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# Comparison on CFD Analysis of Natural Fluid & Nanofluid in Helical Coil Heat Exchanger

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**Abstract: As related to straight tubes, helical tubes are more valuable because of its compact construction and it is being most broadly practiced in several heat transfer applications. Enrichment of heat transfer rate due to helical coil heat exchanger has been described by many scholars. The study of this investigation is the comparison between natural fluidand Nanofluid with the help of CFD on aluminium & copper tubes. The Titanium oxide ($TiO_2$) and Zinc oxide (ZnO) is used as nanofluid and water as its base and also used water as a natural fluid. Helical coil was fabricated by bending 1000 mm length of aluminium & copper tube having 8 mm tube diameter and coil diameter is 35 mm and pitch 15mm. The comparison of pressure drop between water, $TiO_2$ and ZnO fluid is found in this analysis. The result indicates that the ZnO have maximum pressure drop in aluminium tube as compared to other fluid and other tubes. Nano fluids have nano particles and the nano particles which have higher density will give higher pressure drop. Thermal conductivity can increases heats transfer in helical coil heat exchangers. The thermal properties of fluid are lesser as compared to nanofluid. Nano fluids have Nano particles of solid materials which increase the thermal properties of Nano fluid also and also because of vortex flow the pressure drop will be increased.**

**Keywords:** Helical Coil, Heat Exchanger, Nano Fluid, CFD, Pressure Drop.

## I. INTRODUCTION

Heat exchangers have severalapplications including power generation plants, nuclear reactors for generation of electricity, Refrigeration & Air Conditioning (RAC) systems, self-propelled industries, food industries, heat retrieval systems, and chemical handling. The upgrading methods can be distributed into two methods: active and passive methods. The active method requires peripheral forces. The passive methods need discrete surface geometries. Active method and passive methodis normally used forenlightening the performance in heat exchangers because of their compact structure and high heat transfer coefficient. Helical tubes have been declared as one of the passive heat transfer perfection method and they are broadly used in many industrial applications.

Several studies show that the performance in helical tubes heat exchanger is greater to straight tube heat exchanger. The centrifugal force will be occurring because of twisting in tube and it also improves rate of heat transfer because of secondary flow. Helical tube required small volume of base area related to other heat exchangers. The most important problem of helical tube heat exchanger is, only the difficulty in calculating the heat transfer coefficients and the surface area available for heat transfer. This problem comes because of deficiency of data in helical tube heat exchangers, and the poor probability of the flow characteristics around the outside of the coil.

Heat transfer in the fluid is the important factor as it disturbs the size and cost of heat exchanger systems. Conventional fluids like oil and water have partial heat transfer potentialities. There is top priority for developing different group of fluids so as to reduce cost and meet the increasing demand of industry and commerce. By chance, the developments in nano-technology make it possible to get higher efficiency and cost saving in heat transfer methods. Nanoparticles are taken as the fresh group of materials which having several applications in the heat transfer area.

### *A. Nano Fluid*

Nano fluid havemetal particles in fluid which is smaller than a μ(9-10 times) in size and highlyvolatile and capable material, which will be used for increasing factors likethermal conductivity of any metal or material and rate of reactionbecause they are so much strong and reactive.

If the nano particles are properly distributed then the following resultwill be obtained:

- Higher heat conduction
- Stability
- Micro passage cooling without clogging
- Reduced chances of erosion
- Decrease in Pumping Power

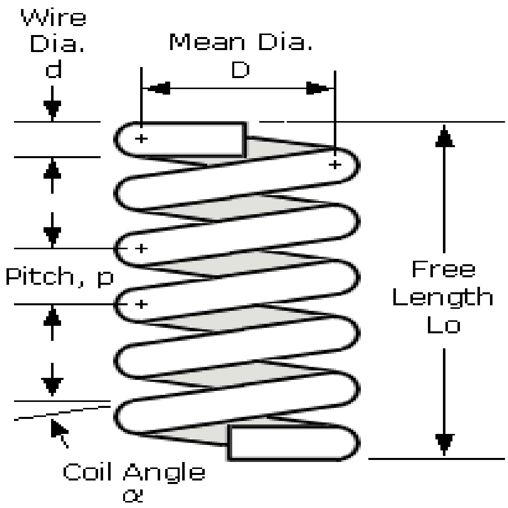


Figure-1. Helical Coil

There are several types of Nano fluids, some are:

- $Al_2O_3$ + Water
- CuO + Water
- ZnO + Water
- $TiO_2$ + Water
- TiN + Water

Out of these we are going to work on Zinc Ozide (ZnO) + Water& $TiO_2$+ water as a Nano fluid and water as a natural fluid in Helical Coil Heat Exchanger.

| **Fluid** | **Thermal Conductivity (W/mK)** | **Specific Heat (J/Kg-K)** | **Density (Kg/m$^3$)** | **Viscosity (Kg/m-s)** |
|---|---|---|---|---|
| **Water** | 0.6 | 4182 | 998.2 | 0.001003 |
| **ZnO** | 25.32 | 3798.58 | 1091.7 | 0.001053 |
| **$TiO_2$** | 0.538 | 3350.28 | 1109.12 | 0.001891 |

Table-1. Properties Of Used Fluids.

## II. LITERATURE REVIEW

It has been widely reported in literature that heat transfer rates in helical coils are higher as compared to a straight tube. Due to the compact structure and high heat transfer coefficient, helical coil heat exchangers are widely used.

Vijaykant Pandey et. al. [1] has done study on the effect of geometrical parameters on heat transfer in helical coil heat exchanger at three different mass flow rate 0.005, 0.02 and 0.05 kg/s. Helical coil was fabricated by bending 1000 mm length of aluminium tube having 6,8,10 mm tube diameter and each time coil diameter should be 40 mm and at same pitch 15 mm and at same length. He found that by increasing the tube diameter 10 mm and at curvature ratio 0.25 at mass flow rate of 0.05 kg/s there is increase in pressure drop of about 12100 Pa (262.275 %) and Nusselt number also increases about 2.25% in comparison to tube diameter 6 and 8 mm and at mass flow rate 0.005 and 0.02 kg/s. This can increases heat transfer in helical coil heat exchangers.

M. Balchandaran et. al [2] has done experimental and CFD study of a helical coil heat exchanger using water as fluid. He found that hot fluid mass flow rate increases, the Overall Heat Transfer Coefficient, Nusselt number, heat transfer coefficient of cold fluid and effectiveness also increases. This is due to helical nature of the coil and the better flow distribution of cold fluid.

Shiva Kumar et. al [3] have worked on both straight tube and helical tube heat exchanger. He has compared CFD results with the results obtained by the simulation of straight tubular heat exchanger of the same length under identical operating conditions. Results indicated that helical heat exchangers showed 11% increase in the heat transfer rate over the straight tube. Simulation results also showed 10% increase in nusselt number for the helical coils whereas pressure drop in case of helical coils is higher when compared to the straight tube.

Fakoor et. al. [4] studied the pressure drop characteristics of nano fluid flow inside a vertical helical coiled tube for laminar flow conditions. Experiments were conducted by varying the pitch circle diameters and also the tube diameters. Results indicated that using helical tubes instead of straight tubes increases the pressure drop exponentially.

J.S. Jayakumar et. al. [5] carried out an experimental study of fluid to fluid heat transfer though a helical coiled tube at different PCD, inside tube diameter and pitch. Heat transfer characteristics were also studied using CFD code fluent. They observed CFD predictions match reasonably with experimental results for all operating conditions.The effect of coil curvature is to supress turbulent fluctuation ascending in the flowing fluid. Thus, it increases the value of Reynolds number required to attain a fully turbulent flow. As the PCD increases the impact of coil curvature on mass flow rate reduces and therefore the centrifugal force plays lesser role. The difference between the Nu at the inner and outer location increases. Same as coil pitch increases the difference of Nu increases. While the pipe diameter is low, the secondary flows are weaker and hence mixing is lesser.

Vinita Sisodiyaet. al. [6] study on the use of Helical coil heat exchangers (HCHEs) with (Aluminium Oxide) $Al_2O_3$ -Water phase change material to understand if HCHEs can yield greater rates of heat transfer. An analytical study was conducted using a counter flow HCHE consisting of 8 helical coils. Two analysis was conducted, one where water was used as heat transfer fluid (HTF) on the coil and sell sides, respectively; while the second one made use of different Volume fractions of $Al_2O_3$ and water on the coil and shell sides, respectively. The result shows that when using an $Al_2O_3$, an increase in heat transfer rate can be obtained when compared to heat transfer results obtained using straight heat transfer sections. It has been concluded that the increased specific heat of the $Al_2O_3$ as well as the fluid dynamics in helical coil pipes are the main contributors to the increased heat transfer.

K. Abdul Hamid et. al. [7] has done work on pressure drop for Ethylene Glycol (EG) based nanofluid. The nanofluid is prepared by dilution technique of $TiO_2$ in based fluid of mixture water and EG in volume ratio of 60:40, at three volume concentrations of 0.5 %, 1.0 % and 1.5 %. It was observed that pressure drop increase with increasing of nanofluid volume concentration and decrease with increasing of nanofluid temperature insignificantly. He found that $TiO_2$ is not significantly increased compare to EG fluid. The working temperature of nanofluid will reduce the pressure drop due to the decreasing in nanofluid viscosity.

Tushaar A Sinha et. al. [8] has done experimental investigation into the thermal properties of nano fluid and he found that the thermal conductivity of Nano fluid increases with the increase in the sonication time, but the viscosity of Nano fluid decreases with it. Also with the increase in settling time, the thermal conductivity decreases and viscosity increases. With the increase in temperature, the thermal conductivity and specific heat of Nano fluid increases and viscosity decreases.

Hemasunder Banka et. al. [9] has done an analytical investigation on the shell and tube heat exchanger using forced convective heat transfer to determine flow characteristics of nano fluids by varying volume fractions and mixed with water , the nano fluids are titanium carbide (TiC), titanium nitride (TiN) and ZnO nanofluid and different volume concentrations (0.02, 0.04, 0.07 & 0.15%) flowing under turbulent flow conditions. CFD analysis is done on heat exchanger by applying the properties of nano fluid with different volume fractions to obtain temperature distribution, heat transfer coefficient and heat transfer rate. He found that heat transfer coefficient and heat transfer rates are increasing by increasing the volume fractions.

## III. COMPUTATIONAL FLUID DYNAMICS (CFD)

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.

## IV. METHODOLOGY

*Step-1*

CFD analysis of helical coil heat exchanger is done by using analysis software i.e. Ansys 14.5.

*A. Pre-processing*

*a). CAD Model*

Design of helical coil by using CAD modeling tools for creating the geometry of the part/assembly of which we want to perform FEA &CAD model is 3D. A helical coil of 1000 mm length, 35 mm PCD, pitch of 15 mm, and the diameter of tube is 8 mm made in Solid works. After making of a CAD model the model can be transfer into the Ansys software for analysis in IGES format.

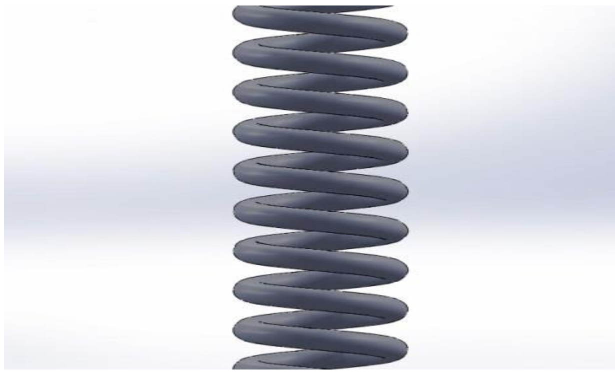

Figure-2 3D Model Of Helical Coil Heat Exchanger.

*Step-2*

*b). Meshing*
*Generate Mesh Model in the Ansys 14.5*

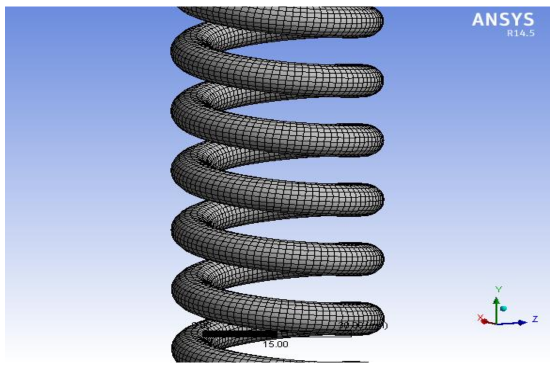


Figure-3 Meshed Model of Helical Coil Heat Exchanger.

*STEP 3*

*Fluent setup* - After mesh setup generation define the following steps in the Ansys fluent 14.5

- Problem type -3D solid
- Type of solver – pressure based
- Multiphase – Volume of fluid
- Physical model – viscous k- two equation turbulence model.

*B. Solution*

*a). Solution Method*

Pressure - velocity - coupling – scheme - simple

- Pressure – standard pressure.
- Momentum- 2 nd order.
- Turbulence –kinetic energy k 2nd order.
- Turbulence dissipation rate – 2nd order.

*b). Solution Initialization*

- Initiate the solution to get the initial solution for the problem. Run solution:
- Run the solution by giving 500 number of iteration by which problem can be solved.

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

## V. RESULT

CFD analysis has been carried out for helical tube heat exchanger which is subjected for different boundary conditions. The numerical study considers the effect of natural fluid that is water and nanofluid such as Zinc Oxide (ZnO) and Titanium Oxide ($TiO_2$) on the flow and heat transfer characteristics of tube.

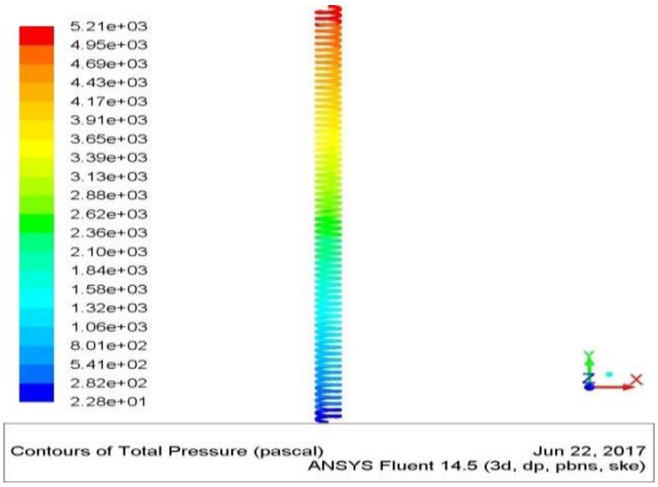


Figure-4 Total Pressure in Copper Helical Coil Using Water As A Fluid.

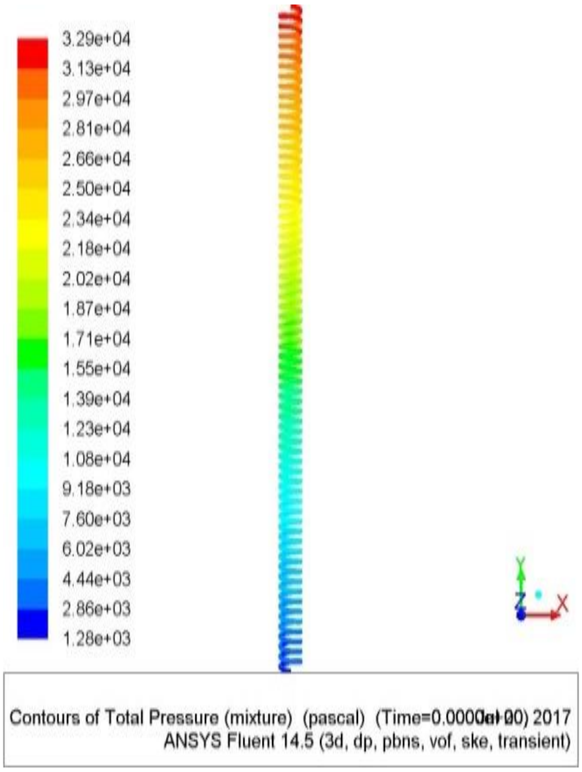


Figure-5 Total Pressure in Copper Helical Coil Usingtio₂ As A Nano Fluid.

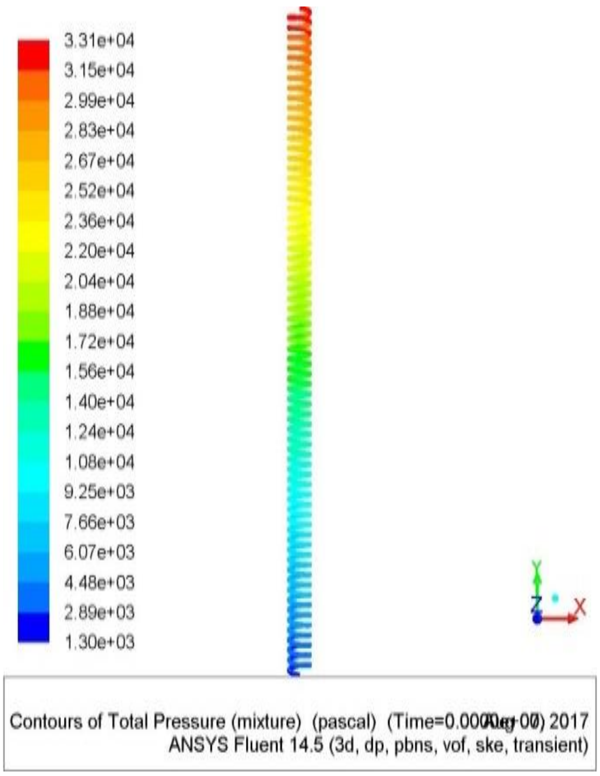


Figure-6. Total Pressure in Copper Helical Coil Using Zno As A Nano Fluid.

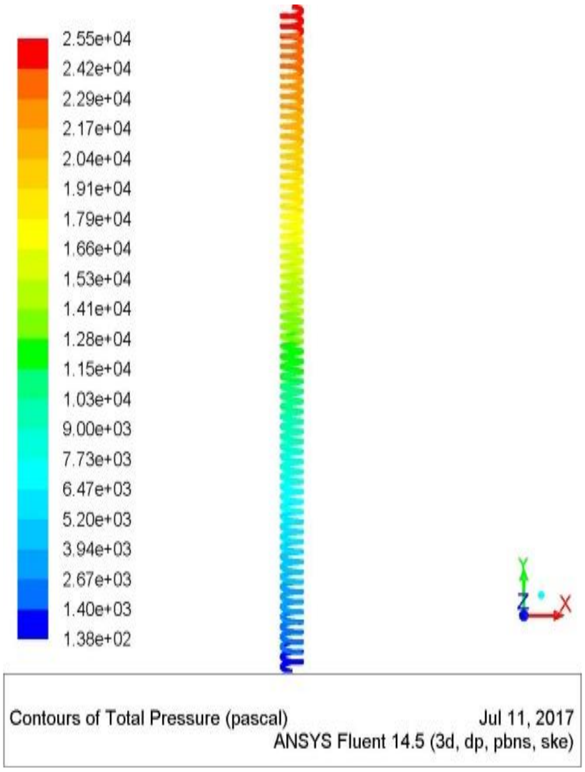


Figure-7 Total Pressure in Aluminium Helical Coil Using Water As A Fluid.

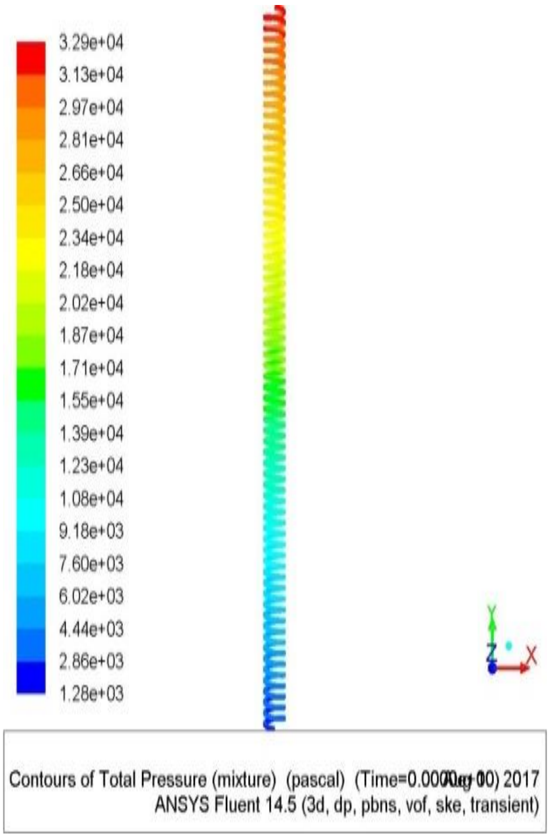


Figure-8 Total Pressure in Aluminium Helical Coil Using $TiO_2$ as A nano Fluid.

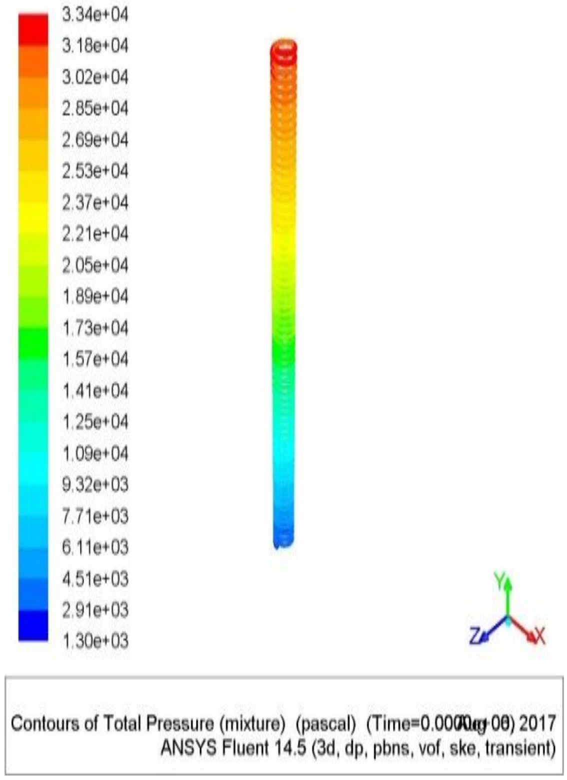


Figure-9 Total Pressure in Aluminium Helical Coil Using Zno As a Nano Fluid.

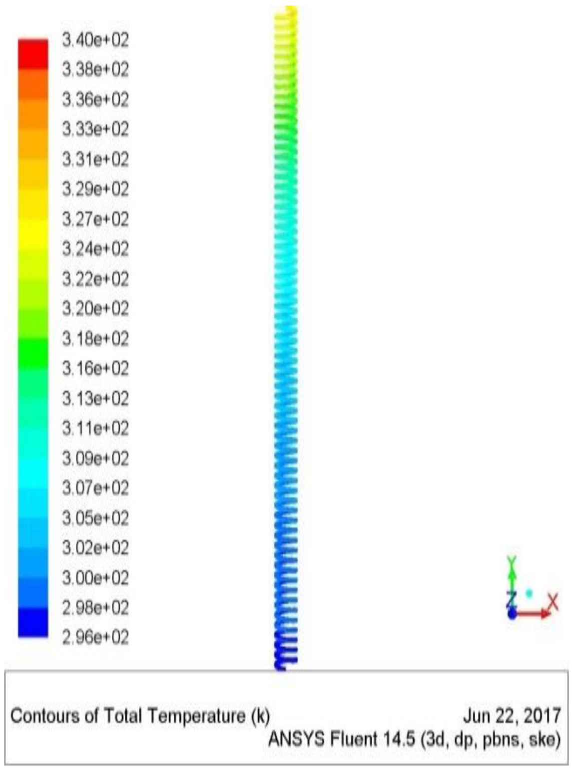


Figure-10 Distribution of Temperature in Copper Helical Coil Using Water As a Fluid.

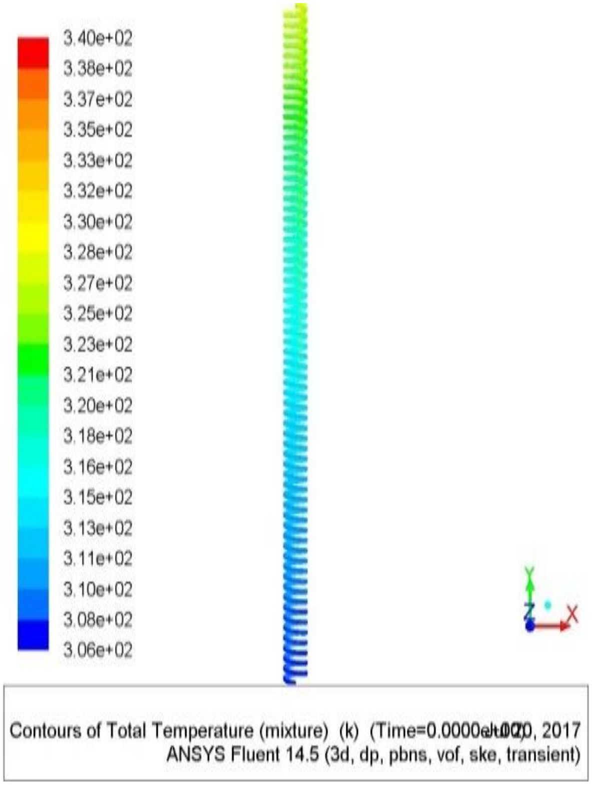


Figure-11 Distribution of Temperature in Copper Helical Coil Using $TiO_2$ As A Nano Fluid.

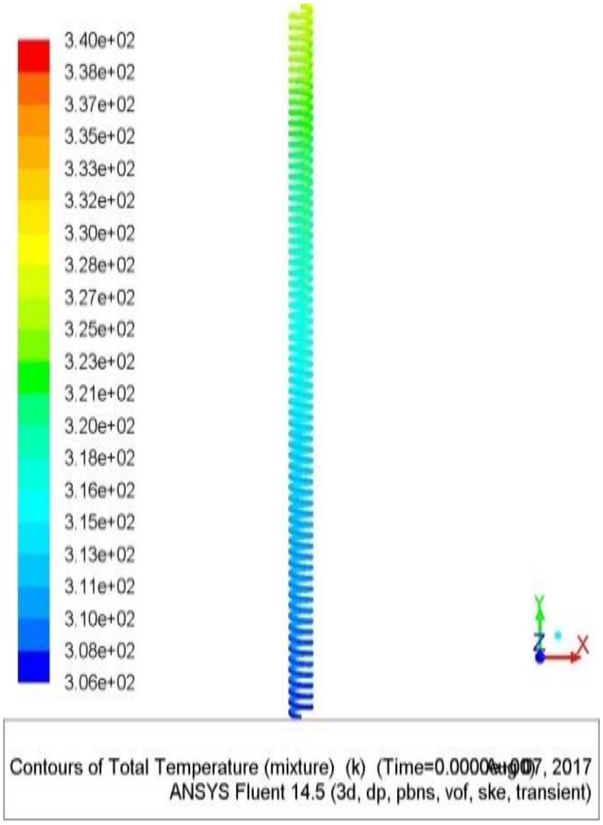


Figure-12 Distribution of Temperature in Copper Helical Coil Using Zno As a Nano Fluid.

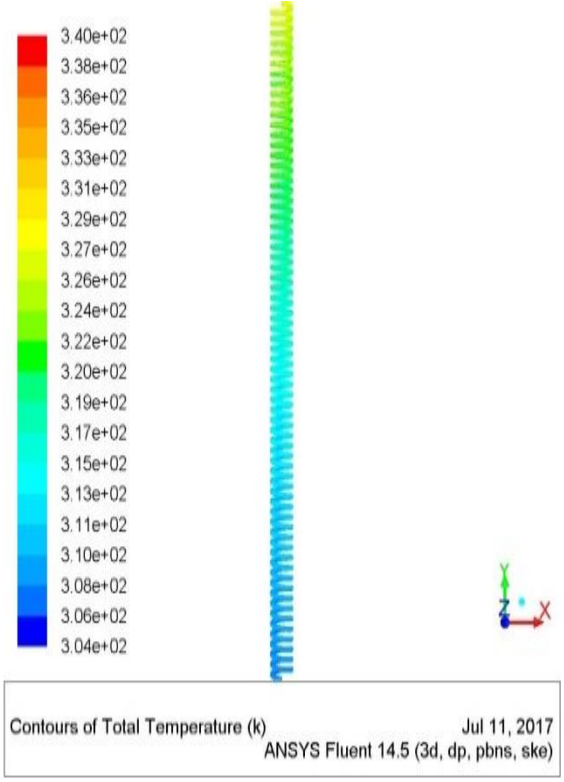


Figure-13 Distribution of Temperature in Aluminium Helical Coil Using Water As a Fluid.

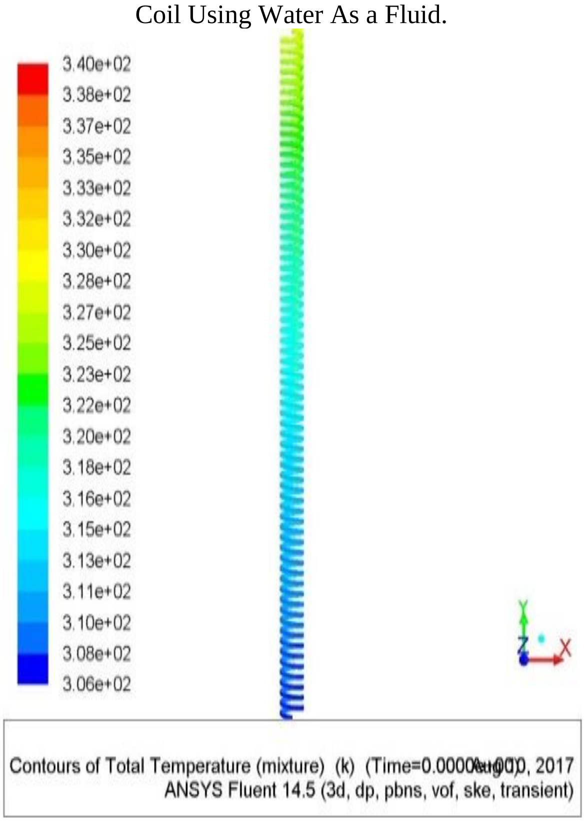


Figure-14 Distribution of Temperature in Aluminium Helical Coil Using $TiO_2$ As a Nano Fluid.

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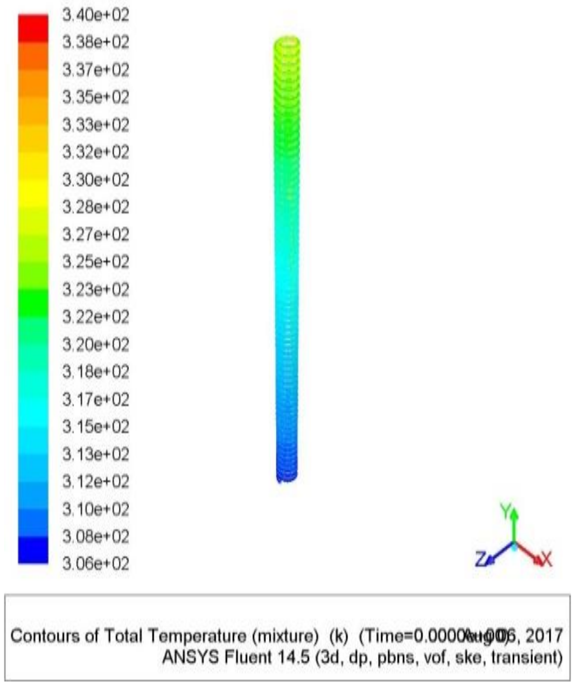


Figure-15 Distribution of Temperature in Aluminium Helical Coil Using Zno As a Nano Fluid.

From above it is clear that when we used the nanofluid then pressure drops increases in ZnObecause of presence of metal particles in the fluid. The numerical study considers the effect of natural fluid that is water and nanofluid such as Zinc Oxide (ZnO) and Titanium Oxide ($TiO_2$) on the flow and heat transfer characteristics of tube. The thermal properties of fluid are lesser as compared to nanofluid. Nano fluids have Nano particles of solid materials which increase the thermal properties of Nano fluid also because of vortex flow the pressure drop will be increased.

| Properties | Water | Zno Nanofluid | $TiO_2$ Nanofluid |
|---|---|---|---|
| Max Temp in copper tube | 326 K | 327 K | 327 K |
| Max Pressure in copper tube | 5218 Pa | 33178 Pa | 32990 Pa |
| Max Temp in aluminium tube | 329 K | 328 K | 327 K |
| Max Pressure in aluminium tube | 25540 Pa | 33458 Pa | 32918 Pa |

Table-2 CFD Analysis Results.

## VI. CONCLUSION

In this paper, analytical investigations are done on the helical coil heat exchanger, to determine pressure drop and temperature distribution of water fluid and a titanium oxide and zinc oxide nanofluid on aluminium coil & helical coil flowing under laminar flow conditions. By observing the CFD analysis results, we know that the material which has high thermal conductivity that fluid will give high pressure drop. The pressure drop is more in aluminium helical coil heat exchanger when zinc oxide nanofluid is used.

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