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Computational Investigation on Helical Coil Heat Exchanger with Nanofluids

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Heat exchangers are critical components in various industrial processes, and their efficiency directly impacts system performance and energy utilization. In the helical coil heat exchanger, three different types of nanofluids are used (CuO/water, Al2O3 /water and ZnO/water). The heat transfer coefficient rate of the helical coil heat exchanger was analytically investigated considering the nanofluid volume fraction in the range of 1-4% and volume flow rates in the range of 3-6L/min respectively. In their study to 3D model of the helical coil heat exchanger is done in SOLID WORKS parametric programming. After modelling, computational fluid dynamics analysis is used to study the heat transfer characteristics of a helical coil heat exchanger using nanofluids under turbulent flow conditions. CuO/Water, TiO2/water and ZnO/Water with volume concentration of (5-7%) are used as the working nanofluid. The heat transfer rate and heat transfer coefficient results of CuO/Water, TiO2/water and ZnO/water are compared with varying volume concentrations. Finally, we conclude the nanofluid and volume concentration that gives better performance.
Keywords: Heat exchangers,helical coil, Nanofluids, CFD.

1. Introduction

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

Helically coiled heat exchangers:

Many engineers in many industries are familiar with the heat transfer process with traditional heat exchangers. They are well known for their use and performance. Even though they have been around for several years, helically coiled heat exchangers are not well known. Helically spun heat switches provide some advantages. Compact size offers a distinct advantage. Higher film coefficient, at which heat is transferred from one fluid to the other through a walls and more effective use of the pressure drop available lead to less comprehensive and efficient designs. Helical geometry enables the handling of variations in high temperatures without high pressure or expensive expansion joints

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Applications of nanofluids

- Nano-fluids are the main and most critical coolants in heat transfer systems such as heat exchangers used in their enhanced thermal properties.
- Electronic cooling system and radiators.

Nanofluids used for their tunable visual properties in solar collector as working fluids

2.0 Literature Survey

V Murali Krishna et. al. [1] In their study to Heat Transfer Enhancement by using ZnO Water Nanofluid in a Concentric Tube Heat Exchanger under Forced Convection Conditions. The nanofluids are prepared at different volumetric concentration (0.1 to 0.5%). For the stability of nanoparticles 10% of surfactant is added to the nano-fluids. The experiment is conducted in a double pipe heat exchanger.

Karishma Jawalkar et. al **[2]** In their study to 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) ANSYS FLUENT 15 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. Hemasunder Banka et. al. **[3]** In their study ton 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.
Arvind Kumar Pathak et. al. **[4]** In their study to 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. 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 %. 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. Shiva Kumar et. al **[7]** 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. J.S. Jayakumar, S.M **[8]** proposed experimental research in helically damped tube of turbulent water and CUO flow properties. The correlation between heat transfer and friction factor is suggested. The findings showed a higher value for the Nussle number compared with the single tube heat exchanger. Rahul Kharat **[9]** proposed the investigation of oil and copper oxide oil and heat transfer properties of the horizontally helically coiled tubes in a constant state of heat flow. In comparative with straight one, nanofluid results showed good results in that tunnel. Nusselt number is the proposed new correlation Mandhapati Raju **[10]** proposed the geometrical parameters of helix radius, pitch of helix, diametrical ratio as considered in helical coil heat exchanger. In this Al_2O_3, SiO_2, CuO, ZnO nanoparticles are used as working fluid. The flow is laminar regime with different base fluids Ahmed M. Elsayed **[11]** proposed the convective heat transfer and drop of water pressure experimentally and numerically Cu Onside in helically coiled tubes under constant boundary state of the wall temperature. The results showed that nanofluid coefficients and pressure reductions increase with the growing concentration of particles.Hemasunder Banka et al. **[12]** carried out a scientific evaluation on shell and tube heat exchangers with pressurised convection heat switch to identify the bodily appearance of nanofluid flows with varying extent fraction and mixing with water. Titanium carbide (TiC) and titanium

nitride are two nanofluids (TiC). TiN) and ZnO nanofluids with extremely high concentrations (0.02, 0.04, 0.07, and 0.15%) drift in turbulent circumstances

3.0 Methods and Materials

The methodology for analyzing the performance of helical coil heat exchangers using nanofluids involves computational fluid dynamics (CFD) simulations. To examined the effect on the heat transfer coefficient and the enter ropy rate of generation of the heat exchanger of volume flow, volume fraction of the nanoparticle, mass flow rate, density, heat conductance, Reynolds number or Nusselt number. Analytical findings showed that nanoflows of CUO and water could increase the coefficient of heat transmission and decrease entropy output respectively by about 7.14% and 6.14%. The survey further noted that increased nanofluid particulate volume fraction and volume fluid flow rate could boost the heat transfer coefficient, and that higher energy efficiency may be observed in reduced the entropy rate. Mass flow rates could be improved at equivalent volume by injecting only nanoparticles into the base fluid and reflecting higher performance. The most important parameters of performance enhancement are density and thermal conductivity. In this analysis, the efficiency of a heat exchanger can be improved through the conversion of working fluids with nanofluids. On the basis of the software, CuO / water nanofluids be a good option.

Table 1: Boundary Conditions of 8L/m Inlet Volume flow rate 8L/min

Type	Inlet Mass flow rate
Faces	Wall
Coordinate system	Default coordinate System
Reference axis	X
Flow parameters	Flow vectors direction: Normal to boundary Volme flow rate to face: 1.44m/sec Fully developed flow: yes
Thermodynamic parameters	Nanofluid inlet Temperature: 300K Constant Heat flux : 200000w/mk

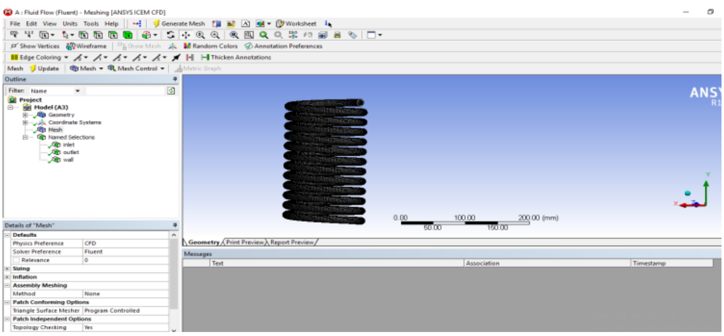

Fig 1: Meshed helical coil

The figure appears to show the meshing of a helical coil heat exchanger model in ANSYS FluentEnsure that the quality is above the acceptable threshold (e.g., 0.2 for tetrahedral meshes).Use the k-ε or k-ω turbulence models for capturing secondary flow effects.

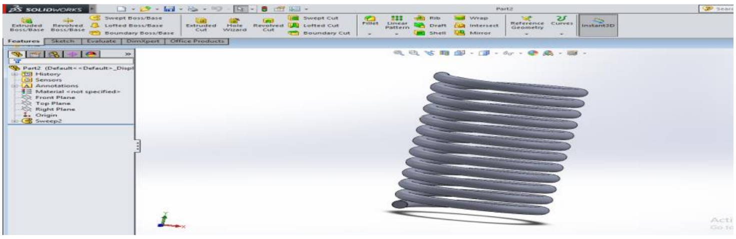

Fig 2: helical coil

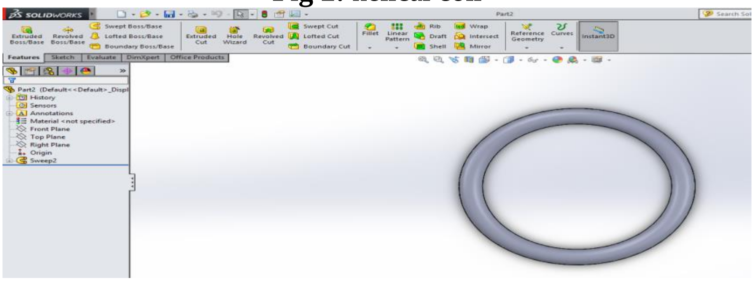

Fig 3: helical2d coil

4. Results And Discussions

The simulation results demonstrate a substantial enhancement in heat transfer when nanofluids are used as the working medium in the helical coil heat exchanger. An extensive method for the study of fluid two-dimensional and three-dimensional flow fields is given in the ANSYS / FLOTRAN CFD (Computational Fluid Dynamics). The ANSYS is capable of modeling an extensive range of analytical types, including airfoils for aircraft wings (lift and drag), supersonic buckets, and complex, tridimensional pipe bend fluid patterns. ANSYS / FLOTRAN may also be used for tasks such as:

Volume flow rate based helical coil(9l/min) titanium oxide

A flow rate of 9 L/min provides a moderately high velocity within the helical coil. This enhances turbulence and secondary flow patterns due to the curvature effect, leading to improved convective heat transfer. The use of titanium oxide nanofluids in a helical coil heat exchanger operating at a flow rate of 9 L/min offers significant advantages in terms of thermal efficiency. However, system designs must account for pressure drop and long-term stability of the nanofluid to achieve optimal performance

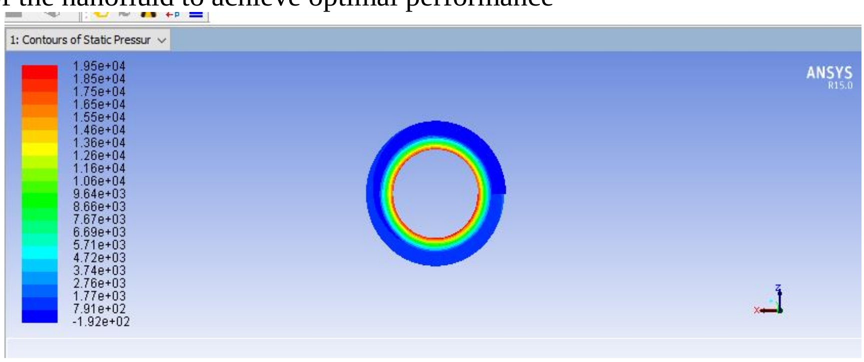

Fig 3: Pressure Distribution 9L/m volume flow rate of TiO_2

The provided figure shows the static pressure distribution for a helical coil heat exchanger with TiO_2 nanofluid at a volume flow rate At 9 L/min, the flow rate creates sufficient velocity for effective heat transfer but also increases the overall pressure drop. Optimizing the flow rate is critical to balancing heat transfer enhancement and hydraulic performance

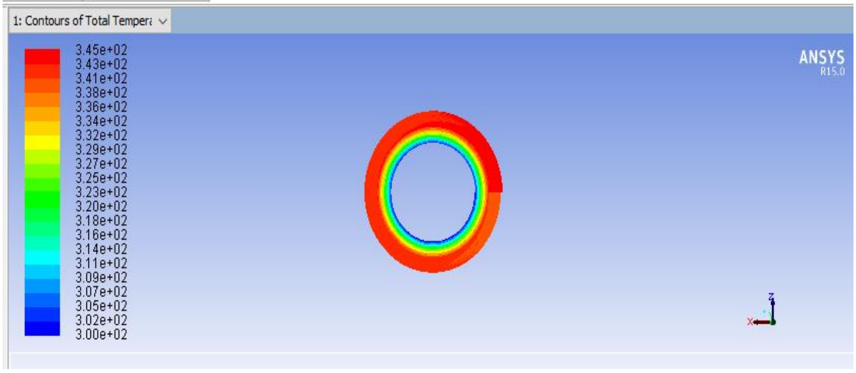

Fig 4: Temperature Distribution 9L/m volume flow rate of TiO_2

The provided figure represents the temperature distribution contours for a helical coil heat exchanger using TiO_2 nanofluid at a volume flow rate of 9 L/min. This simulation result from ANSYS shows how heat is distributed across the cross-section of the helical coil.

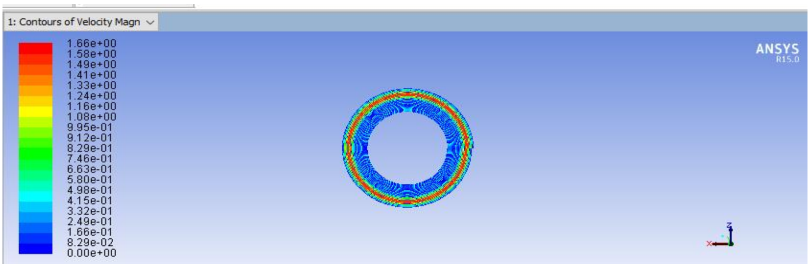

Fig 5: Velocity Distribution of the Coil of TiO_2

Above figure depicts the velocity distribution within a coil, potentially involving TiO_2 particles in a fluid flow simulation, as analyzed in ANSYS Fluent or a similar computational fluid dynamics (CFD) tool.

Pressure Distribution 7 L/m volume flow rate of ZnO

To analyzing the pressure distribution, you can gain valuable insights into the flow characteristics and optimize the design of the ZnO coil for specific conditions

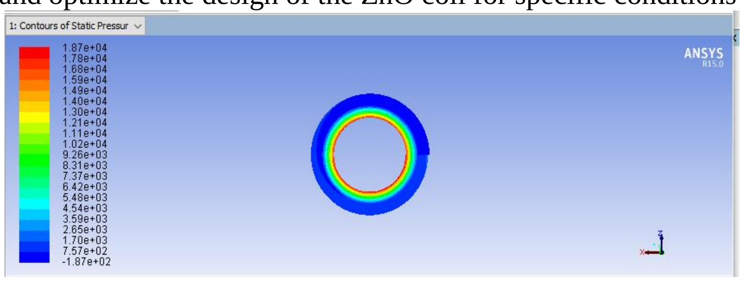

Fig 6: Pressure Distribution 7 L/m volume flow rate of ZnO

Above figure depicts the static pressure distribution within a coil at a 7 L/min flow rate for a system potentially involving ZnO in a fluid simulation, as analyzed in ANSYS Fluent or a similar CFD tool. The contour scale on the left indicates the pressure range, with red representing high-pressure regions and blue indicating low-pressure zones.

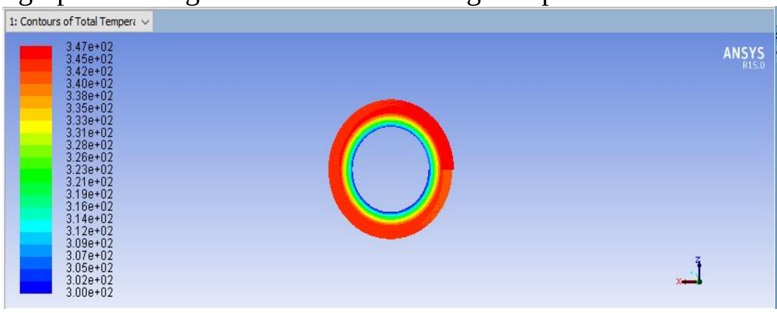

Fig 7: Temperature Distribution 7L/m volume flow rate of ZnO

Above figure to suggests a radial temperature gradient within the ZnO coil, with higher temperatures near the inner wall. However, a more detailed analysis is required to fully understand the underlying physics and the factors contributing to this temperature distribution from 3.00e+02 K to 3.476e+02 K .

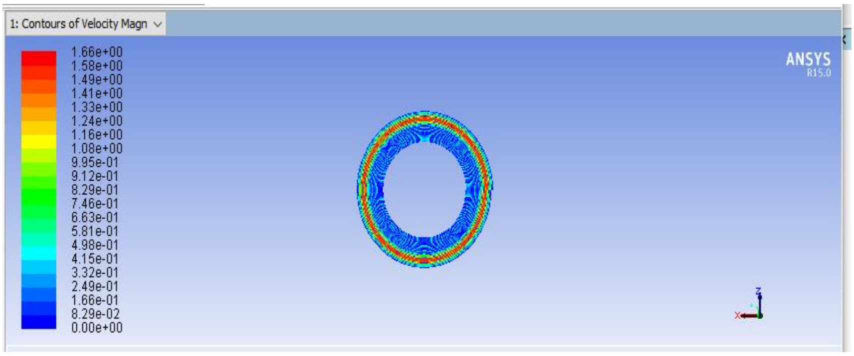

Fig 8: Velocity Distribution of the Coil of ZnO

The velocity distribution suggests that the flow within the coil is predominantly radial. The velocity is higher near the inner wall of the coil and decreases towards the outer wall. the range of velocity magnitudes, from 0 m/s to 1.660 m/s.

Volume Flow Rate Based Helical Coil (9l/Min) Zinc -Oxide

To evaluate a helical coil with a volume flow rate of 9 L/min for a fluid containing zinc oxide (ZnO), here's how the physics and performance can be interpreted based on simulation results

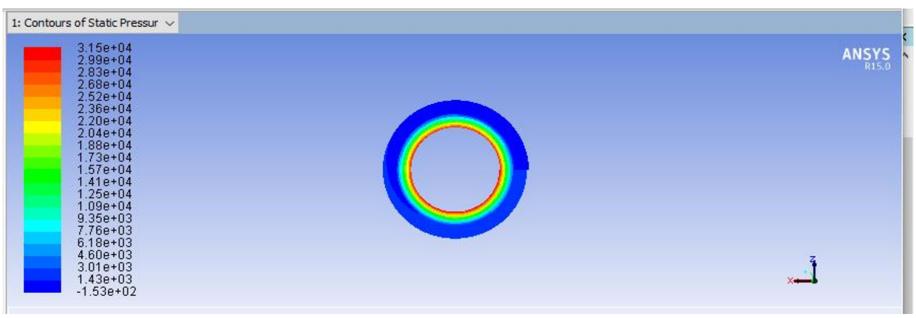

Fig 9: Pressure Distribution 9L/m volume flow rate of ZnO

Above figure to illustrates the static pressure distribution for a ZnO fluid system at a 9 L/min volume flow rate. Compared to the 7 L/min flow rate, the pressure magnitude appears to have increased, as evident from the scale extending to higher values (up to ~3.15e4 Pa).

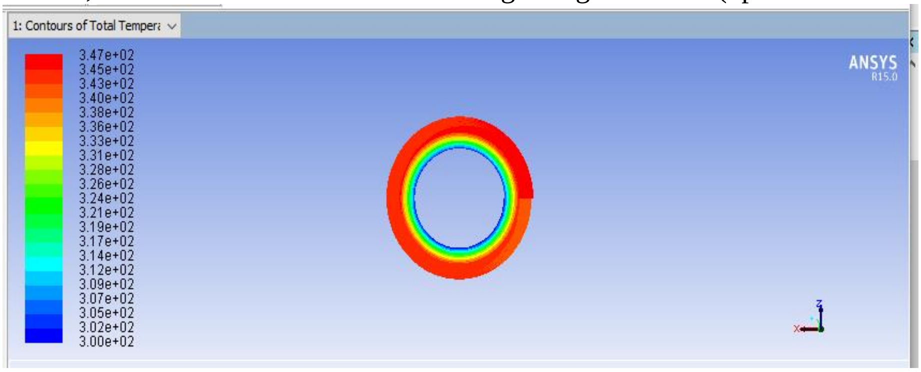

Fig 10: Temperature Distribution 9L/m volume flow rate of ZnO

Above figure 10 to suggests a radial temperature gradient within the ZnO coil, with higher temperatures near the inner wall. The denser the contour lines, the higher the temperature gradient.

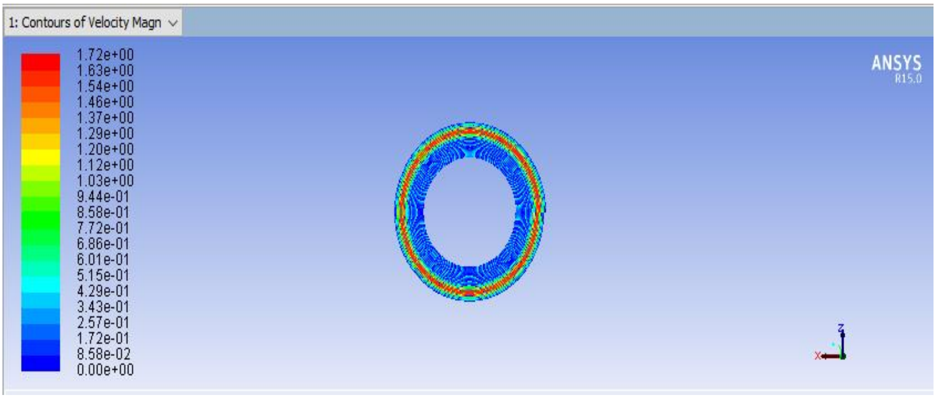

Fig 11: Velocity Distribution of the Coil of ZnO

Above figure 11 To analyze the velocity distribution concentration from 5% to 7% and also at different volume flow rates from 7L/min to 9L/min. For Cuo (7%), with a volume flow rate of 9L / min is 12587, the maximum coefficient is achieved.057 W/m^2-k. For CuO (5%), the maximum thermal transfer rate is achieved at a flow rate of 7L / min of 30.41kw

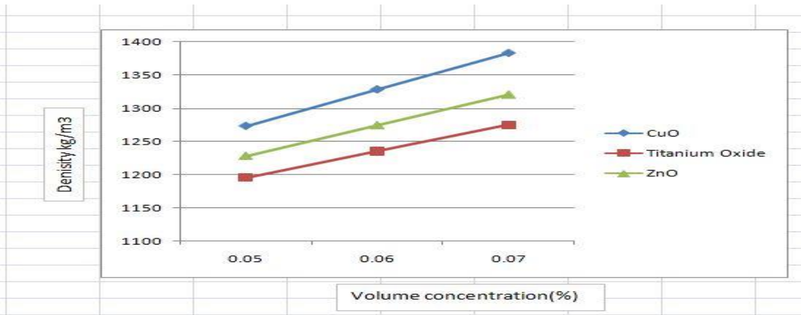

Fig 12: Variation of density with nanofluids mass flow rate for different volume concentration for different nanofluids (CuO, TiO_2, ZnO)

Above figure to concentration of different nanofluids (CuO,TiO_2,ZnO) is observed. The maximum density obtained for CuO at 7% is 1383.326Kg/m^3. The minimum density obtained for TiO_2 at 5% is 1195 Kg/m^3

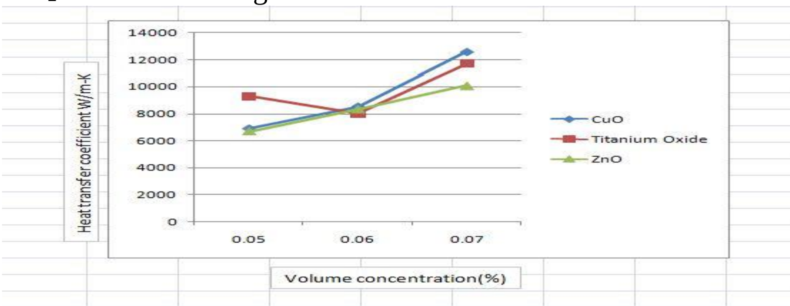

Fig13 : Variation of heat transfer coefficient with nanofluids mass flow rate for different volume concentration for different nanofluids (CuO, TiO_2, ZnO)

Coefficient of thermal transmission V's volume of nanofluid concentrations (CuO, TiO2,ZnO) is observed. The coefficient of maximum thermal transfer achieved for the CuO at 7% is 12587.0574 W / m2-k. The coefficient of minimum thermal transfer at 5% is 6707 W / m2-k for the ZnO.

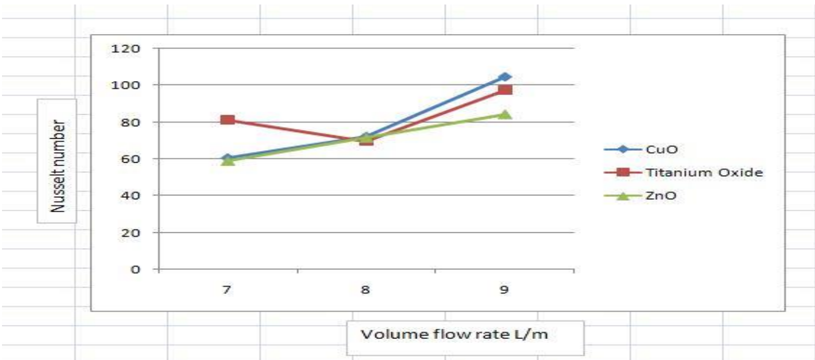

Fig 14: Variation of nusselt number with nanofluids mass flow rate for different volume floe rate for different nanofluids (CuO, TiO_2, ZnO)

Graph: Nusselt number Vs volume flow rate of different nanofluids (CuO, TiO_2, ZnO) is observed. The maximum Nusselt number obtained for CuO at 9L/min is 104.4. The minimum Nusselt number obtained for ZnO at 7L/min is 58.99.

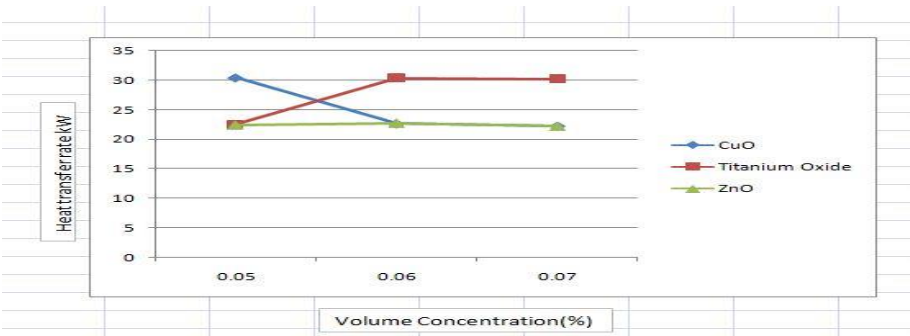

Fig 15: Variation of heat transfer rate with nanofluids mass flow rate for different volume concentration for different nanofluids (CuO, TiO_2, ZnO)

Heat transfer rate Vs volume concentration of different nanofluids (CuO, TiO_2, ZnO) is observed. The maximum heat transfer rate obtained for CuO at 5% is 30.413Kw. The minimum heat transfer obtained for ZnO at 7% is 22.27Kw.

5. Conclusion

The conclusion for a study or discussion on helical coil heat exchangers with nanofluids could be structured as follows The integration of nanofluids into helical coil heat exchangers significantly enhances their thermal performance due to the unique properties of nanofluids, such as improved thermal conductivity and heat transfer coefficients. Analytical findings have shown that, CuO / water nanofluids may have inc Increased the gain of different nanofluids. In addition revealed that the increase in the particles volume fractions and the constancy of the volume flow rate of nanofluids could boost heat transfer coefficient. According to this study, using nanofluids to replace work fluid in a heat exchanger can increase its efficiency. The results of this investigation may indicate which CuO/water nanofluids are most effective.

- The optimal coefficient of heat transfer is achieved for CuO at 7% is 12587.057 W/m^2-k
- The optimum rate of heat transfer is achieved for CuO at 5% is 30.414 Kw
- The minimum Heat transfer coefficient is obtained for ZnO at 5% is 6707.78 W/m^2-k
- The minimum Heat transfer rate is obtained for ZnO at 7% is 22.27 Kw

Future Scope

- In this article, a study of geometry using nanofluid as a working fluid in a helical belt will be carried out under the CFD Analysis.
- The heat transfer rate can increase further when we use other material instead of copper
- When we add the heat exchange dimples, the heat transfer rate will also be increased.
- When we use coils, the heat transfer rate also increases.

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