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Comparison on Computational Fluid Dynamics Analysis of Zinc Oxide, Silicon Dioxide and Manganese Oxide Nano-fluid Using Oil as a Base Fluid in a Helical Coil Heat Exchanger

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ABSTRACT: A helical coiled heat exchanger is generally functional in industrial applications due to its compact structure, larger heat transfer area and higher heat transfer capability, etc. The importance of compact heat exchangers (CHEs) has been recognized in aerospace, automobile, gas turbine power plants, and other industries for the last 60 years or more due to several factors. However flow and heat transfer phenomena related to helically coil-tube heat exchanger are very sophisticated. A computational fluid dynamics (CFD) methodology using ANSYS FLUENT 14.5 is used here to investigate pressure drop of different nano-fluids (Zinc Oxide, Magnesium Oxide & Silicon Dioxide) on the heat transfer characteristics in a helically coil-tube. Analysis has been done for different nano-fluids using oil as its base of a helical coil tube by some boundary conditions. Based on the CFD results, the oil give higher pressure drop as compared to water when using a nano-fluid in a helical coil heat exchanger using oil as its base.

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

I. INTRODUCTION

There are various fields in which heat exchangers are being used for the effective purpose. The industrial survey in previous year comments that there is demand of heat exchanger with increased heat transfer rate than which is being provided by the conventional. Various attempts are made to use suspended micro particles in the conventional fluid. It has the effect but it used to clog the flow in micro channel. Heat transfer enhancement techniques have been one of the main thermal engineering research fields since the fuel crisis in 1970s. Active, passive and compound heat transfer enhancement methods have been developed. Helical coils, additives to fluids, swirl flow devices, rough and extended surfaces are all passive enhancement techniques while application of electric, acoustic and magnetic fields and fluid system vibration are active techniques. Passive methods were preferred due to their simplicity in manufacturing, lower cost and longer operating life.

Later in early 20's when the nanotechnology was involving, the idea was proposed to use nano-fluids for increase heat transfer rate. This characteristic of nano-fluid made nano fluid a dominant contestant in the area of heat transfer. So the technology available today is sufficient to prepare nano-fluid. 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

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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. There are different types of nano-fluids that can be made by using different nano particles and base fluid combinations. [14]

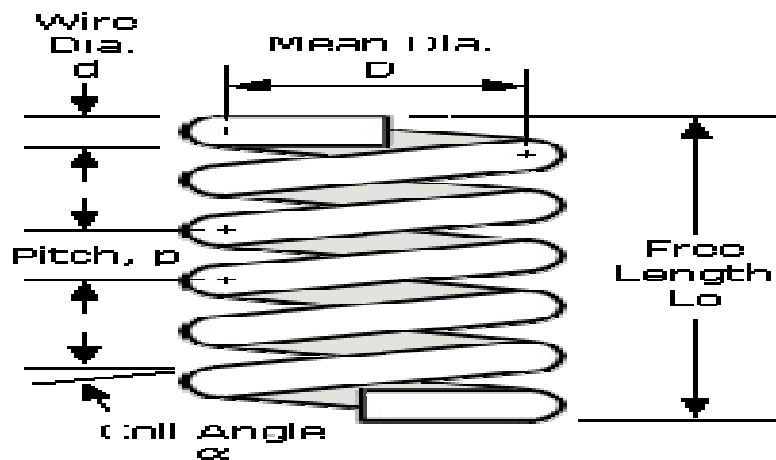


Figure 1: Helical Coil [12]

Nano Fluid

Nano fluid have metal particles in fluid which is smaller than a μ (9-10 times) in size and highly volatile and capable material, which will be used for increasing factors like thermal conductivity of any metal or material and rate of reaction because they are so much strong and reactive.

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

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

II. 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.

Arvind Kumar Pathaket. al. [1] has done his study on the comparison of CFD analysis of Natural Fluid and Nano fluid in a helical coil heat exchanger. He has used water as a natural fluid and Titanium Oxide (TiO_2) and Zinc Oxide (ZnO) is used as a Nano fluid with base as water. He has fabricated a helical coil of aluminium and copper by bending 1000 mm of tube with 8 mm tube diameter, pitch 15 mm and coil diameter is 35 mm. He found that aluminium coil give more pressure drop on Zinc oxide Nano fluid as compared to other tubes and fluids.

Vijaykant Pandey et. al. [2] have 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. The relation between pressure drop and mass flow rate has been obtained for

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three different curvature ratio 0.15, 0.2, 0.25 at three different mass flow rates. The result shows 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 increase heat transfer in helical coil heat exchangers. The increase in heat transfer are a consequences of curvature of the coil which induces centrifugal force to act on moving fluid resulting in development of secondary flow.

Hemasunder Banka et. al. [3] have 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 Nano fluid 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.

K. Abdul Hamid et. al. [4] has done work on pressure drop for Ethylene Glycol (EG) based Nano fluid. The Nano fluid 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 %. The experiment was conducted under a flow loop with a horizontal tube test section at various values of flow rate for the range of Reynolds number less than 30,000. The experimental result of TiO_2 Nano fluid pressure drop is compared with the Blasius equation for based fluid. It was observed that pressure drop increase with increasing of Nano fluid volume concentration and decrease with increasing of Nano fluid temperature insignificantly. He found that TiO_2 is not significantly increased compare to EG fluid. The working temperature of Nano fluid will reduce the pressure drop due to the decreasing in Nano fluid viscosity.

T. Srinivas et. al. [5] have done experimental study on heat transfer Enhancement using Copper Oxide (CuO)/Water Nano fluid in a Shell and Helical coil heat exchanger. Experiments have been carried out in a shell and helical coil heat exchanger at various concentrations of CuO nanoparticles in water (0.3, 0.6, 1, 1.5 & 2%), speed (500, 1000 and 1500rpm) and shell side fluid (heating medium) temperatures (40, 45 & 50°C). Water has been used as coil side fluid. He found that the heat transfer rate increases with increase in concentration of CuO/water Nano fluid. This can be attributed to increased thermal conductivity of base fluid due to the addition of nano particles.

Fakoor et. al. [6] are studied the pressure drop characteristics of Nano fluid flow inside vertical helically coiled tubes are investigated experimentally for the laminar flow regime. The temperature of the tube wall is maintained constant at around 95 C to have isothermal boundary condition Experiments are implemented for fluid flow inside helically coiled tubes and a straight one. A wide range of various variables is taken into account. Pitch to tube-diameter ratio ranges between 1.6 and 6.1 and coil-to-tube diameter ratio varies from 14.1 to 20.5. Heat transfer oil is used as the base fluid, and Multi-Walled Carbon Nano Tubes (MWCNTs) are utilized as the additive to provide the nano fluids. The working fluids are extremely temperature dependent, so rough correlations are proposed to predict their thermo-physical properties. Regarding the experimental data, utilization of helical coiled tubes instead of straight ones increases the pressure drop exponentially. Irrespective of the tube geometry in which the fluid flows, Nano fluid flows show higher rate of pressure drop compared to that of the base fluid flow.

Shiva Kumar et. al [7] 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.

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M. Balchandaran et. al [8] have done experimental study and CFD simulation of helical coil heat exchanger using Solid works Flow Simulation using water as fluid. The fluid used for both coil and tube side is water. The flow rate of both fluids is maintained below as laminar and the flow rate of cold fluid is kept constant while that of hot fluid is changed. The readings during experimental study are taken once steady state has reached. The performance parameters pertaining to heat exchanger such as effectiveness, overall heat transfer coefficient, velocity contours, temperature contours etc. have been reported. Based on the results, it is inferred that the heat transfer rates and other thermal properties of the helical coil heat exchanger are comparatively higher than that of a straight tube heat exchanger.

Vinita Sisodiya et. al. [9] 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 shell 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 NTU effectiveness relationship of the HCHE when Al_2O_3 fluid is used approaches that of a heat exchanger with a heat capacity ratio of zero. The heat transfer results have shown 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.

III.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.

IV.METHODOLOGY

Step-1

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

Pre-processing

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, 50 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.

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Step-2

MESHING

Generate Mesh Model in the Ansys 14.5

STEP 3

Fluent setup - After mesh setup generation, the following steps will take in the Ansys fluent 14.5

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

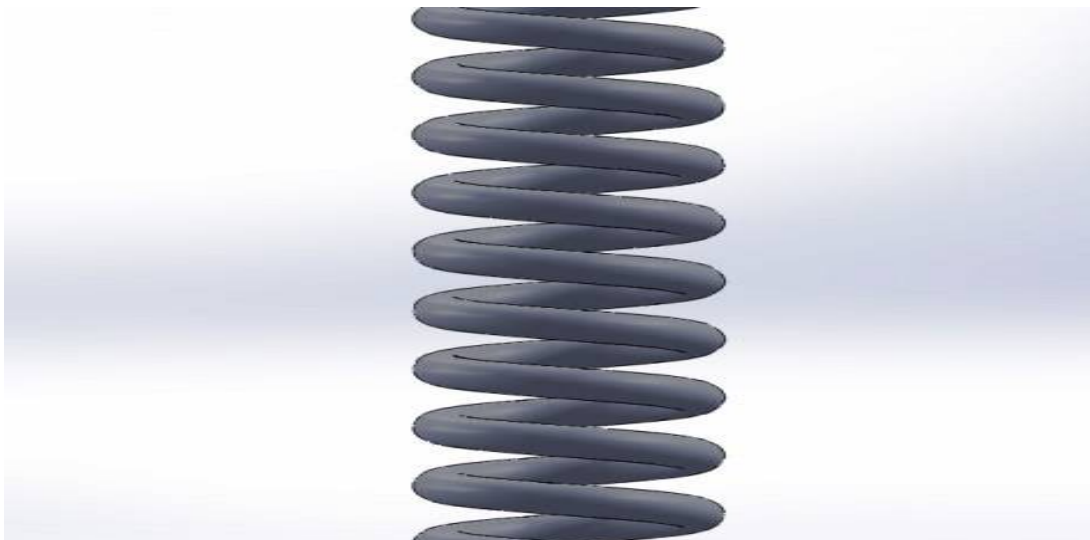


Figure-2 3D model of helical coil heat exchanger 2

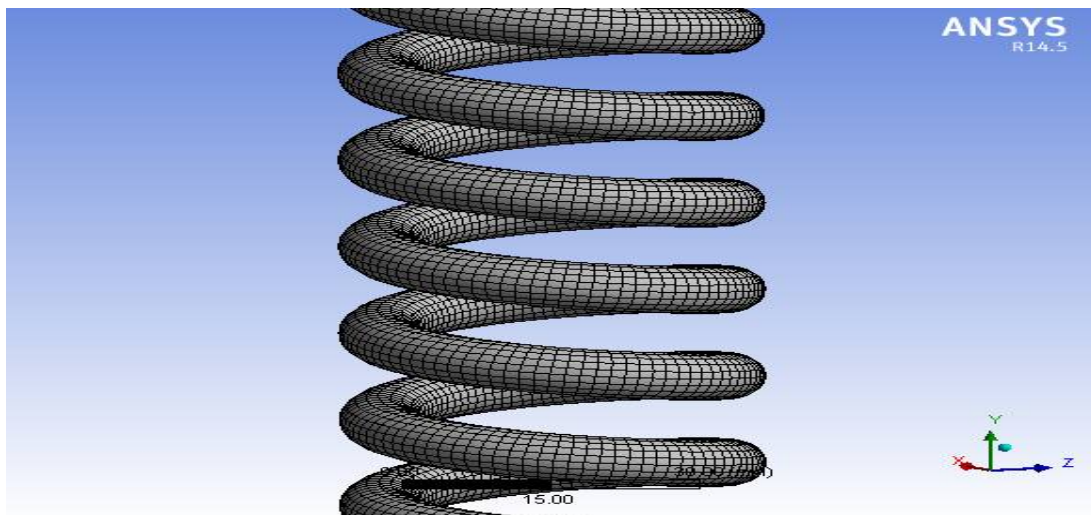


Figure-3 Meshed Model of Helical Coil Heat Exchanger

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Solution

Solution method

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

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. RESULTS

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 nano-fluid such as Zinc Oxide (ZnO), Silicon Dioxide (SiO₂) and Manganese Oxide (MgO) transfer characteristics of copper tube.

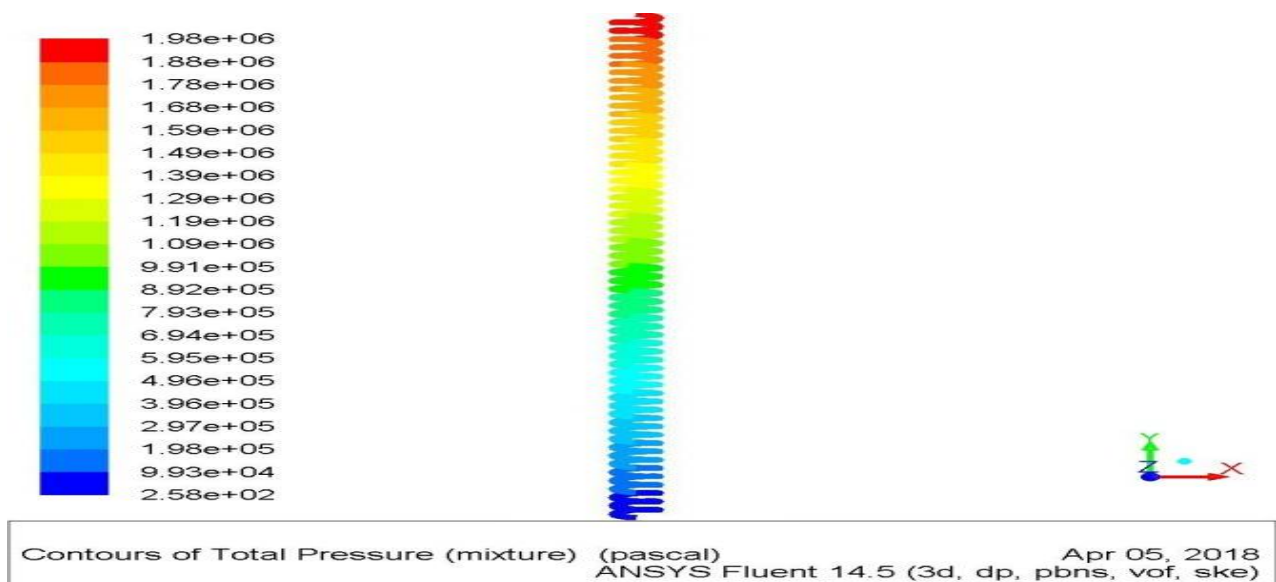


Figure-4 Total Pressure in Helical Coil using Manganese Oxide Nano-fluid using oil as its base fluid

In the above figure the Pressure in helical coil starts from 258 Pa and the maximum pressure in Helical Coil while using Manganese Oxide nano-fluid using oil as it base is 1987229 Pa.

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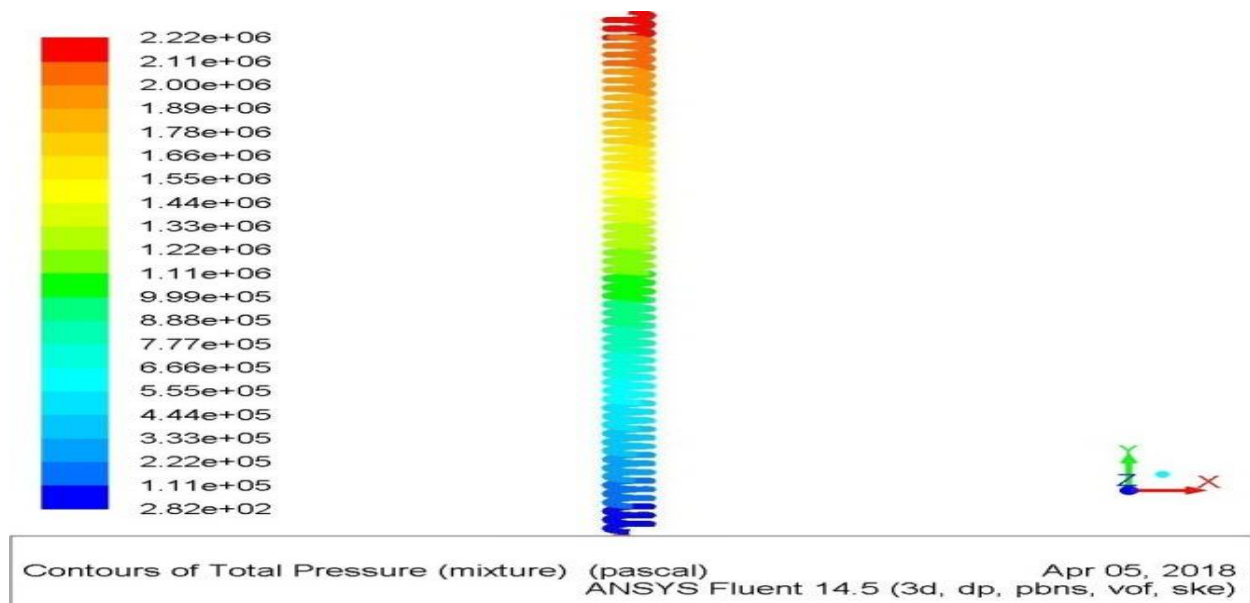


Figure-5 Total Pressure in Helical Coil using Silicon Dioxide Nano-fluid using oil as its base fluid

In the above figure the Pressure in helical coil starts from 282 Pa and the maximum pressure in Helical Coil while using Silicon Dioxide nano-fluid using oil as it base is 2220293 Pa.

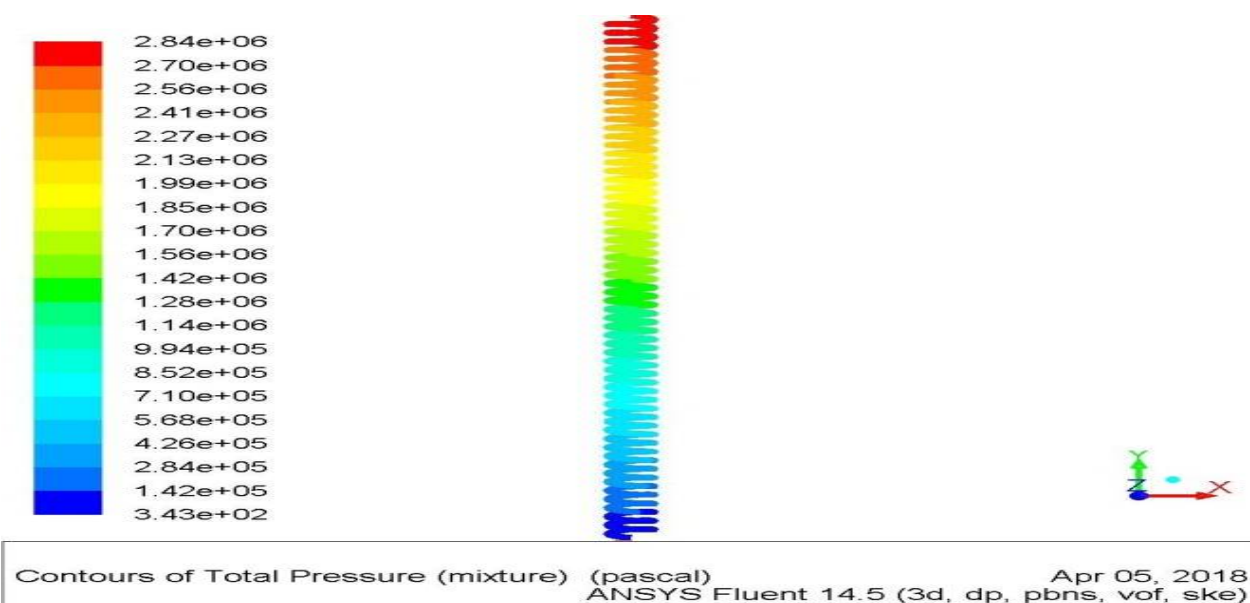


Figure-6 Total Pressure in Helical Coil using Zinc Oxide Nano-fluid using oil as its base fluid

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In the above figure the Pressure in helical coil starts from 343 Pa and the maximum pressure in Helical Coil while using Zinc Oxide nano-fluid using oil as it base is 2840143 Pa.

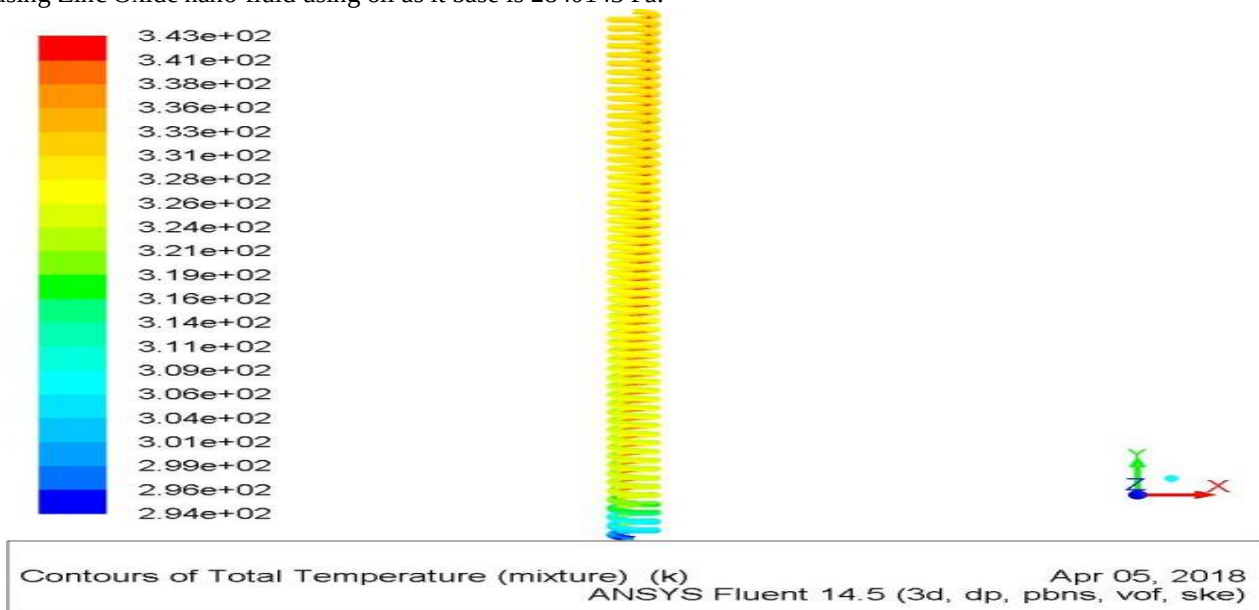


Figure-7 Temperature Distribution in Helical Coil using Manganese Oxide Nano-fluid using oil as its base fluid

In the above figure the when the pressure is 258 Pa then the Temperature is 294K and when the coil have maximum pressure then the maximum temperature is 333.2K

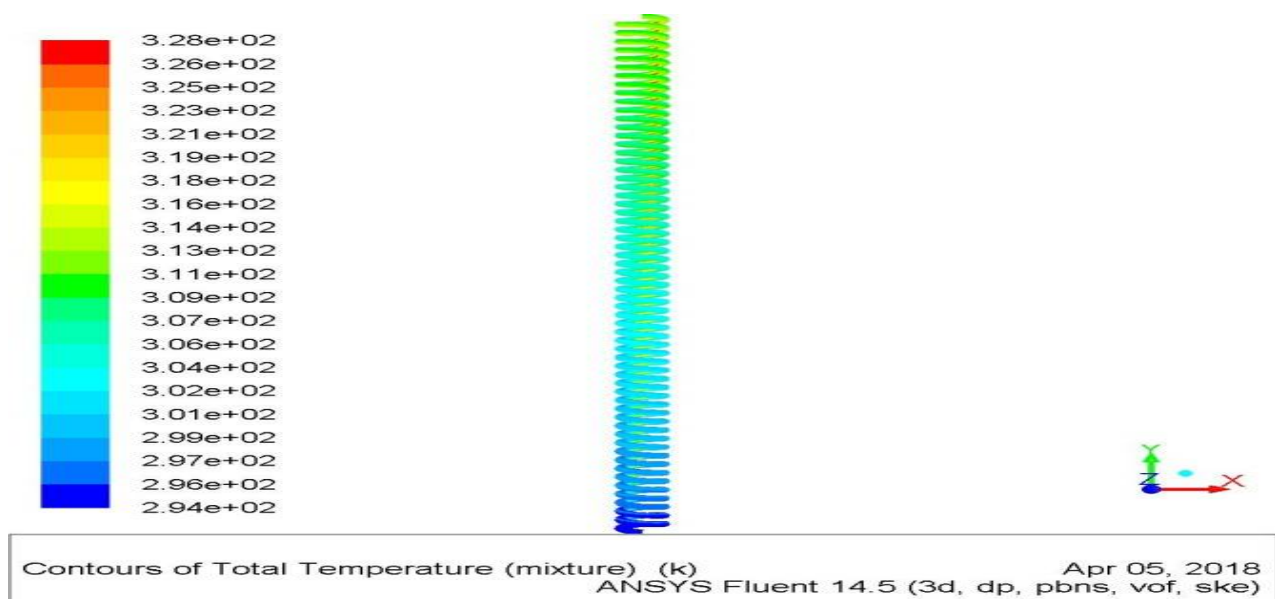


Figure-8 Temperature Distribution in Helical Coil using Silicon Dioxide Nano-fluid using oil as its base fluid

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In the above figure the when the pressure is 282 Pa then the Temperature is 294K and when the coil have maximum pressure then the maximum temperature is 314.4K

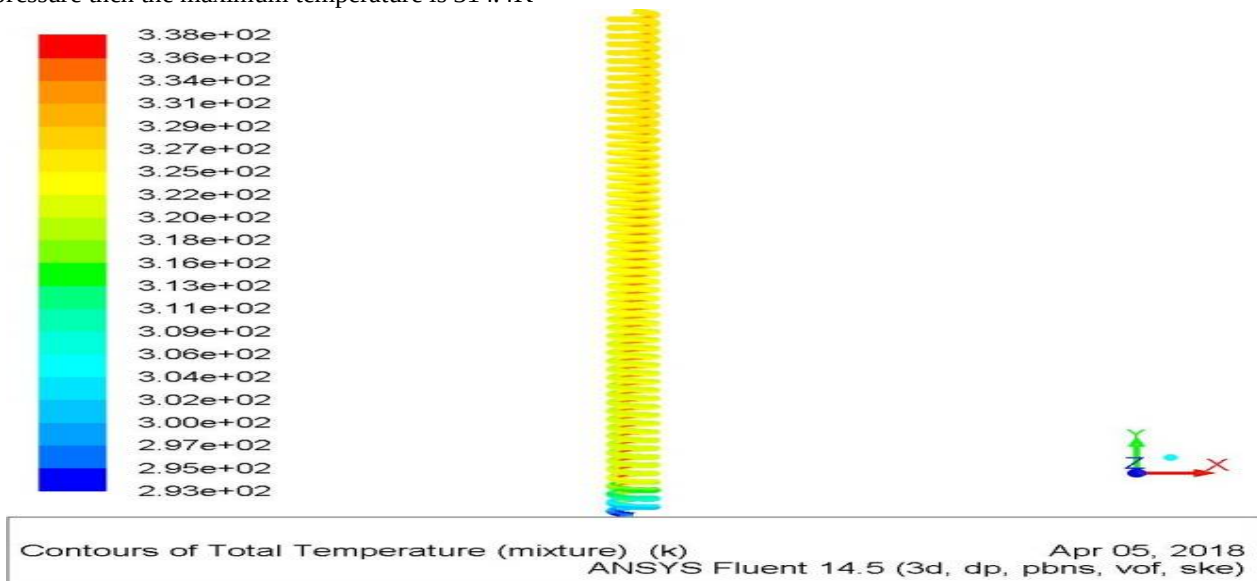


Figure-9 Temperature Distribution in Helical Coil using Zinc Oxide Nano-fluid using oil as its base fluid

In the above figure the when the pressure is 343 Pa then the Temperature is 293K and when the coil have maximum pressure then the maximum temperature is 328.6K

Table-1 CFD Analysis Result of Nano-fluid

Nano-fluid	Maximum Pressure	Temperature at Max. Pressure
ZnO	2840143 Pa	328.6 K
SiO ₂	2220293 Pa	314.4 K
MgO	1987229 Pa	333.2 K

From above it is clear that when we used the nano-fluid the pressure drops is higher in ZnO nano-fluid with oil as its base fluid. The numerical study considers the effect of nano-fluid such as Zinc Oxide (ZnO), Manganese Oxide (MgO) and Silicon Dioxide (SiO₂) on the flow and heat transfer characteristics of tube. The thermal properties of other nano-fluid are lesser as compared to Zinc oxide nano-fluid. Zinc Oxide has 2840143 Pa on 328.6 K temperature. 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. In this Research we are using oil as its base fluid which gives high pressure drop as compared to water.

VI.CONCLUSION

In this paper, analytical investigations are done on the helical coil heat exchanger, to determine pressure drop and temperature distribution of Manganese oxide, Silicon Dioxide and Zinc oxide nano-fluid on copper helical coil, flowing under laminar flow conditions. By observing the CFD analysis results, we found that the nano-fluid which has high thermal conductivity and specific heat that fluid will give high pressure drop. As compare to water the oil is used as base fluid oil and creates more pressure. The pressure drop is more when Zinc oxide nano-fluid flow is used.

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REFERENCES

1. Arvind Kumar Pathak, Yogesh Kumar Tembhurne, MohitGangwar, "Comparison on CFD Analysis of Natural Fluid and Nano Fluid in Helical Coil Heat Exchanger" International Journal of Innovative Science and Research Technology, Volume 2, Page 83-90, 2017.
2. Vijaykant Pandey, Dinesh Kumar Koli, "CFD analysis of helical coil heat exchanger" International Journal of Engineering Associates, Volume 4, Page 95-99, 2015.
3. Hemasunder Banka, Dr. V. Vikram Reddy, M. Radhika, "CFD Analysis of Shell and Tube Heat Exchanger using Titanium Carbide, Titanium Nitride and Zinc Oxide Nanofluid" International Journal of Innovations in Engineering and Technology, Special Issue, Page 315-322, 2016.
4. K. Abdul Hamid, W. H. Azmi, RizalmanMamat, N. A. Usri and GohalamhassanNajafi, "Effect of Titanium Oxide Nanofluid Concentration on Pressure drop" ARPJ Journal of Engineering and Applied Sciences, Volume 10, Page 7815-7820, 2015
5. T. Srinivas, A. VenuVinod, "Heat Transfer Enhancement using CuO/Water Nanofluid in a Shell and Helical Coil Heat Exchanger" Elsevier, Volume 127, Page 1271-1277, 2015.
6. Fakoor-Pakdaman, M.A. Akhavan- Behabadi,P. Razi, "An empirical study on the pressure drop characteristics of Nanofluid flow inside helically coiled tubes" International Journal of Thermal Sciences, Volume 65, Page 206-213, 2013.
7. Shiva Kumar, K VasudevKaranth, "Numerical analysis of a Helical Coiled Heat Exchanger using CFD" International Journal of Thermal Technologies, Volume 3, Page 126-130, 2013.
8. M. Balachandaran, "Experimental and CFD study of a Helical Coil Heat Exchanger using Water as Fluid" International Journal of Mechanical and Production Engineering, Volume 3, Page 87-91, 2015.
9. Vinita Sisodiya, Dr. AnkurGeete, "Heat Transfer analysis of Helical coil Heat Exchanger with Al_2O_3 Nanofluid" International Journal of Engineering and Technology, Volume 3, Page 366-370, 2016.
10. Jayakumar J. S., S.M. Mahajani, J.C. Mandal, P.K. Vijayan, RohidasBhoi, "Experimental and CFD estimation of heat transfer in helically coiled heat exchangers" Chemical Engineering Research and Design, Volume 86, Page 221-232, 2008.
11. Sarit Kumar Das, Stephen U. S. Choi, Hrishikesh E Patel, "Heat Transfer in Nano fluids -A Review" Heat Transfer Engineering, Volume 27, 2006.
12. <http://engglearning.blogspot.in/2011/03/helical-spring.html>
13. Prof. Alpesh Mehta, Dinesh k Tantia , Nilesh M Jha , Nimit M Patel, "Heat Exchanger using Nano Fluid" International Journal of Advanced Engineering Technology, Volume 3, Page 49-54, 2012.
14. Amol Bari, HemantBhutte, NirmalWaykole, AjeetYadav, Swapnil Mane, "Study of tube in tube concentric parallel flow heat exchanger using Nano fluid" International Journal of Advanced Research, Volume 4, Page 1376-1383, 2016
15. Kevin Kunnassery, Rishabh Singh, Sameer Jackeray, "Experimental analysis of helical coil heat exchanger by using different compositions of nano fluids" International Journal of Innovative and Emerging Research in Engineering, Volume-4, Page 219-229, 2017.
16. S. Bahrehmand, M.Abbassi, "Heat transfer and performance analysis of nanofluid flow in helically coiled tube heat exchangers" Elsevier, Page 628-637, 2016.
17. Amitkumar S. Puttewar , A.M. Andhare, "Design and thermal evaluation of Shell and Helical coil Heat exchanger" International Journal of Research in Engineering and Technology, Volume-4, Page 416-423, 2015.
18. RamdasAnantRaoGaddekar, Sanjay Kumbhare, "Experimental Investigation for Thermal Conductivity Enhancement of Ethylene Glycol Based Nano fluid Containing ZnO Nanoparticles" International Journal for Research in Applied Science and Engineering Technology, Volume 3, Page 206-212., 2015.
19. PramodDeshmukh, Vikram D Patil, Prof. BaviskarDevakant, "CFD analysis of heat transfer in helical coil tube in tube heat exchanger" International Journal of Innovation in Engineering Research and Technology, Volume 3, Issue 1, 2016.