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RESEARCH ARTICLE

CFD ANALYSIS COMPARISON OF TAPERED HELICAL AND SQUARE COIL HEAT EXCHANGER BU USING DIFFERENT TYPES OF NANOFLUID WITH OIL AS ITS BASE FLUID IN ALUMINIUM AND COPPER TUBE

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ABSTRACT

The recovery of waste heat has been a topic of concern for large-scale industrial companies for several decades. This recovery not only makes an operation more environment friendly, but it also helps to cut costs. In addition to this, it can reduce the amount of resources needed to power a facility. Many industries have implemented different methods of waste heat recovery. In this present paper the efforts are made to understand that how to compare the heat transfer rate in Copper and aluminium tapered helically coiled tube heat exchanger using different types of Nano fluid with Oil as a base fluid in Tapered Helical Coil Heat Exchanger with the help of CFD on copper and aluminium tube. TheAl_2O_3&MgO, are used as Nano fluid and oil as a base fluid. Tapered Helical coil was fabricated by bending 500 mm length of copper tube having 10mm tube diameter, 50mm pitch coil diameter, 20mm pitch and tapered angle 2^0 and Square shaped coil was fabricated by bending 500 mm length of copper tube having 10mm square side, 50mm pitch coil dia, 20 mm pitch and tapered angle 2^0. The comparison of pressure drop and temperature variation between MgO and Al_2O_3nano fluid with oil as its base in aluminium and copper tube found in this analysis. The result indicates that the MgO nanofluid with oil as a base fluid in helical copper tube have maximum pressure drop and also have maximum temperature variation compare with other nano fluid and other material.

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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. A helical coil are necessary for various heat exchangers, nuclear reactors and in chemical engineering, because of large quantity of heat is transferring in a small space with high heat transmission rates and slight residence time dispersals even it suffers through a disadvantage of larger pressure drop. 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.

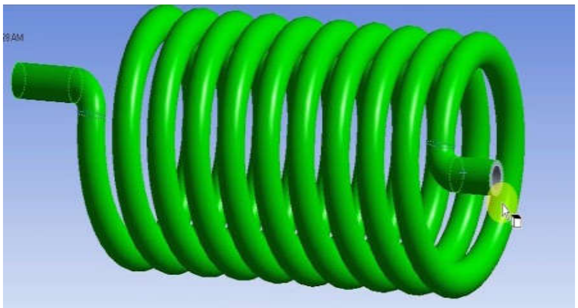

Figure 1. Helical Coil Heat Exchanger [24]

APPLICATIONS OF HELICAL COIL

Applications of helical coil heat exchangers in various heat transfer applications are:

- Helical coils are used for transmitting heat in chemical industries because of high heat transfer coefficient as compared to other configurations.
- Due to compact shape they can be recycled in heat transfer applications with space limitations, for e.g. marine cooling systems, cooling of lubricating oil, steam generation in marine system and industrial applications.
- Helically coiled tubes are broadly used in cryogenic industry for the liquefaction of gases.
- The helical coil heat exchangers are used in food beverage industries like in food treating and pre-heating, for storing them at desired temperatures and pasteurization of liquid food objects.
- Helical coil heat exchangers are also used as condensers in HVACs.
- Helical coils are used in hydrocarbon processing industries for recovery of CO2 & for cooling of liquid hydrocarbons.
- Also employed in polymer industries for cooling purposes.

NANO FLUID: Nowaday, 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.

- Brownian motion of nano particles.
- Liquid layering at the liquid/particle edge.
- Ballistic nature of heat transport in nano particles.
- 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.

GA Sheikhzadeh et al. [1] has done work onEffect of Al_2O_3-water nanofluid on heat transfer and pressure drop in a three-dimensional micro-channelafter analysis of his work he found that Addition of nanoparticles increased average Nusselt number, which indicated higher heat transfer into the fluids. Thus nano-fluids could be a promising replacement for pure water in micro-channel where there is need to more efficient heat transfer

K. Abdul Hamid et al. [2] has done work on pressure drop for Oil (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.

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.

M. Balchandaran et al [4] 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.

AshkanAlimoradi et.al [5] has done his Investigation of exergy efficiency in shell and helically coiled tube heat exchangers. He presents exergy analysis for forced convection heat transfer in shell and helically coiled tube heat exchangers. The effect of operational and geometrical parameters on the exergy efficiency was investigated. Water is selected as the working fluid of both sides. Results show that, the efficiency decreases linearly with the increase of the fluids dimensionless inlet temperature difference. Based on the results, a correlation was developed to predict the efficiency for wide range of mass flow rates ratio (0.1 <Rm< 4), fluids dimensionless inlet temperature difference (0 < RT < 0.8), product of Reynolds numbers (3.31E+8 < (Rec. Resh) < 1.32E+9) and dimensionless geometrical parameters. According to this equation it was found that, the coil which has the maximum number of turns and minimum diameter is more efficient than other coils which have the same length and pitch.

Arvind Kumar Pathaket al. [6] 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 gives more pressure drop on Zinc oxide Nano fluid as compared to other tubes and fluids.

B. Sidda Reddy et al. [7] studied helical tube heat exchanger as compared to straight tubular heat exchanger in both counter flow and parallel flow by variable parameters like pitch, mass flow rate , temperature and pitch coil diameter. He use outside diameter of stainless steel cylinder of 63.5 mm and inside diameter of stainless steel cylinder 1.058D mm, thickness of tube vary from 6 mm to 9 mm, flow rate of cold and hot water is taken 0.0625 kg/s and 0.166 kg/s. The initial temperature of cold and hot water is 300C and 1000C is taken. Result show that heat transfer increase in counter flow configuration when hot fluid mass flow rate is increased. Increase in pitch coil diameter decreases the rate of heat transfer at same configuration and at same mass flow rate. Also if the coil pitch increases there is decrease in heat transfer at same mass flow rate. Helical coils ensuring larger surface area which allows the fluid to be interacting with the walls for greater period of time. So that there is enhancement in heat transfer as compare to that of straight pipe.

KarishmaJawalkar et al. [8] has done CFD analysis of Manganese oxide, Silicon Dioxide and Zinc oxide nano-fluid on copper helical coilby using oil as a base fluid, She fabricated a copper coilhelical coil of 1000 mm length, 50mm PCD, pitch of 15 mm, and the diameter of tube is 8 mm made in Solid works, she observed after doing CFD analysis 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.

K Palanisamy [9] investigates the heat transfer and the pressure drop of cone helically coiled tube heat exchanger using (Multi wall carbon nano tube) MWCNT/water nanofluids. The MWCNT/water nanofluids at 0.1%, 0.3%, and 0.5% particle volume concentrations were prepared with the addition of surfactant by using the two-step method. The tests were conducted under the turbulent flow in the Dean number range of 2200 < De < 4200. The experiments were conducted with experimental Nusselt number is 28%, 52% and 68% higher than water for the nanofluids volume concentration of 0.1%, 0.3% and 0.5% respectively. It is found that the pressure drop of 0.1%, 0.3% and 0.5% nanofluids are found to be 16%, 30% and 42% respectively higher than water.

Shiva Kumar et al [10] 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.

T. Srinivas et al. [11] 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 & 50^0C). 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.

Vinita Sisodiya et al. [12] 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 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.

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.

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

SOLUTION

- **Solution Method:** Choose the Solution method to solve the problem i.e. First order, second order.
- **Solution Initialization:** Initialized the solution to get the initial solution for the problem.
- **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 15

Pre-processing:

CAD Model: Generation of 3D model by using SOLIDWORKS and exporting to the IGES format and then import in ANSYS fluent 15.

CAD modelling / meshing has been done by following steps

- Open Solid works then select part for modelling.
- In part modelling select circle of 50 mm diameter.
- After that select helix geometry of pitch 20 mm, tapered angle 2^0 and length 500 mm,same for square.
- Now again come to circle command and at the end of helix pierce it.

Then select sweep command and in sweep command selecting tube then click to curve and geometry came.

Table 1. Parameters of Geometry of Helical Coil

S.No.	Dimensional Parameters	Dimensions
1	Pitch Coil Diameter	50 mm
2	Tube Diameter	10 mm
3	Pitch	20 mm
4	Tube Length	500 mm
5	Tapered angle	2^0

Table 2. Parameters of Geometry of Square Coil

S.No.	Dimensional Parameters	Dimensions
1	Pitch Coil Diameter	50 mm
2	Side of square	10 mm
3	Pitch	20 mm
4	Tube Length	500 mm
5	Tapered angle	2^0

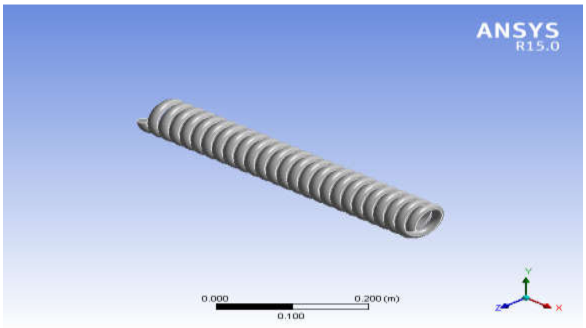

Figure 2. 3D model of tapered helical coil heat exchanger with PCD 50 mm, tapered angle $2^0$and tube diameter 10 mm

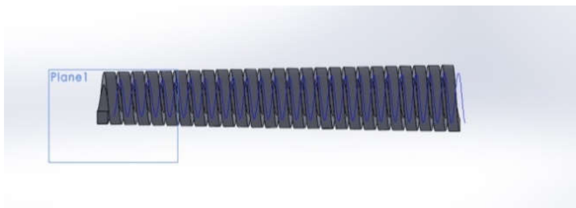

Figure 3 : 3D model of square coil heat exchanger with PCD 50 mm, tapered angle $2^0$and tube diameter 10 mm

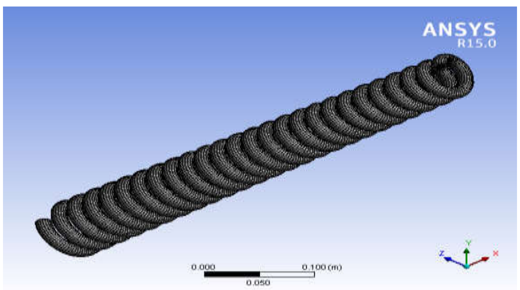

Figure 4: Meshing of Helical Coil HeatExchanger

Mesh type	Fine grid mesh
No. of nodes	160447
No. of elements	130754

Table 3. Helical Coil Meshing Statistics

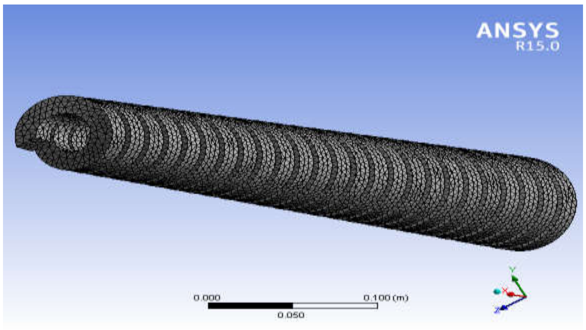

Figure 5. Meshing of Square Coil Heat Exchanger

Table 4. Square Coil Meshing Statistics

Mesh type	Fine grid mesh
No. of nodes	200489
No. of elements	167698

STEP 3

Fluent Setup: After mesh setup generation define the following steps in the ANSYS fluent 15.

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

STEP 4

Fluid Property

Table 5. Properties of Oil

Type of fluid	Oil
Density (ρ)	800 kg/m^3
Viscosity (μ)	0.2 kg/m-s
Specific heat (Cp)	1.67 KJ/Kg-K
Thermal conductivity (k)	0.162 Watt/mK

Table 6. Properties of Magnesium oxide

Type of fluid	MgO Nanofluid
Density (ρ)	3600 kg/m^3
Viscosity (μ)	0.00189 kg/m-s
Specific heat (Cp)	0.88 KJ/Kg-K
Thermal conductivity (k)	30 Watt/mK

Table 7. Properties of Alumina

Type of fluid	Al_2O_3Nanofluid
Density (ρ)	3600 kg/m3
Viscosity (μ)	0.00184 kg/m-s
Specific heat (Cp)	0.765 KJ/Kg-K
Thermal conductivity (k)	36 Watt/mK

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 AND DISCUSSION

The pressure drop data were collected for the configuration of taperedhelical and tapered square coil for the MgO and Al_2O_3 nanofluid as oil its base in aluminium and copper tube. The various effects were observed.

- CFD computations were done for copper coiled tube.
- CFD computations were done for aluminium coiled tube.
- Performance parameters adopted for comparison of pressure drop and temperature distribution in all the cases.
- Effect of pressure drop on the tapered helical coil made by aluminium using Al_2O_3 nanofluid andoil as its base fluid.

Table 9. Effect of pressure drop on the taperedaluminium helical coil by using Al_2O_3 nanofluid as oil as its base fluid.

Case	Tube diameter	Fluid	Pressure drop (Pa)
1	10 mm	Al_2O_3 Nano fluid	225480

Effect of Temperature on the aluminium tapered helical coil by using Al_2O_3 nanofluid with oil as its base fluid on high pressure.

Table 10. Effect of Temperature on the taperedhelical coil by using Al_2O_3 nanofluid with oil as its base fluid on high pressure

Case	Tube diameter	Fluid	Temperature (K)
1	10 mm	Al_2O_3 Nano fluid	322

Effect of pressure drop on the tapered helical coil made by aluminium using MgO nanofluid and oil as its base fluid.

Table 11 . Effect of pressure drop on the tapered aluminium helical coil by using MgO nanofluid as oil as its base fluid.

Case	Tube diameter	Fluid	Pressure drop (Pa)
1	10 mm	MgO Nano fluid	228383

Effect of Temperature on the aluminium tapered helical coil by using MgO nanofluid with oil as its base fluid on high pressure.

Table 12. Effect of Temperature on the taperedhelical coil by using MgO nanofluid with oil as its base fluid on high pressure

Case	Tube diameter	Fluid	Temperature (K)
1	10 mm	MgO Nano fluid	323

Effect of pressure drop on the tapered helical coil made by copper using Al_2O_3 nanofluid and oil as its base fluid.

Table 13: Effect of pressure drop on the tapered copper helical coil by using Al_2O_3 nanofluid as oil as its base fluid.

Case	Tube diameter	Fluid	Pressure drop (Pa)
1	10 mm	Al_2O_3 Nano fluid	225343

Effect of temperature on the copper tapered helical coil by using Al_2O_3 nanofluid as oil as its base fluid on high pressure.

Table 14: Effect of temperature on the coppertapered helical coil by using Al_2O_3nanofluid as oil as its base fluid on high pressure

Case	Tube diameter	Fluid	Temperature (K)
1	10 mm	Al_2O_3Nano fluid	330

Effect of pressure drop on the copper tapered helical coil by using MgO nanofluid as oil as its base fluid

Table 15: Effect of pressure drop on the tapered copper helical coil by using MgO nanofluid as oil as its base fluid.

Case	Tube diameter	Fluid	Pressure drop (Pa)
1	10 mm	MgO Nano fluid	228981

Effect of temperature on the Copper tapered helical coil by using MgO nanofluid as oil as its base fluid on high pressure.

Table 16. Effect of temperature on the Copper tapered helical coil by using MgO nanofluid as oil as its base fluid on high pressure

Case	**Tube diameter**	**Fluid**	**Temperature (K)**
1	10 mm	MgO Nano fluid	331

Effect of pressure drop on the tapered aluminium square coil by using Al_2O_3 nanofluid as oil as its base fluid.

Table 17. Effect of pressure drop on the tapered aluminium square coil by using Al_2O_3 nanofluid as oil as its base fluid

Case	Tube diameter	Fluid	Pressure drop (Pa)
1	10 mm	Al_2O_3Nano fluid	168584

Effect of temperature on the tapered aluminium square coil by using Al_2O_3 nanofluid as oil as its base fluid.

Table 18: Effect of temperature on the aluminium tapered square coil by using Al_2O_3 nanofluid as oil as its base fluid

Case	Tube diameter	Fluid	Temperature (K)
1	10 mm	Al_2O_3Nano fluid	318

Effect of pressure drop on the tapered aluminiumsquare coil by using MgO nanofluid as oil as its base fluid.

Table 19. Effect of pressure drop on the tapered aluminium square coil by using MgO nanofluid as oil as its base fluid

Case	Tube diameter	Fluid	Pressure drop (Pa)
1	10 mm	MgO Nano fluid	183797

Effect of temperature on the tapered aluminium quare coil by using MgO nanofluid as oil as its base fluid on high pressure.

Table 20. Effect of temperature on the tapered aluminium square coil by using MgO nanofluid as oil as its base fluid on high pressure.

Case	Tube diameter	Fluid	Temperature (K)
1	10 mm	MgO Nano fluid	320

Effect of pressure drop on the tapered copper square coil by using Al_2O_3 nanofluid as oil as its base fluid.

Table 21: Effect of pressure drop on the tapered copper square coil by using Al_2O_3 nanofluid as oil as its base fluid

Case	Tube diameter	Fluid	Pressure drop (Pa)
1	10 mm	Al_2O_3 Nano fluid	168782

Effect of temperature on the tapered copper square coil by using Al_2O_3 nanofluid as oil as its base fluid on high pressure.

Table 22. Effect of temperature on the square coil by using Al_2O_3 nanofluid as oil as its base fluid on high pressure.

Case	Tube diameter	Fluid	Temperature (K)
1	10 mm	Al_2O_3 Nano fluid	309

Effect of pressure drop on the tapered copper square coil by using MgO nanofluid as oil as its base fluid.

Table 23: Effect of pressure drop on the tapered copper square coil by using MgO nanofluid as oil as its base fluid.

Case	Tube diameter	Fluid	Pressure drop (Pa)
1	10 mm	MgO Nano fluid	170810

Effect of temperature on the copper tapered square coil by using MgO nanofluid as oil as its base fluid.

Table 24. Effect of temperature on the tapered copper square coil by using MgO nanofluid as oil as its base fluid.

Case	Tube diameter	Fluid	Temperature (K)
1	10 mm	MgO Nano fluid	312

Case-1 Tube Diameter is 10 mm, Al_2O_3nanofluid is used as oil as its base fluid in aluminium tapered helical coil, Pressure drop is 225480 Pa

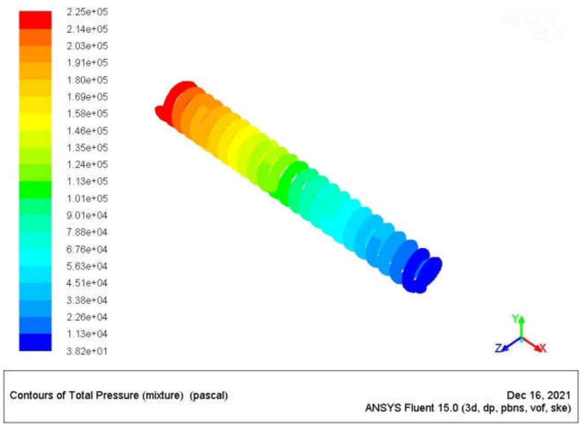

Figure 6 : Total Pressure in aluminium tapered helical coil using Al_2O3 nanofluid as oil as a base fluid

Case-2 Tube Diameter is 10 mm, MgO nanofluid is used as oil as its base fluid in aluminium tapered helical coil, pressure drop is 228383 Pa.

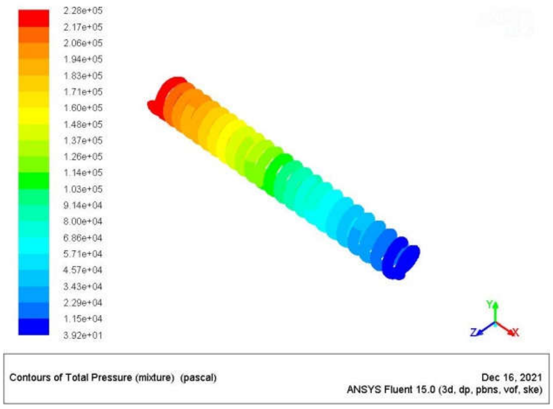

Figure 7. Total Pressure in aluminium taperedhelical coil using MgO as a nano fluid and oil as a base fluid

Case-3 Tube Diameter is 10 mm, Al_2O_3 nanofluid is used as oil as its base fluid in copper tapered helical coil, pressure drop is 225343 Pa.

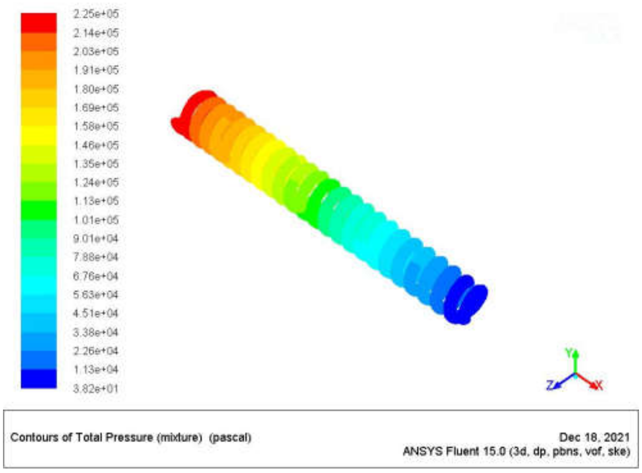

Figure 8 .Total Pressure in copper taperedhelical coil using Al_2O_3 as a nano fluid and oil as a base fluid.

Case-4 Tube Diameter is 10 mm, MgO nanofluid is used as oil as its base fluid in copper tapered helical coil, pressure drop is 228981 Pa.

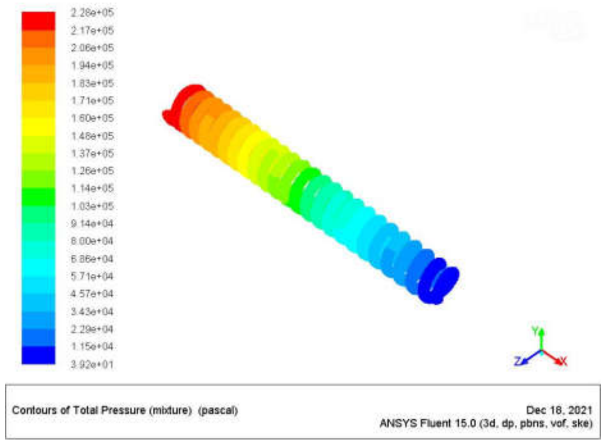

Figure 9. Total Pressure in copper taperedhelical coil using MgO as a nano fluid and oil as a base fluid

Case-5 Tube Diameter is 10 mm, Al_2O_3 nanofluid is used as oil as its base fluid in aluminium taperedsquare coil, pressure drop is 168584 Pa.

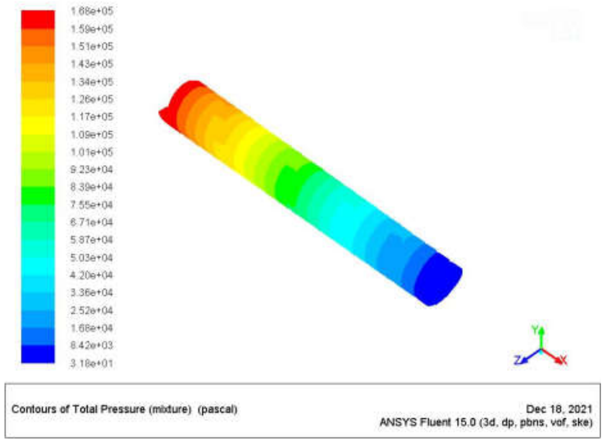

Figure 10. Total Pressure in aluminiumtapered square coil using Al_2O_3as a nano fluid and oil as a base fluid

Case-6 Tube Diameter is 10 mm, MgO nanofluid is used as oil as its base fluid in aluminium taperedsquare coil, pressure drop is 183797 Pa

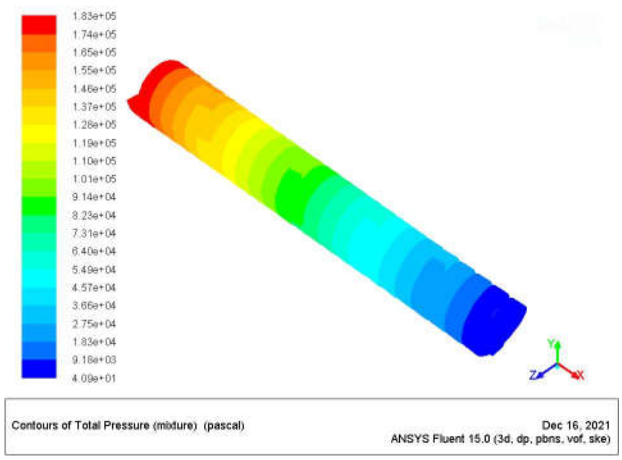

Figure 11. Total Pressure in aluminiumtapered square coil using MgO as a nano fluid and oil as a base fluid

Case-7 Tube Diameter is 10 mm, Al_2O_3nanofluid is used as oil as its base fluid in copper tapered square coil, pressure drop is 168782 Pa

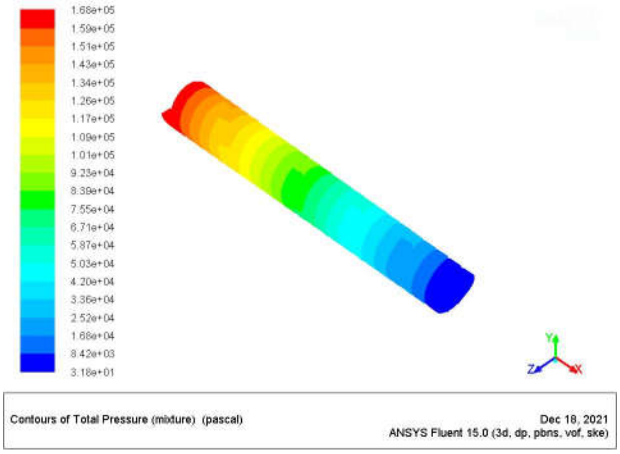

Figure 12. Total Pressure in copper taperedsquare coil using Al_2O_3 as a nano fluid and oil as a base fluid

Case-8 Tube Diameter is 10 mm, MgO nanofluid is used as oil as its base fluid in copper tapered square coil, pressure drop is 170810 Pa

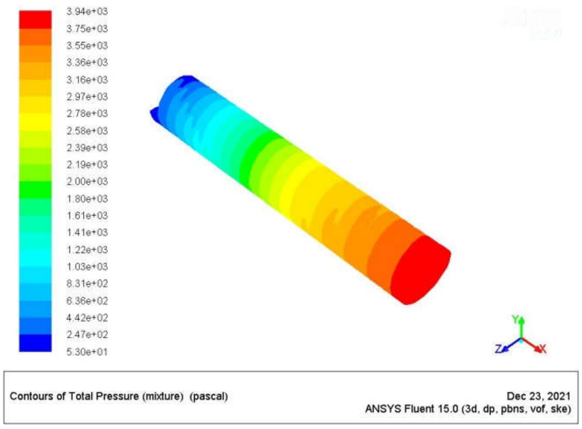

Figure 13. Total Pressure in copper tapered square coil using MgO as a nano fluid and oil as a base fluid

Case-9 Tube Diameter is 10 mm, Al_2O_3 nanofluid is used as oil as its base fluid in aluminium tapered helical coil, Max temperature is 322K

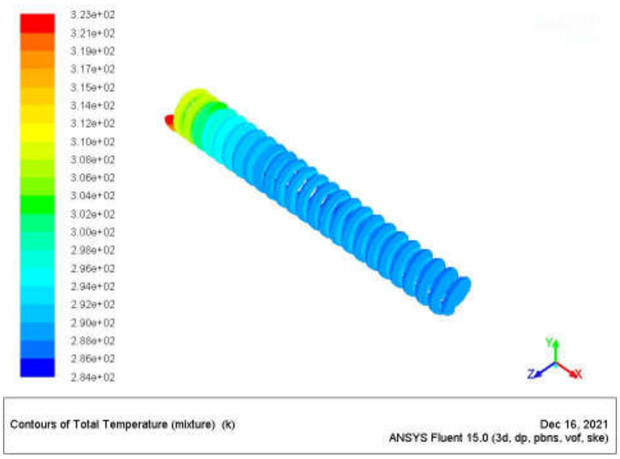

Figure 14. Distribution of temperature in Aluminiumhelical coil using Al_2O_3nanofluid using oil as its base.

Case-10 Tube Diameter is 10 mm, MgO nanofluid is used as oil as its base fluid in aluminium tapered helical coil, Max temperature is 323K

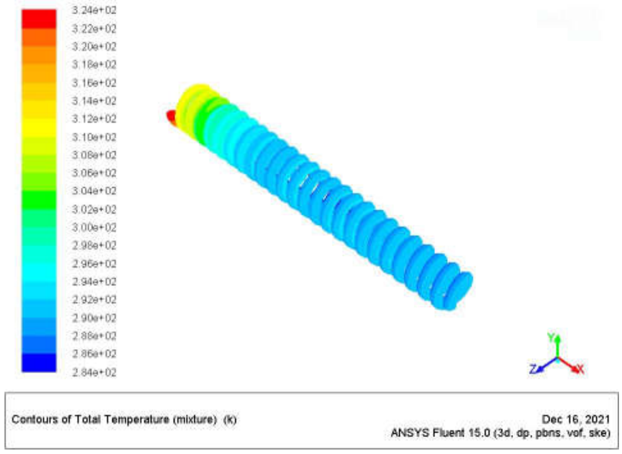

Figure 15. Distribution of temperature in Aluminium tapered helical coil using MgOnanofluid using oil as its base.

Case-11 Tube Diameter is 10 mm, Al_2O_3 nanofluid is used as oil as its base fluid in copper tapered helical coil, Max temperature is 330K.

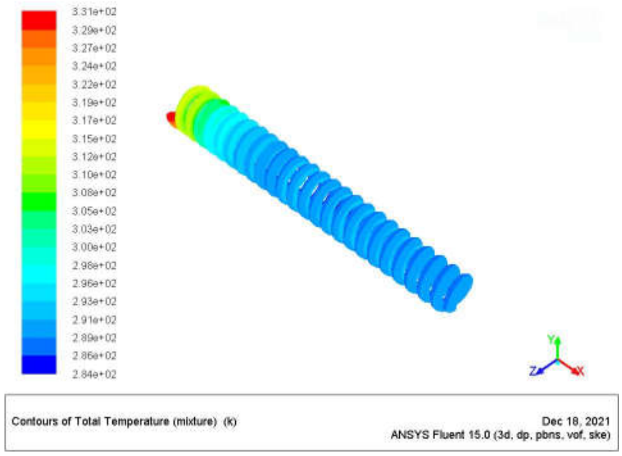

Figure 16. Distribution of temperature in Copper tapered helical coil using Al_2O_3nanofluid using oilas its base.

Case-12 Tube Diameter is 10 mm, MgO nanofluid is used as oil as its base fluid in copper tapered helical coil, Max temperature is 331K

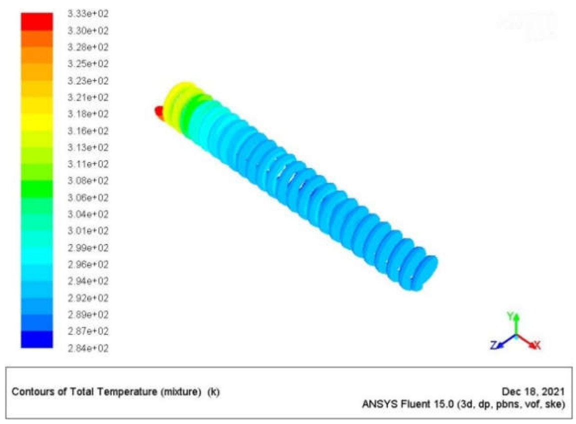

Figure 17: Distribution of temperature in Copper tapered helical coil using MgOnanofluid using oilas its base.

Case-13 Tube Diameter is 10 mm, Al_2O_3 nanofluid is used as oil as its base fluid in aluminium taperedsquare coil, Max temperature is 318K

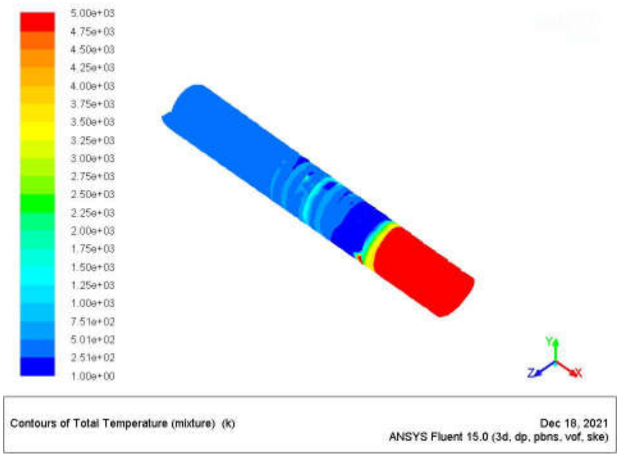

Figure 18: Distribution of temperature in aluminium tapered square coil using Al_2O_3nanofluid using oil as its base

Case-14 Tube Diameter is 10 mm, MgO nanofluid is used as oil as its base fluid in aluminium taperedsquare coil, Max temperature is 320K

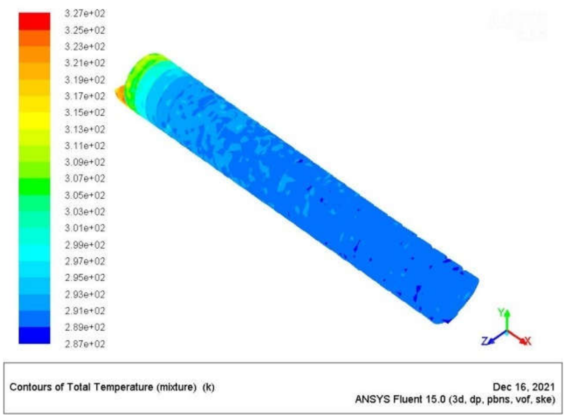

Figure 19. Distribution of temperature in Aluminium tapered square coil using MgOnanofluid using oil as its base.

Case-15 Tube Diameter is 10 mm, Al_2O_3 nanofluid is used as oil as its base fluid in copper tapered square coil, Max temperature is 309K

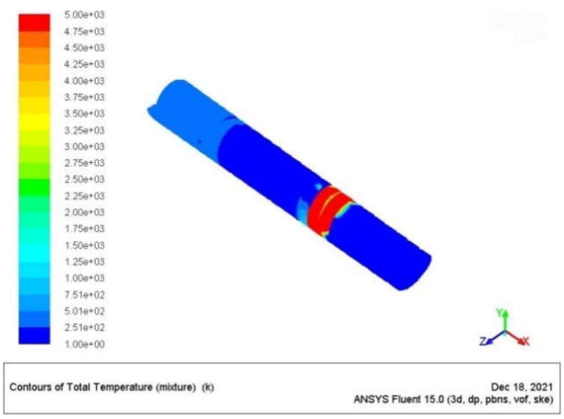

Figure 20. Distribution of temperature in Copper tapered square coil using Al_2O_3nanofluid using oilas its base.

Case-16 Tube Diameter is 10 mm, MgO nanofluid is used as oil as its base fluid in copper taperedsquare coil, Max temperature is 312K

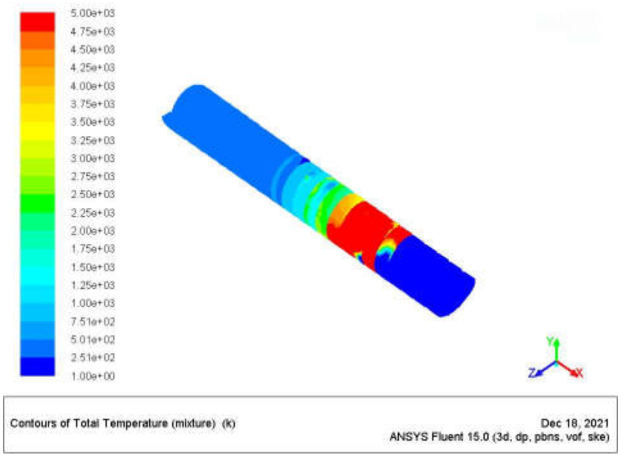

Figure 21: Distribution of temperature in Copper tapered square coil using MgOnanofluid using oilas its base.

From above it is clear that when we used the MgO nanofluid using oil as a base fluid in tapered helical coil then pressure drops increases in MgO because of presence of metal particles and the base fluid properties. The numerical study considers the effect of MgO nanofluid using oilas its base fluid and Al_2O_3 nanofluid using oil as its base fluid in copper and aluminium tube on the flow and heat transfer characteristics of tube.

CONCLUSION

In this paper, analytical investigations are done on the tapered helical and tapered square coil heat exchanger, to determine pressure drop and temperature distribution of an oil as a base fluid and a Al_2O_3 and MgO as a nanofluid on copper and aluminium tapered helical and aluminium and copper tapered square 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 and also a material which is good in its properties. The pressure drop is more in MgO nanofluid with oil as a base fluid in coppertaperedhelical coil heat exchanger.

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