshment from name-brand manufacturers, packed to suit the needs of customers, are in just as high request as fresh products – particularly among urban buyers. Heat exchange is a key element that points on these products‘ journey to the person who lastly consumes. Cooling is vital but not sufficient alone; in addition, loss of liquid and vitamins must be efficiently prevented. Heat exchangers form us set criteria with awe to energy efficiency, mid-air throw and effectiveness. These are crucial features for accessibilities, food distribution centres, storerooms, invention halls and hypermarkets require tremendous cooling duty. The heat exchangers can be upgraded to execute heat-transfer duty by transferring of heat and upsurge techniques as active and passive techniques. The active technique involves exterior forces, e.g. electric field and surface vibrations etc. The passive technique requires fluid flow behaviour and distinct apparent geometries. Curved tubes are used for transferring of heat improvement procedures, relatively a lot of heat transfer applications.

Helical coils are distinguished coiled tubes which have been used in multiplicity of solicitations e.g. heat recovery, air-conditioning and refrigeration schemes, chemical reactors and dairy practices. Helical coil heat exchanger is the modern improvement of heat exchangers, to fulfill the industrial demand. Pressure drop features are essential for calculating fluid effect to overwhelmed pressure drops and for arrangement of necessary mass flow rates. The pressure drops are also a function of the pipe curvature. The curvature creates secondary flow arrangement which is perpendicular to main axial stream path. This secondary flow has insignificant capability to increase heat transfer allocated to mixing of the fluid. The strength of secondary flow established in the tube. It is the value of tube diameter and coil diameter. The force which arises due to curvature of the tube and results in secondary flow advancement with increased rate of heat transfer is centrifugal force.

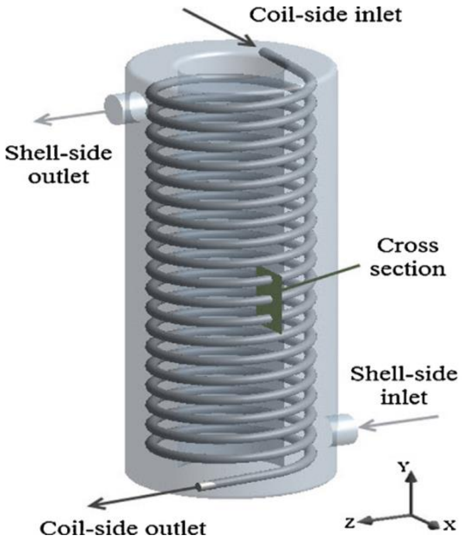

Figure 1 : Helical Coil Heat Exchanger

NANO FLUID

Now a day, it is seen that the liquid coolants which are used today, they have very poor thermal conductivity (with the omission of liquid metal, which cannot be used at most of the relevant useful temperature ranges). For example, water is evenly poor in heat conduction than copper, in the case with engine coolants, the oils, and organic coolants. The liquid having thermal conductivity and it will be limited by the natural restriction on creating turbulence or increasing area. To overcome this problem the suspension of solid in cooling liquid is a better option and a new fluid will be made which is used to increase the thermal conduction behaviour of cooling fluids.

Nanofluid are fluid particles which are a lesser amount even a μ (nearly 10-9 times smaller) in diameter and very reactive and effective material which can be used to rise factor like rate of reaction, thermal conductivity of some metal or material are that much reactive and offered four possible methods in nano fluids which may contribute to thermal conduction.

a) Brownian motion of nano particles.
b) Liquid layering at the liquid/particle edge.
c) Ballistic nature of heat transport in nano particles.
d) Nano particle clustering in nano fluids.

The Brownian motion of nano particles is too slow to transfer heat over a nano fluid. This mechanism works well only when the particle collecting has both the positive and negative effects of thermal conductivity which is gained indirectly through convection.

LITERATURE REVIEW

Helical coil is very compact in structure and it possess high heat transfer coefficient that why helical coils heat exchangers are widely used. In literature it has been informed that heat transfer rate of helical coil is larger than straight tube.

Hamid Abdi et. al. [1] The main goal of this work is heat transfer in slow incompressible flows by nanoparticles in tubes of different shapes. Water volume fraction error - Al2O3 nanofluid passes through spiral, spiral and circular straight tubes, triangular, square and rectangular sections of different Re. When the nanoparticles are added to the water and the liquid length is reached, the temperature drops to the wall temperature and at VF = 7%**.** This is the minimum length. The addition of nanoparticles to the base fluid of all shapes and sizes increases the pressure drop. Again, for a constant volume fraction, the spiral geometry has the largest pressure drop to the minimum straight pipe pressure. As Re release increases, the pressure drop generally increases across the item for all spiral, spiral, and straight geometries. Round pipes have a corresponding maximum and minimum pressure drop

K. Abdulhamid et. al. [2] worked on pressure drop in petroleum-based (EG) nanofluids. Nanofluids are prepared by diluting TiO2 in three volume concentrations of 0.5%, 1.0% and 1.5% in a base fluid of water and EG mixed in a volume ratio of 60:40. Experiments were performed under a flow loop with a horizontal tube test section at different flow rate values in a range of Reynolds numbers below 30,000. The experimental results of pressure drop for TiO2 nanofluid have been compared with the Blasius equation for the base fluid. An increase in pressure drop with increasing nanofluid concentration and a slight decrease in pressure drop with increasing nanofluid temperature were observed. He found that TiO2 did not increase significantly compared to EG liquids. The working temperature of nanofluids reduces the pressure drop due to the reduction of nanofluid viscosity.

Hemasunder Banka et al [3] performed analytical studies on shell and tube heat exchangers using forced convection heat transfer to determine the properties of nanofluid flow by changing the volume fraction and mixing with water. Nanofluids include titanium carbide (TiC) and titanium nitride (TiN).) and zinc oxide nanofluids with different volume concentrations (0.02, 0.04, 0.07 and 0.15%) flow in turbulent conditions. Using the properties of nanofluids with different volume fractions, CFD analysis of heat exchangers is performed to determine the temperature distribution, heat transfer coefficient, and heat transfer coefficient. He found that increasing the volume fraction increases the heat transfer coefficient and the heat transfer coefficient.

M. Balchandaran et al. [4] conducted experimental studies and CFD simulations of a helical coil heat exchanger using Solid Works flow simulation with water as the fluid. The fluid used on both the coil side and the tube side is water. The flow rate of both fluids below is maintained as laminar flow, the cold fluid flow rate is kept constant and the hot fluid flow rate is variable. Measurements are made during the experimental study after reaching a steady state. Performance parameters related to heat exchangers such as effectiveness, overall heat transfer coefficient, velocity curves and temperature curves are reported. Based on the results, it is assumed that the heat transfer coefficient and other thermal properties of spiral coil heat exchangers are relatively higher than straight tube heat exchangers.

Ashkan Alimoradi et.al [5] Exergy efficiency has been studied in shell and spiral tube heat exchangers. He presents an exergy analysis of forced convection heat transfer in spiral shell and tube heat exchangers. We investigated the effects of operational and geometrical parameters on exergy efficiency. Water is chosen as the working fluid for both sides. The results show that the efficiency decreases linearly with the increase of the inlet temperature difference without fluid dimension. Based on the results, a wide range of mass flow ratios (0.1 < Rm < 4), dimensionless fluid inlet temperature difference (0 < RT < 0.8), Reynolds number product (3.31E+ 8 < (Rec. Resh) < 1.32E + 9)) and dimensionless geometric parameters. According to this formula, we found that a coil with the highest number of turns and the smallest diameter is more efficient than other coils with the same length and pitch.

B. Sidda Reddy et al. [6] Helical tube heat exchangers were studied in comparison with straight tube heat exchangers in opposite flow and parallel flow with variable parameters such as pitch, mass flow rate, temperature and pitch coil diameter. He uses a stainless steel cylinder with an outer diameter of 63.5 mm and a stainless steel cylinder with an inner diameter of 1.058D mm, the thickness of the pipe varies from 6 mm to 9 mm, and the flow rate of cold and hot water is 0.0625 kg/s and 0.166 kg taken by /s. Second, the initial temperature of cold and hot water is 300°C and 1000°C. The results show that with the increase in the mass flow rate of the thermal fluid, the heat transfer in the counter flow configuration increases. As the pitch coil diameter increases, the heat transfer coefficient decreases for the same configuration and mass flow rate. Also, as the coil pitch increases, the heat transfer decreases with the same mass flow rate. A helical coil provides a larger surface area and allows the fluid to interact with the wall for a longer

COMPUTATIONAL FLUID DYNAMICS

Computational fluid dynamics, as the name implies it is a subject that deals with computational approach to fluid dynamics with numerical solution of the equations which bring about the flow of the fluid and although it is also called computational fluid dynamics; it does not just deal with the equations of the fluid flow, it is also generic enough to be able to solve simultaneously together the equations that direct the energy transfer and as well the equations that determine the chemical reaction rates and how the chemical reaction proceeds and mass transfer takes place; all these things can be tackled together in an identical format. So, this outline enables us to deal with a very complex flow circumstances in reasonably fast time, such that for a particular set of conditions, an engineer will be capable to simulate and see how the flow is taking place and what kind of temperature distribution there is and what kind of products are made and where they are formed, so that we can make changes to the parameters that are under his control to modify the way that these things are happening. So, in that case CFD becomes a great tool of design for an engineer. It is also a great tool for an analysis for an examination of a reactor or equipment which is not functioning well because in typical industrial applications.

METHODOLOGY

PRE PROCESSING

CAD Modeling: Creation of CAD Model by by means of CAD modeling tools for making the geometry of the part/assembly of which we want to accomplish FEA. CAD model may be 2D or 3D.

1. **Type of Solver:** Pick the solver for the problem from Pressure Based and density based solver.
2. **Physical model:** Choose the required physical model for the problem i.e. laminar, turbulent, energy, multiphase, etc.
3. **Material Property:** Choose the Material property of flowing fluid.
4. **Boundary Condition:** Define the desired boundary condition for the problem i.e. velocity, mass flow rate, temperature, heat flux etc.

SOLUTION

1. **Solution Method:** Choose the Solution method to solve the problem i.e. First order, second order.
2. **Solution Initialization:** Initialized the solution to get the initial solution for the problem.
3. **Run Solution:** Run the solution by giving no of iteration for solution to converge.

Post Processing

For viewing and clarification of result, this can be viewed in various formats like graph, value, animation etc.

STEP 1

CFD analysis of helical coil heat exchanger by using ANSYS 18.2.

Pre-processing:

CAD Model: Generation of 3D model by using ANSYS fluent 18.2.

S.No.	Dimensional Parameters	Dimensions
1	Pitch Coil Diameter	60 mm
2	Tube Diameter	10 mm
3	Pitch	25 mm
4	Tube Length	500 mm

Table 1 : Parameters of Geometry of Helical Coil

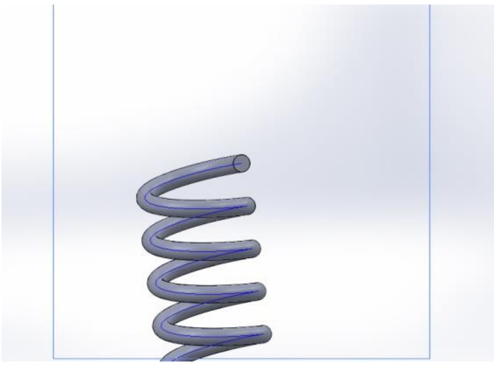

Figure 2: 3D model of helical coil heat exchanger with PCD 60 mm and tube diameter 10 mm.

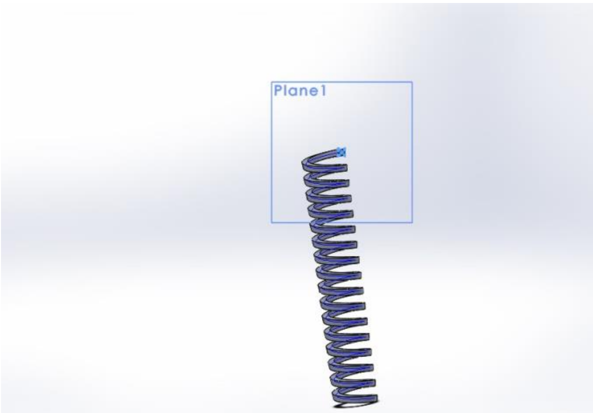

Figure 3: 3D model of square coil heat exchanger with PCD 60 mm and side of square is 10 mm.

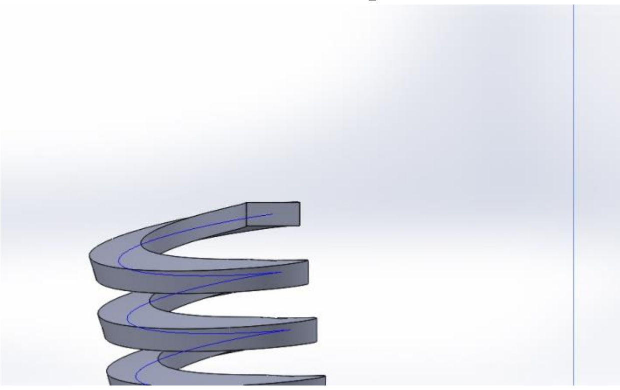

Figure 4: 3D model of rectangular coil heat exchanger with PCD 60 mm and side of rectangle is 10x20 mm.

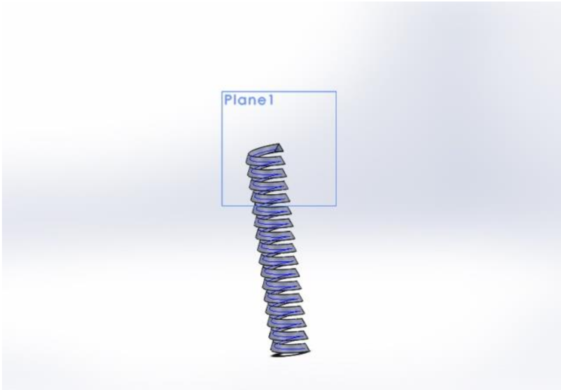

Figure 5: 3D model of triangular coil heat exchanger with PCD 60 mm and distance from its centre is 10 mm.

STEP 2

Mesh – Generate mesh model in the ANSYS

Making meshed model of helical coil heat exchanger with pitch circle diameter and tube diameter. Meshing is a critical operation in CFD. In the meshing, the CAD geometry is discretized into large numbers of nodes and elements. The arrangement of nodes and elements in space in appropriate manner is called meshing. The accuracy of analysis and time duration is depending on the meshing size and locations. When increasing in mesh size (increasing number of element), the CFD analysis decreases its but the accuracy increases.

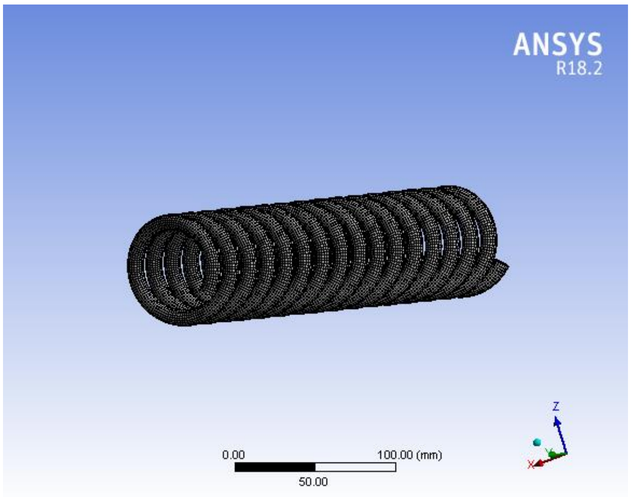

Figure 6: Meshed model of helical coil heat exchanger with PCD 60 mm and tube diameter 10 mm.

Mesh type	Fine grid mesh
No. of nodes	164897
No. of elements	138534

Table 2 Meshing Statistics of Circular Helical Coil

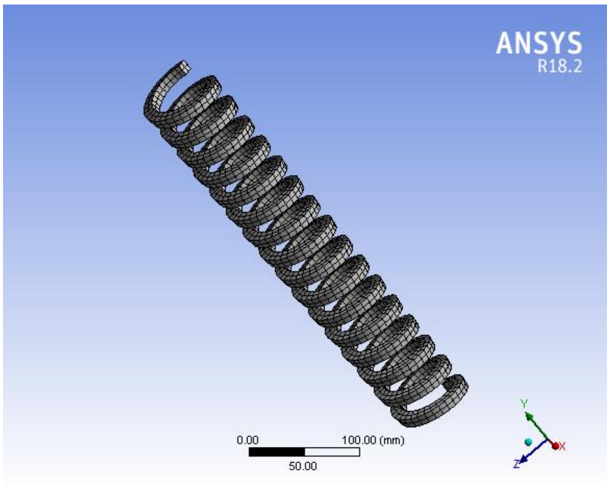

Figure 7: Meshed model of square coil with PCD 60 mm and side of square 10 mm.

Mesh type	Fine grid mesh
No. of nodes	20489
No. of elements	17698

Table 3 Meshing Statistics of Square Coil

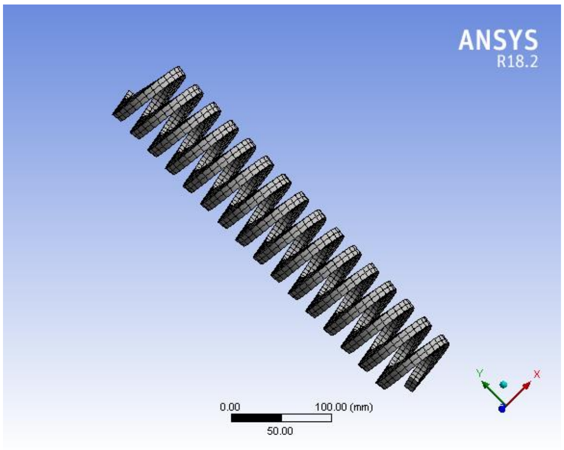

Figure 8: Meshed model of rectangular coil with PCD 60 mm and side of 10x20 mm.

Mesh type	Fine grid mesh
No. of nodes	24569
No. of elements	18768

Table 5 Meshing Statistics of Rectangular Coil

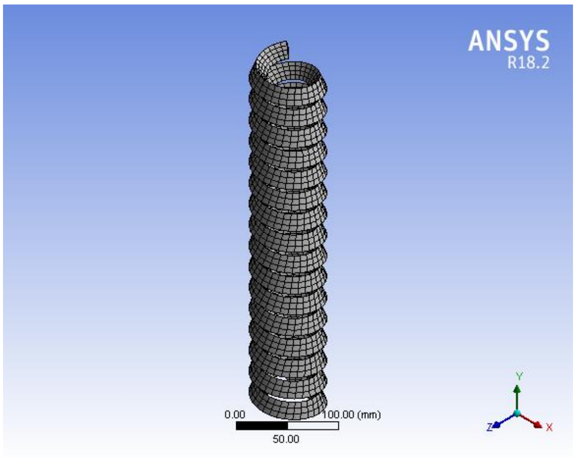

Figure 9: Meshed model of triangular coil with PCD 60 mm and distance from its centre is 10mm.

Mesh type	Fine grid mesh
No. of nodes	34510
No. of elements	24515

Table 6 Meshing Statistics of Triangular Coil

STEP 3
Fluent Setup:
After mesh setup generation define the following steps in the **ANSYS** fluent 18.2.

- Problem Type -3D solid
- Type of Solver – pressure
- Physical Model – viscous k- two equation turbulence model
- Mixture- mixture

STEP 4
Fluid Property Fluid Property

Density (ρ)	998.2 kg/m^3
Viscosity (μ)	0.2 kg/m-s
Specific heat (C_p)	1670 J/Kg-K
Thermal conductivity (k)	0.162 Watt/mK

Table No.7 Property of water

Density (ρ)	4230 kg/m^3
Viscosity (μ)	0.000189 kg/m-s
Specific heat (C_p)	0.692 KJ/Kg-K
Thermal conductivity (k)	8.4 Watt/mK

Table No.8 Property of TiO_2 Nanofluid

SOLUTION
Solution Method
Pressure - Velocity - Coupling – Scheme - Simple

- Pressure – standard pressure
- Momentum- 2nd order
- Turbulence –kinetic energy 2nd order

- Turbulence dissipation rate 2nd order

Solution Initialisation

Initiate the solution to get the initial solution for the problem.

Run Solution

Run the solution by giving 500 number of iteration for solving the convers.

Post Processing

For viewing and interpret of result, the result can be viewed in various formats like graph, value, animations etc.

RESULTS & DISCUSSION

1. The pressure drop data were collected for the configuration of circular helical, square shaped helical coil, rectangular shaped helical coil and triangular shaped helical coil for TiO_2 nanofluid as water as its base in copper tube. The various effects were observed.
2. CFD computations were done for copper coiled tube.
3. Performance parameters adopted for comparison of pressure drop and temperature distribution in all the cases.
4. Effect of pressure drop on the circular shaped helical coil by using TiO_2 nanofluid as water as its base fluid.

Case	Tube diameter	Fluid	Pressure drop (Pa)
1	10 mm	TiO_2 Nano fluid	14856

Table 9: Effect of pressure drop on the circular helical coil by using TiO_2 nanofluid as water as its base fluid.

5. Effect of Temperature on the circular shaped helical coil by using TiO_2 nanofluid with water as its base fluid.

Case	Tube diameter	Fluid	Temperature (K)
1	10 mm	TiO_2 Nano fluid	344.8

Table 10: Effect of Temperature on the circular helical coil by using TiO_2 nanofluid with water as its base fluid on high pressure

6. Effect of pressure drop on the square shaped helical coil by using TiO_2 nanofluid as water as its base fluid.

Case	Tube diameter	Fluid	Pressure drop (Pa)
1	10 mm	TiO_2 Nano fluid	14084

Table 11: . Effect of pressure drop on the square helical coil by using TiO_2 nanofluid as water as its base fluid.

7. Effect of Temperature on the square shaped helical coil by using TiO_2 nanofluid with water as its base fluid.

Case	Tube diameter	Fluid	Temperature (K)
1	10 mm	TiO_2 Nano fluid	344

Table 12: Effect of Temperature on the square helical coil by using TiO_2 nanofluid with water as its base fluid on high pressure

8. Effect of pressure drop on the rectangular shaped helical coil by using TiO_2 nanofluid as water as its base fluid.

Case	Tube diameter	Fluid	Pressure drop (Pa)
1	10 mm	TiO_2 Nano fluid	3484

Table 13: Effect of pressure drop on the rectangular helical coil by using TiO_2 nanofluid as water as its base fluid.

9. Effect of Temperature on the rectangular shaped helical coil by using TiO_2 nanofluid with water as its base fluid.

Case	Tube diameter	Fluid	Temperature (K)
1	10 mm	TiO_2 Nano fluid	343.8

Table 14: Effect of temperature on the rectangular helical coil by using TiO_2 nanofluid as water as its base fluid on high pressure.

10. Effect of pressure drop on the triangular shaped helical coil by using TiO_2 nanofluid as water as its base fluid.

Case	Tube diameter	Fluid	Pressure drop (Pa)
1	10 mm	TiO_2 Nano fluid	8706

Table 15: Effect of pressure drop on the triangular helical coil by using TiO_2 nanofluid as water as its base fluid.

11. Effect of Temperature on the triangular shaped helical coil by using TiO_2 nanofluid with water as its base fluid.

Case	Tube diameter	Fluid	Temperature (K)
1	10 mm	TiO_2 Nano fluid	344.3

Table 16: Effect of temperature on the triangular helical coil by using TiO_2 nanofluid as water as its base fluid on high pressure.

Case-1 Tube Diameter is 10 mm, TiO2 nanofluid is used as water as its base fluid in a circular helical coil, Pressure drop is 14856 Pa

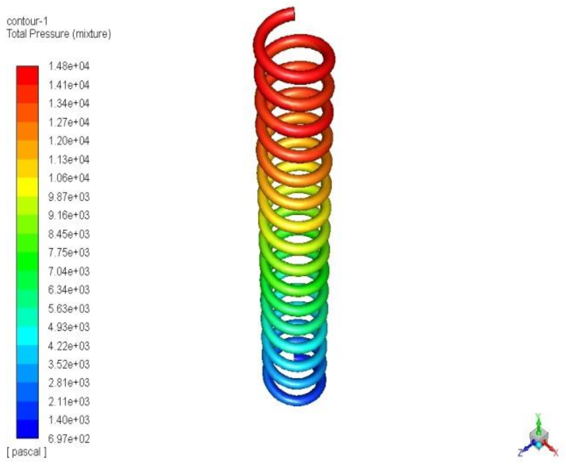

Figure 10: Total Pressure in circular helical coil using TiO2 nanofluid and water as a base fluid

Case-2 Tube of square side is 10 mm, TiO_2 nanofluid is used as water as its base fluid in square helical coil, pressure drop is 14084 Pa.

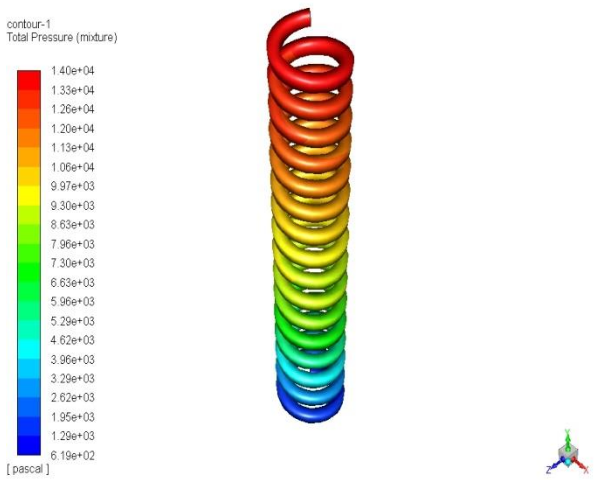

Figure 11: Total Pressure in square helical coil using TiO_2 as a nano fluid and water as a base fluid

Case-3 Tube of rectangular side is 10x20 mm, TiO_2 nanofluid is used as water as its base fluid in rectangular helical coil, pressure drop is 3484 Pa.

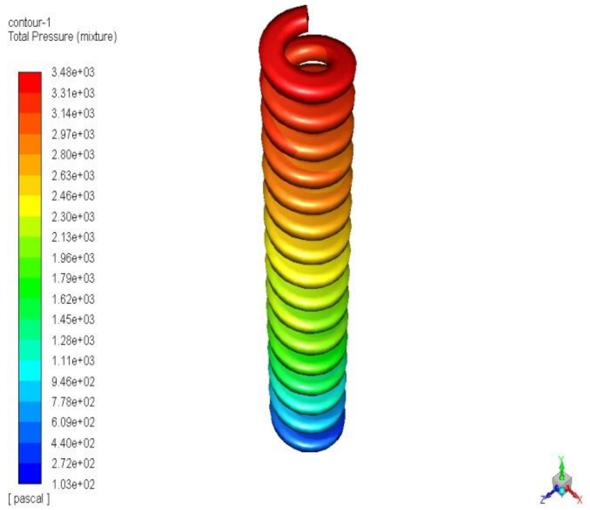

Figure 12: Total Pressure in rectangular helical coil using TiO_2 as a nano fluid and water as a base fluid.

Case-4 Tube of side of triangular is 10 mm at its distance from its centre, TiO_2 nanofluid is used as water as its base fluid in triangular helical coil, pressure drop is 8706 Pa.

Figure 13 : Total Pressure in triangular helical coil using TiO_2 as a nano-fluid and water as a base fluid

Case-5 Tube of circular tube dia is 10 mm, TiO_2 nanofluid is used as water as its base fluid in circular helical coil, Max temperature is 344.8 K

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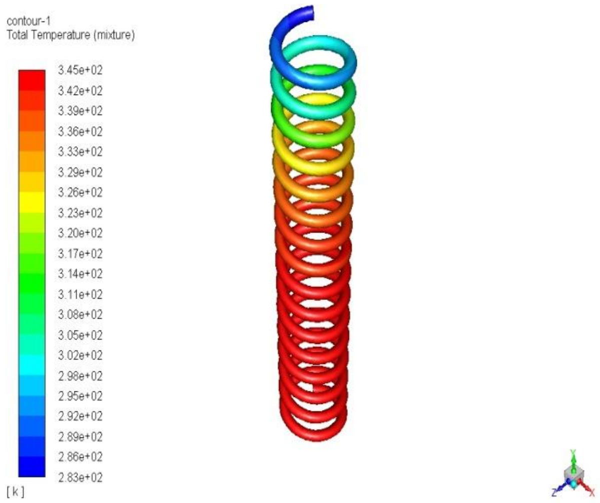

Figure 14: Distribution of temperature in circular helical coil using TiO_2 nanofluid using water as its base.

Case-6 Square side is 10 mm, TiO_2 nanofluid is used as water as its base fluid in square helical coil, Max temperature is 344 K

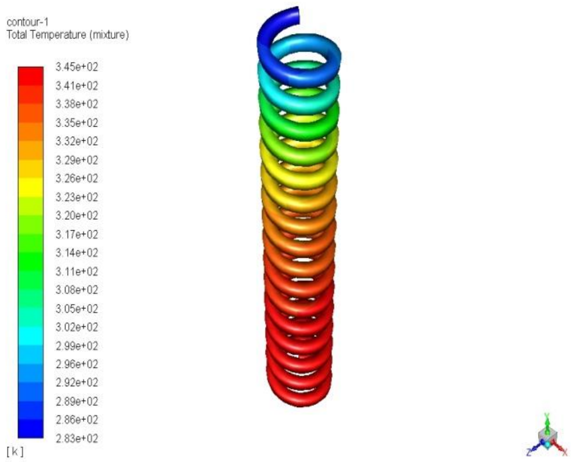

Figure 15: Distribution of temperature in square helical coil using TiO_2 nanofluid using water as its base.

Case-7 Rectangular coil of side 10 mm x 20 mm, TiO_2 nanofluid is used as water as its base fluid in rectangular helical coil, Max temperature is 343.8 K.

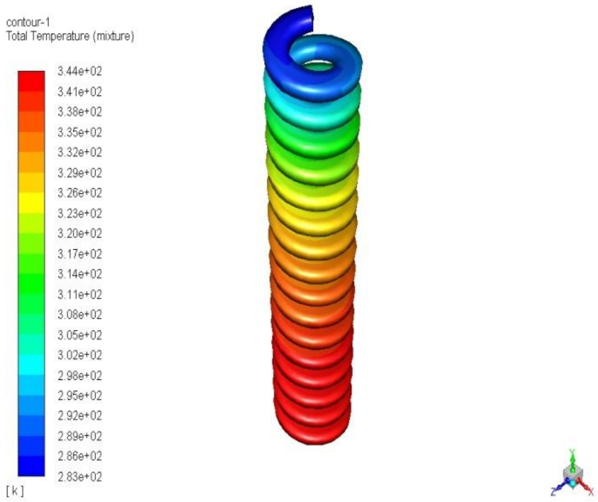

Figure 16: Distribution of temperature in Rectangular helical coil using TiO_2 nanofluid using water as its base.

Case-8 Triangular tube distance from its centre is 10 mm, TiO_2 nanofluid is used as water as its base fluid in triangular helical coil, Max temperature is 344.3K

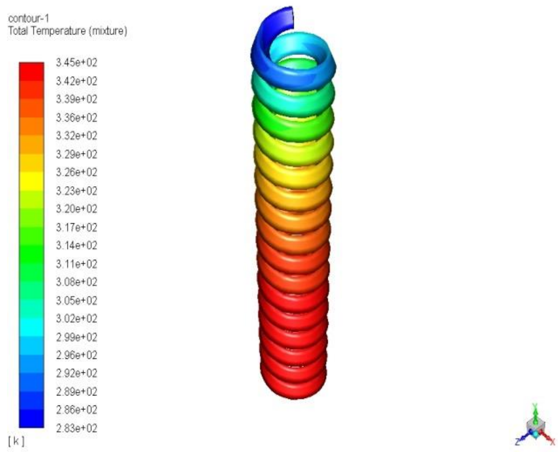

Figure 17: Distribution of temperature in triangular helical coil using TiO_2 nanofluid using water as its base.

From above it is clear that when we used the TiO_2 nanofluid using oil water as a base fluid in circular helical coil then pressure drops increases in this shape of coil because of presence of metal particles and the base fluid properties. The numerical study considers the effect of TiO_2 nanofluid using water as its base fluid in circular, square, rectangular and triangular tube on the flow and heat transfer characteristics of tube.

CONCLUSION

In this paper, analytical investigations are done on the Helical coil heat exchanger There is a change in design of helical coil gives the variation in pressure drop as circular helical coil give more pressure drop as compared to other helical coil. Increase in centrifugal force due to increases in curvature ratio of coil, mass flow rate and tube diameter. This increases more generation of secondary flow inside helical coil. Secondary flow produces additional transport of fluid and strong mixing (advection – diffusion) in the fluid over the cross section of pipe.

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