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RESEARCH ARTICLE

COMPARISON ON CFD ANALYSIS OF TiO_2 NANOFLUID WITH WATER & ETHYLENE GLYCOL AS A BASE FLUID IN TAPERED 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. The study of this investigation is the comparison CFD Analysis of TiO_2 Nano-Fluid with Water and Ethylene Glycol as a base fluid in Tapered Helical Coil Heat Exchanger with the help of CFD on copper tube. The Titanium Oxide (TiO_2), are used as Nano fluid and water and ethylene glycol is a base fluid. Tapered Helical coil was fabricated by bending 500 mm length of copper tube having 10mm tube diameter, 50mm pitch coil diameter, 2^0mm pitch and 20 tapered angle. The comparison of pressure drop and temperature variation between TiO_2 nano fluid with water as its base and TiO_2 nanofluid with ethylene glycol as its base is found in this analysis. The result indicates that the TiO_2 nanofluid with ethylene glycol as a base fluid have maximum pressure drop and TiO_2 nanofluid with water as its base fluid have maximum temperature variation compare with ethylene glycol as a base fluid. A computational fluid dynamics (CFD) methodology using ANSYS FLUENT 15 is used here to investigate pressure drop of Titanium Oxide (TiO_2) nanofluid with ethylene glycol and water as its base fluid on the heat transfer characteristics in a tapered helically coil-tube.

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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.

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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.

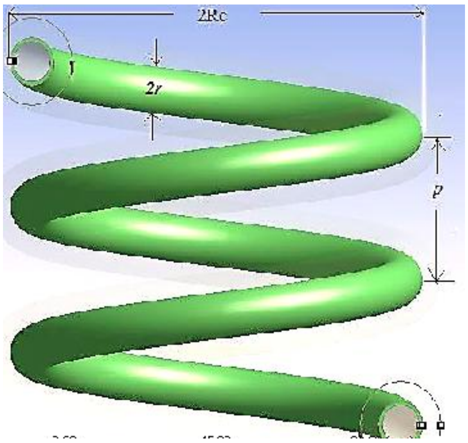

Figure 1. Helical Coil Heat Exchanger

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: Nowadays, 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.

THERMAL CONDUCTIVITY BOOST IN NANOFLUIDS

The boost of the thermal conductivity of nano-fluids above that of the base fluid is frequently a few times better than what would have been given by micro-meter sized suspensions. So distant, the base fluids used include water, ethylene glycol, transformer oil, and toluene. The nanoparticles that are used nowadays can be broadly divided into three groups: ceramic particles, pure metallic particles, and carbon nanotubes (CNTs). Diverse mixtures of the nano particles and fluids give nano-fluids. When the particles of the nanofluid are properly dispersed, then these features of nano-fluids are expected:

- Higher heat conduction: More heat will be transferred if the surface area of nanoparticles is larger. Particles of the nanofluid are finer than 20 nm and it carry 20% of their atoms on their surface. Thermal interaction will be available because of finer nanoparticles. Alternative benefit is the flexibility of the particles, attributable to the insignificant size, which may be carry about micro-convection of fluid and hence it improved heat transfer in heat exchanger. Dispersion of heat in the fluid will be increased at a faster rate because of the micro-convection and increasing heat transfer. If there will be increase in temperature then the thermal conductivity of nano-fluids increases significantly.
- Irregular enrichment of thermal conductivity: The most significant feature which was observed in nano-fluids was an irregular growth in thermal conductivity which was so far beyond opportunities and it is much advanced than any theory might predict.
- Stability: The particles in nano fluids are in nano size by which they weigh less and the probabilities of sedimentation are also a smaller amount. The particles can be settled and the nano fluids may be stable if the sedimentation is reduced but it is the foremost drawback of suspensions.
- Micro-channel cooling without clogging: Nano-fluids can not only a well medium for heat transfer, but it will also be perfect for micro-channel uses where high heat loads are faced. Highly leading fluid and a larger heat transfer area will be occurred by the mixture of micro-channels and nano-fluids. This cannot be reached with meso or micro-particles because they choke micro-channels.

Nanoparticles have only a hardly any hundreds or thousands of atoms which are the orders of magnitude and it is much slighter than the micro-channels.

- Reduced probabilities of erosion: Nanoparticles are very small in size, and the momentum they can report to a solid wall is much smaller. This reduced momentum reduces the probabilities of erosion of components like heat exchangers, pipelines and pumps.
- Small concentration and Newtonian behaviour: Large improvement of thermal conductivity was reached with a very small concentration of particles that will be completely maintained the Newtonian behaviour of the fluid. The increase in viscosity was minimal; hence, pressure drop was increased only marginally.
- Particles size necessity: The upgrading of thermal conductivity was found to depend if the situation is unlike with micro slurries and the thermal conductivity was not only on particle absorption but it also on particle size. In broad, there was as increase in thermal conductivity was observed with decreasing in particle size and it is the important feature which was observed in nano-fluids, distant beyond opportunities and considerably higher than any theory could predict.

LITERATURE REVIEW

KarishmaJawalkar et. al (1) has done her study on the comparison on CFD Analysis of Zinc oxide, Silicon dioxide and manganese oxide nano fluid using oil and water as a base fluid in a Helical Coil Heat Exchanger. A computational Fluid dynamics (CFD) methodology ANSYS FLUENT 15 is used here to investigate pressure drop of different nano-fluids (Zinc Oxide, Magnesium Oxide & SiliconDioxide) 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.

Sunil Kumar et al. (2) has done his investigation on the optimize design of helical coil heat exchanger by using fins and the Compare pressure & temperature by conventional design. The final outcome of the study increase the total heat transfer rate inside the domain. And increase the pressure drop inside the domain. The water outlet temperature decrease up to 315k and cold outlet temperature increase up to 320 k. and total pressure drop increase with the temperature increases. Finally the CFD data were compared with previous data the total pressure drop increase up to 0.65 bar for case-2.the overall efficiency of the system incites up to 5% to 6%.

Arvind Kumar Pathak et al. (3) 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 (TiO2) 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 of 15 mm and coil diameter is 35 mm. He has done his work on 0.05 kg/s mass flow rate. He found that aluminium coil give more pressure drop on Zinc oxide Nano fluid as compared to other tubes of aluminium and copper and also water, titanium oxide nanofluids. Vijaykant Pandeyet. al. (4) has completed his study on the outcome of geometrical parameters on heat transfer in helical coil heat exchanger at three dissimilar mass flow rate 0.005, 0.02 and 0.05 kg/s. Helical coil was made-up by bending 1000 mm length of aluminium tube having 6,8,10 mm tube diameter and each period coil diameter should be 40 mm and at equivalent pitch 15 mm and at same length. The relation between pressure drop and mass flow rate has been gained for three different curvature ratio 0.15, 0.2, 0.25 at three dissimilar mass flow rates. The result displays 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 growth 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 upsurges heat transfer in helical coil heat exchangers. The upsurge in heat transfer are a consequences of curvature of the coil which encourages centrifugal force to act on moving fluid ensuing in development of secondary flow.

K. Abdul Hamid et. al. (5) has done work on pressure drop for Ethylene Glycol (EG) based nanofluid. The nanofluid is prepared by dilution technique of TiO2 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 TiO2 nanofluid pressure drop is compared with the Blasius equation for based fluid. It was observed that pressure drop increase with increasing of nanofluid volume concentration and decrease with increasing of nanofluid temperature insignificantly. He found that TiO2 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.

Palanisamy et. al (6) observes the heat transfer and the pressure drop of cone helically coiled tube heat exchanger by (Multi wall carbon nano tube) MWCNT/water nanofluids. The MWCNT/water nanofluids at 0.1%, 0.3%, and 0.5% atom volume absorptions were equipped with the calculation of surfactant by using the two-step method. The investigations were showed under the turbulent flow in the Dean number range of 2200 <De <4200. The tests were attended with tentative 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 originate that the pressure drop of 0.1%, 0.3% and 0.5% nanofluids are found to be 16%, 30% and 42% respectively more than water.

Hemasunder Banka et. al. (7) has done an methodical investigation on the shell and tube heat exchanger by forced convective heat transfer to determine flow physical appearance of nano fluids by fluctuating volume fractions and mixed with water, the nano fluids are titanium carbide (TiC), titanium nitride (TiN) and ZnO nanofluid and dissimilar volume concentrations (0.02, 0.04, 0.07 & 0.15%) flowing under turbulent flow conditions. CFD analysis is done on heat exchanger by relating 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 growing by cumulative the volume fractions.

Shiva Kumar et al (8) have controlled on both straight tube and helical tube heat exchanger. He has compared CFD results with the results found by the replication of straight tubular heat exchanger of the same length under identical operating conditions. Results specified that helical heat exchangers showed 11% increase in the heat transfer rate over the straight tube. Simulation results also presented 10% increase in nusselt number for the helical coils whereas pressure drop in circumstance of helical coils is higher when compared to the straight tube.

COMPUTATIONAL FLUID DYNAMICS: Computational simulation is technique for examiningfluid flow, heattransfer and relatedphenomenasuch as chemicalreactions. This project uses CFD for analysis of flow and heattransfer. CFD analysisaccepted out in the numerous industries isused in R&D and manufacturing of aircraft, internal combustion engines and in power plant combustion as well as in manyindustrial applications. The advancement in the high speed computers and the computationalfluiddynamics (CFD) has a great impression on the engineering strategy and survey of the heatexchangers. In the previousdecades, explain compound geometry and complex drift problem to increasingcapability of design and examination and for decreasing the cost and time. The CFD methodology has appear to become an effective approach for collecting information to improve engineering design and investigation of heatexchangers.

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 20 and length 500 mm.
- 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

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

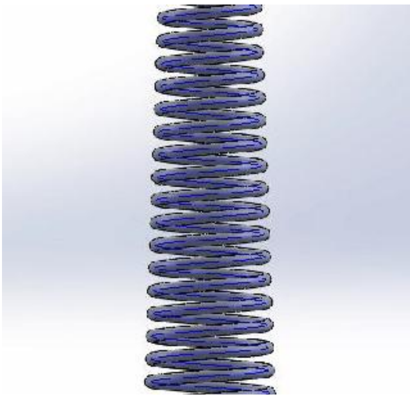

Figure 2. 3D model of helical coil heat exchanger with PCD 50 mm, tapered angle 2^0 and tube diameter 10 mm

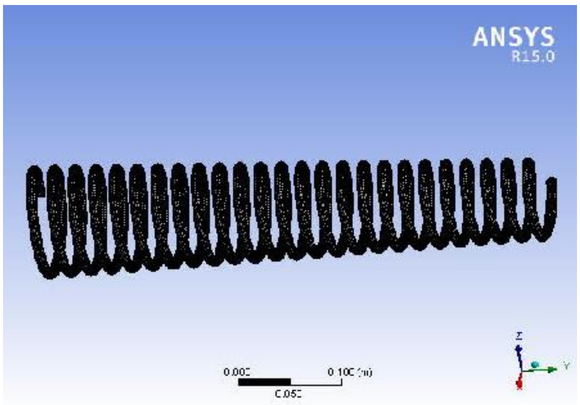

Figure 3. Meshing of Tapered Helical Coil Heat Exchanger

Table 2. Meshing Statistics

Mesh type	Fine grid mesh
No. of nodes	306306
No. of elements	257633

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 3. Properties of Water

Type of fluid	Water
Density (ρ)	998.2 kg/m3
Viscosity (μ)	0.0010003 kg/m-s
Specific heat (Cp)	4.182 KJ/Kg-K
Thermal conductivity (k)	0.6 Watt/K

Table 4. Properties of Titanium Oxide

Type of fluid	Titanium Oxide Nanofluid
Density (ρ)	1109.12 kg/m3
Viscosity (μ)	0.00189 kg/m-s
Specific heat (Cp)	3.350 KJ/Kg-K
Thermal conductivity (k)	0.538 Watt/K

Table 5. Properties of Ethylene Glycol

Type of fluid	Ethylene Glycol
Density (ρ)	1111.4 kg/m3
Viscosity (μ)	0.0157 kg/m-s
Specific heat (Cp)	2.415 KJ/Kg-K
Thermal conductivity (k)	0.252 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 tapered helical coil for the TiO_2 nanofluid as water its base and TiO_2 nanofluid as ethylene glycol as its base fluid. The various effects of mass flow rate and the tube diameter were observed.

- CFD computations were done for copper helical coiled tube.
- Performance parameters adopted for comparison of pressure drop and temperature distribution in all the cases.
- Effect of pressure drop on the copper coil by using TiO_2 nanofluid as water as its base fluid.

Table 5. Effect of pressure drop on the copper 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	1994

5. Effect of Temperature on the copper coil by using TiO_2 nanofluid with water as its base fluid on high pressure.

Table 6. Effect of Temperature on the copper coil by using TiO_2 nanofluid with water as its base fluid on high pressure

Case	Tube diameter	Fluid	Temperature (K)
1	10 mm	TiO2 Nano fluid	339

6. Effect of Temperature on the copper coil by using TiO_2 nanofluid with ethylene glycol as its base fluid on high pressure

Table 7. Effect of Temperature on the copper coil by using TiO_2 nanofluid with ethylene glycol as its base fluid on high pressure

Case	Tube diameter	Fluid	Temperature (K)
1	10 mm	TiO2 Nano fluid	338

Case-1 Tube Diameter is 10 mm, TiO_2 nanofluid is used as water as its base fluid in copper helical coil, Pressure drop is 1994 Pa

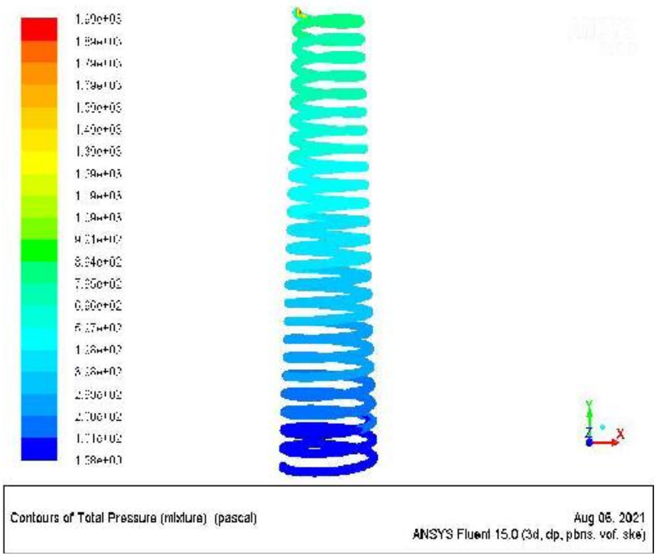

Figure 4. Total Pressure in copper helical coil using water as a fluid

Case-2 Tube Diameter is 10 mm, TiO_2 nanofluid is used as ethylene glycol as its base in copper tapered helical coil, pressure drop is 5028 Pa.

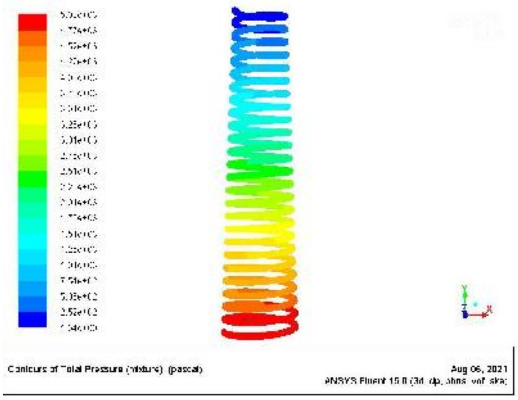

Figure 5 . Total Pressure in copper tapered helical coil using TiO_2 as a nano fluid and ethylene glycol as a base fluid

Case-3 Tube Diameter is 10 mm, TiO_2 nanofluid is used as water as its base fluid in copper helical coil, Max temperature is 339K

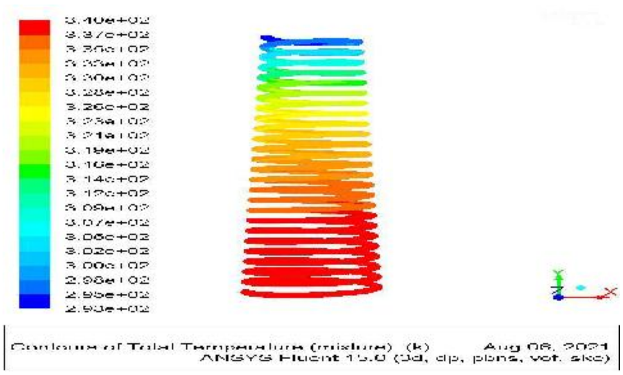

Figure 6. Distribution of temperature in Copper tapered helical coil using TiO_2 nanofluid using water as its base

Case-4 Tube Diameter is 10 mm, TiO_2 nanofluid is used as ethylene glycol as its base in copper tapered helical coil, maximum temperature is 338K

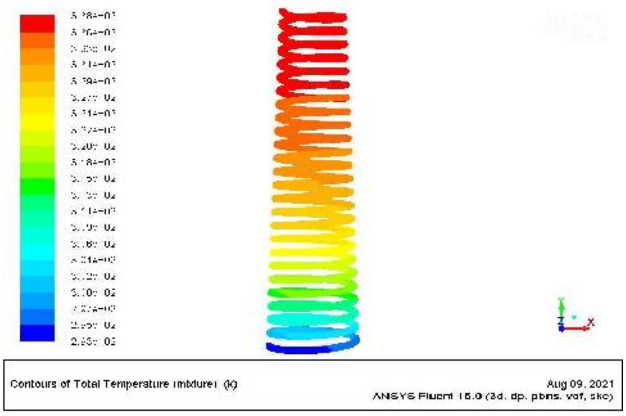

Figure 7. Distribution of temperature in Copper tapered helical coil using TiO2 nanofluid using ethylene glycol as a base fluid

From above it is clear that when we used the TiO_2 nanofluid using ethylene glycol as a base fluid then pressure drops increases in TiO_2 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 and TiO_2 nanofluid using ethylene glycol as its base fluid on the flow and heat transfer characteristics of tube. The thermal belongings of fluid are minor as compared to nanofluid. Nano fluids have Nano particles of solid constituents which increase the thermal properties of Nano fluid also because of vortex flow the pressure drop will be enlarged.

CONCLUSION

In this paper, analytical investigations are done on the tapered helical coil heat exchanger, to determine pressure drop and temperature distribution of water fluid, ethylene glycol and a titanium oxide nanofluid on copper 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 titanium oxide nanofluid with ethylene glycol as a base fluid in tapered helical coil heat exchanger is used.

REFERENCES

1. KarishmaJawalkar, VijaykantPandey, PoonamWankhede 2018. Comparison on Computational Fluid Dynamics Analysis of Zinc Oxide, Silicon Dioxide and Magnesium Oxide Nano fluid using oil as a base fluid in Helical Coil Heat Exchanger‖, International Journal of Innovative Research in Science, Engineering & Technology, Volume 7, Page 2777-2786.
2. Sunil Kumar, Dr. DK Gupta 2020. Optimising Design and analysis on the Helically Coiled Tube Heat Exchanger carrying Nanofluids by providing fins‖ Smart Moves Journal IJO Science, Volume 6, Page 23-31.
3. Arvind Kumar Pathak, Yogesh Kumar Tembhurne, MohitGangwar 2017. 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.
4. VijaykantPandey, Dinesh Kumar Koli 2015. CFD analysis of helical coil heat exchanger‖ International Journal of Engineering Associates, Volume 4, Page 95-99.
5. K. Abdul Hamid, W. H. Azmi, RIzalmanMamat, N. A. Usri and GohalamhassanNajafi 2015. Effect of Titanium Oxide Nanofluid Concentration on Pressure drop‖ ARPN Journal of Engineering and Applied Sciences, Volume 10, Page 7815-7820.
6. Palanisamy, K. P.C. Mukesh Kumar 2019. Experimental investigation on convective heat transfer and pressure drop of cone helically coiled tube heat exchanger using carbon nanotubes/ water nanofluids‖, Elsevier – Heliyon 5.
7. Hemasunder Banka, Dr. V. Vikram Reddy, M. Radhika 2016. 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.
8. Shiva Kumar, K VasudevKaranth 2013. Numerical analysis of a Helical Coiled Heat Exchanger using CFD‖ International Journal of Thermal Technologies, Volume 3, Page 126-130.
9. M. Balachandaran 2015. 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.
10. Vinita Sisodiya, Dr.AnkurGeete 2016 ―Heat Transfer analysis of Helical coil Heat Exchanger with Al2O3 Nanofluid‖ International Journal of Engineering and Technology, Volume 3, Page 366-370.

11. Fakoor-Pakdaman, M.A. Akhavan- Behabadi,P. Razi 2013. 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.
12. AshkanAlimoradi 2017. Study of thermal effectiveness and its relation with NTU in Shell and helically coiled tube heat exchanger‖ Elsevier Case Studies in Thermal Engineering, Volume 9, Page 100–107.
13. T. Srinivas, A. VenuVinod 2015. Heat Transfer Enhancement using CuO/Water Nanofluid in a Shell and Helical Coil Heat Exchanger‖ Elsevier, Volume 127, Page 1271-1277.
14. Tushar A. Sinha, Amit Kumar, NikhileshBhargava and Soumya S Mallick 2014. An Experimental Investigation into the Thermal Properties of Nano Fluid‖ Applied Mechanical Engineering, Volume 4, Issue 1.
15. Jayakumar J. S., S.M. Mahajani, J.C. Mandal, P.K. Vijayan, RohidasBhoi, 2008. Experimental and CFD estimation of heat transfer in helically coiled heat exchangers‖ Chemical Engineering Research and Design, Volume 86, Page 221-232.
16. Amar Raj Singh Suri, Anil Kumar, Rajesh Maithani 2017. Effect of square wings in multiple square perforated twisted tapes on fluid flow and heat transfer of heat exchanger tube‖ Elsevier Case Studies in Thermal Engineering, Volume 10, Page 28-43.
17. Ram Kishan, Devendra Singh, Ajay Kumar Sharma 2020. CFD Analysis of Heat Echanger using Ansys Fluent‖, International Journal of Mechanical Engineering and Technology‖, Volume 11, Page 1-9.
18. JaafarAlbadr, SatinderTayal, MushtaqAlasadi 2013 ―Heat transfer through heat exchanger using Al2O3 nanofluid at different concentrations‖ Elsevier, Volume-1, Page 38-44.
19. N. K. Chavda, Jay R. Patel, t H. Patel, Atul P. Parmar 2014 ―Effect of nanofluid on heat transfer characteristics of double pipe heat exchanger: part-1: effect of aluminum oxide nanofluid‖ International Journal of Research in Engineering and Technology, Volume-3, Page 42-52.
20. B. ChinnaAnkanna, B. Sidda Reddy 2014. Performance Analysis of Fabricated Helical Coil Heat Exchanger‖, International Journal of Engineering & Research, Volume 3, Page 33-39.
21. Sunny Sobby P, MaahaskeSiddharth D, Parikh Yash B. Numerical simulation of a tube in tube helical coil heat exchanger using CFD. International journal of applied engineering research 2014; Vol. 9: pp. 5209-5220.
22. Pawar S.S, ShettyPritam, John Ancila, JagtapPravin. Experimental study for comparison of overall heat transfer coefficient in helical coils of fixed length using water. International journal of latest research in science and technology 2015; Vol. 4: pp. 161-166.
23. WandongZheng, HuanZheng, Shijun You, Tianzhen Ye 2016 ―The thermal characteristics of a helical coil heat exchanger for seawater source heat pump in cold winter‖ Elsevier, Volume-146, Page 549-558.
24. Changnian Chen, Jitian Han and Li Shao 2017 ―The characteristics of Pressure Drop and Heat transfer of Coils Used in Solar Collectors‖ Elsevier, Volume-7, Page 351-357.
25. BaghelRakesh&UpadhayayaSushant. Effect of coil diameter in archimedan spiral coil. International journal of applied engineering research 2013; Vol. 8: pp. 2151- 2156.
26. AnkannaChinna B, Reddy Sidda B. Performance analysis of fabricated helical coil heat exchanger. International journal of engineering research 2014; Vol. 3: pp.33-39.
27. PramodDeshmukh, Vikram D Patil, Prof. BaviskarDevakant 2016 ―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.
28. A K Singh 2008 ―Thermal Conductivity of Nano fluids‖ Defence Science Journal, Volume 58, Page 600-607.
29. Amol Bari, HemantBhutte, NirmalWaykole, AjeetYadav, Swapnil Mane 2016 ―Study of tube in tube concentric parallel flow heat exchanger using nanofluid‖ International Journal of Advanced Research, Volume 4, Page 1376-1383.
30. V. Murali Krishna 2016 ―Heat Transfer Enhancement by using ZnO Water Nanofluid in a Concentric Tube Heat Exchanger under Forced Convection Conditions‖ International Journal of Innovations in Engineering and Technology, Volume-7, Page 177-184.

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