Review Article

IJCRR
Section: Technology
Sci. Journal
Impact Factor
4.016
ICV: 71.54

A Review on Comparison of Computational Fluid Dynamics Analysis of Natural Fluid & Nanofluid in Helical Coil Heat Exchanger

Arvind Kumar Pathak[1], Yogesh Kumar Tembhurne[2], Mohit Gangwar[3]

[1]M-Tech Research Scholar Mechanical Engineering Department BERI Bhopal (M.P.); [2]Assistant Professor Mechanical Engineering Department BERI Bhopal (M.P.); [3]Professor (Principal) BERI Bhopal (M.P.)

ABSTRACT

As associated to straight tubes, helical tubes are more valuable because of its compact construction and it has been experienced as ace of the passive heat transfer improvement techniques and is being most widely practiced in several heat transfer applications. Many researchers are trying to improve the heat transfer rate in a helical coil heat exchanger. This Research paper shows the comparison between natural fluid and Nanofluid with the help of Computational Fluid Dynamics (CFD) on aluminium & copper tubes. The Zinc oxide (ZnO) and Titanium oxide (TiO2) is used as nanofluid and water as its base.

Key Words: Helical Coil, Heat Exchanger, Nano Fluid, CFD, Pressure Drop

INTRODUCTION

Heat exchangers were used in a wide-ranging of applications including power generation plants, nuclear reactors for generation of electricity, Refrigeration & Air Conditioning (RAC) systems, self-propelled industries, food industries, heat retrieval systems, and chemical handling. The upgrading methods can be distributed into two groups: active and passive methods. The active method requires peripheral forces. The passive methods need discrete surface geometries. Both methods have been commonly used to improve performance of heat exchangers. Due to their compact structure and high heat transfer coefficient helical tubes have been declared as one of the passive heat transfer improvement method and they are broadly used in many industrial applications. [1, 4, 17].

Several studies have specified that helical tubes are greater to straight tubes when working in heat transfer applications. The centrifugal force will be occurring because of twisting in tube and it improves the heat transfer rate in secondary flow. This sight can be useful, especially in the laminar flow system. Heat transfer rate of helical tube is more than straight tube heat exchanger. It required small volume of base area related to other heat exchangers. The major problem of helical tube heat exchanger is the difficulty in calculating the heat transfer coefficients and the surface area available for heat transfer. This problem comes because of deficiency of data in helical tube heat exchangers, and the poor probability of the flow characteristics around the outside of the coil. [1, 4, 23, 25]

Heat transfer fluid is one of the serious factors 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 nanotechnology make it possible to get higher efficiency and cost saving in heat transfer methods. Nanoparticles are taken as the fresh group of materials which having potential applications in the heat transfer area.

Corresponding Author:
Arvind Kumar Pathak, M-Tech Research Scholar Mechanical Engineering Department BERI Bhopal (M.P.),
Mob: 9589929018; Email: arvind.pathak212@gmail.com

ISSN: 2231-2196 (Print) **ISSN:** 0975-5241 (Online) **DOI:** 10.7324/IJCRR.2017.9197

Received: 19.08.2017 **Revised:** 05.09.2017 **Accepted:** 20.09.2017

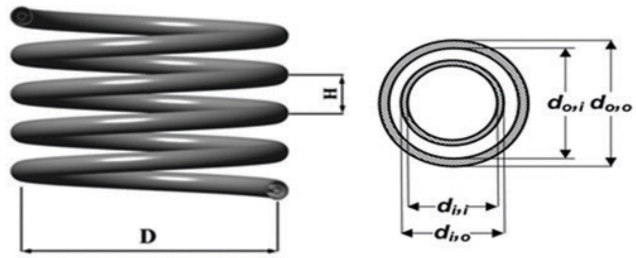

Figure-1[27]

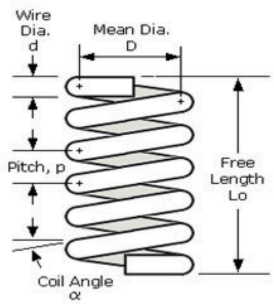

Figure-2 [28]

Nano Fluid

Nano fluid is nothing but fluid particles which are less than even a micron (9-10 times) smaller in diameter and highly reactive and proficient material which can be used to increase factor like rate of reaction, thermal conductivity of any metal or material, they are that much reactive and strong.[21]

There are different types of Nano fluids basically:

a) Al_2O_3 + Water
b) CuO + Water
c) ZnO + Water
d) TiO_2 + Water
e) TiN + Water [3,7]

The following benefits are expected when the nano particles of nano fluids are properly circulated:

i. **Heat conduction is higher:**The thermal interaction is directly available if the particles are finer than 20 nm & if they carry 20% of their atoms on their surface. The nanoparticle is of µ size so there will be the advantage in the movement of particles and it increased the heat transfer because of micro convection of fluid. When the nano particles having large heat surface area then the large heat transfer is allowable. Dispersion of heat is increasing in the fluid at a faster rate because of large heat transfer. When there will be a rise in temperature then the thermal conductivity of nanofluid increases significantly.[18,26]

ii. **Stability:** The nanoparticle of nano-fluids is smaller in size (9-10 times smaller) or in µ size, so they are weightless, that's why the chances of sedimentation are reduced.When sedimentation is reducing it will provide the stability in nanofluid by settling the nanoparticles.[18,26]

iii. **Choking not occurs in Micro passage cooling:**For transferring of heat in heat exchanger the nanofluid is a best optionin overall and they can be perfect for micro passage uses where high heat loads are faced. A large area of heat transfer and highly conducting fluids will occur by the mixture of micro passage and nanofluid and it cannot be managed with meso or micro-particles because they clog micro passages. Nano particles are smaller in size it is µ which is very small to micro passage.[18,26]

iv. **Probabilities of erosion reduced:**The momentum which is conveyed by a solid wall is minor because nanoparticles are very small. The probability of erosion of components is reducing when the momentum reduces and it occursin pipelines, pumps and heat exchangers.[18,26]

v. **Pumping power is reducing:**Pumping power is increasing by a factor of ten when the heat transfer of conventional fluid is increased by a factor of two. If there is a severe increase in fluid viscosity then the pumping power will be increased satisfactory. Thus, a large savings in pumping power can be attained. Thermal conductivity can be increased by small volume fraction of particles. [18,26]

The four unique features are listed below.

i. **Improvement of thermal conductivity:**In nanofluid the nano particles are there which have high thermal conductivity and by the properties of nano particles the thermal conductivity of nano fluid is also increased. [20]

ii. **Stability:**Nano fluids can be worked as a stabilized agent.

iii. **Small absorption and Newtonian behaviour:** The nano particles in nano fluid used in very small absorption by completely maintaining the Newtonian behaviours of the fluid then there is improvement in the thermal conductivity.The development in viscosity was minimal; hence, pressure drop was increased to some extent.

iv. **Dependency in particles size:**Dissimilar the condition with micro slurries, the improvement of conductivity was found to be governed by not only on particle concentration but also on particle size. There is increased in improvement in conductivity when the particles size is reduced.

All the above possibilities are compulsory for starting the research in nanofluid with this probability that the nanofluid will play a very important role for developing the next generation of technology.Nanofluid is stable and so much is expecting from nanofluid with various application in future. It is necessary to say that this field of research is very important, with inputs from chemistry, mechanical and chemical engineering, physics, and material science. [26]

Table 1: Specification of Helical Coil Heat Exchanger

Sr. No	Specification	Dimension
1	PCD	35 mm
2	Tube Dia	8 mm
3	Material	Aluminium and Copper
4	Length of the tube	1000 mm
5	Pitch	15 mm

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.

Vijaykant Pandey et. al. [1] have done the study on the effect of geometrical constraints 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 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 increases 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.

M. Balchandaran et. al. [2] have done the 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.

K. Abdul Hamid et. al. [3] have done their work on pressure drop for Ethylene Glycol (EG) based nanofluid. The nanofluid is prepared by dilution technique of TiO_2 in based fluid of mixture water and EG in volume ratio of 60:40, at three volume concentrations of 0.5 %, 1.0 % and 1.5 %. 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 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 TiO_2 is not significantly increased compare to EG fluid. The working temperature of nanofluid will reduce the pressure drop due to the decreasing in nanofluid viscosity.

Shiva Kumar et. al. [4] have worked on both straight tube and helical tube heat exchanger. He has compared CFD results with the results obtained by the simulation of straight tubular heat exchanger of the same length under identical operating conditions. Results indicated that helical heat exchangers showed 11% increase in the heat transfer rate over the straight tube. Simulation results also showed 10% increase in nusselt number for the helical coils whereas pressure drop in case of helical coils is higher when compared to the straight tube.

Fakoor et. al. [5] arestudied the pressure drop characteristics of nanofluid 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, nanofluid flows show higher rate of pressure drop compared to that of the base fluid flow.

Ahskan Alimoradi et. al. [6] are investigated on the effect of operational and geometrical parameters on the thermal effectiveness of shell and helically coiled tube heat exchangers. Analysis was performed for the steady state. The working fluid of both sides is water, that its viscosity and thermal conductivity were assumed to be dependent on temperature. Based on the results, two correlations have been developed to predict the thermal effectiveness, for wide ranges of mass flow rates ratio, dimensionless geometrical parameters and product of Reynolds numbers. The result was found for same values of Number of transfer units (NTU) and Capacity ratio (Cr), the effectiveness is averagely 12.6% less than the effectiveness of parallel flow heat exchangers and this difference is approximately constant.

Hemasunder Banka et. al. [7] 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 nanofluid and different volume concentrations (0.02, 0.04, 0.07 & 0.15%) flowing under turbulent flow conditions. CFD analysis is done on heat exchanger by applying the properties of nano fluid with different volume fractions to obtain temperature distribution, heat transfer coefficient and heat transfer rate. He found that heat transfer coefficient and heat transfer rates are increasing by increasing the volume fractions.

T. Srinivas et. al. [8]have done experimental study on heat transfer Enhancement using Copper Oxide (CuO)/Water Nanofluid 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 nanofluid. This can be attributed to increased thermal conductivity of base fluid due to the addition of nano particles.

Tushaar A Sinha et. al. [9] have done experimental investigation into the thermal properties of nano fluid on the effect of sonication time, settling time and temperature on the thermal conductivity, viscosity and specific heat of zinc oxide (ZnO, 14 nm and 25 nm size) and single walled carbon nanotube (SWCNT, 10nm size) based Nano fluid are investigated and the results of ZnO with Deionized (DI) water and EG as base fluids are compared. The experimental results indicate that the studied parameters have a remarkable effect on the thermal properties of Nano fluid. The rate of enhancement in thermal conductivity of EG based Nano fluid is found to be less than that of water based Nano fluid. The SWCNT based DI water Nano fluid found to be very unstable i.e. the nanoparticles settle down very rapidly. The 0.02% volume fraction of SWCNT nanoparticles suspension results in 10% increase in the specific heat of DI water. A decrement of 24% and 13% in the specific heat of 14 nm size ZnO based Nano fluid were obtained at a volume fraction of 0.001% and 0.002% respectively.

J.S. Jayakumar et. al. [10] carried out an experimental study of fluid to fluid heat transfer though a helical coiled tube at different PCD, inside tube diameter and pitch. Heat transfer characteristics were also studied using CFD code fluent. They observed CFD predictions match reasonably with experimental results for all operating conditions.The effect of coil curvature is to supress turbulent fluctuation ascending in the flowing fluid. Thus, it increases the value of Reynolds number required to attain a fully turbulent flow. As the PCD increases the impact of coil curvature on mass flow rate reduces and therefore the centrifugal force plays lesser role. The difference between the Nu at the inner and outer location increases. Same as coil pitch increases the difference of Nu increases. While the pipe diameter is low, the secondary flows are weaker and hence mixing is lesser.

Amar Raj Singh Suri et. al. [11] has done an experimental study on Nusselt number (Nu_{rs}) and friction factor (f_{rs}) of heat exchanger circular tube fitted with multiple square perforated with square wing twisted tape inserts. The experimental determination encompassed the geometrical parameters namely, wing depth ratio (W_d/W_t) of 0.042–0.167, perforation width ratio (a/W_t) of 0.250, twist ratio (T_l/W_t) of 2.5, and number of twisted tapes (N_t) T of 4.0. The effect of multiple square perforated twisted tape with square wing has been investigated for the range of Reynolds number (Re_n) varied from 5000 to 27,000. The maximum enhancement in Nu_{rs} and f_{rs} is observed to be 6.96 and 8.34 times of that of the plain circular tube, respectively. Correlations of Nu_{rs}, f_{rs} and η_p are established in term of Re_n and geometrical parameters of wings twisted tape which can be used to predict the values of Nu_{rs}, f_{rs} and η_p with considerably good accuracy.

Wandong Zheng et. al. [12] are studied on a high density polyethylene helical coil heat exchanger is firstly adopted by a seawater source heat pump system and experiments are conducted to study the thermal performance of the heat exchanger in icy condition. The external convective heat transfer coefficient is calculated by the experimental results and used in the development of the mathematical models. To predict the heat transfer process of the Heat Coil Heat Exchanger (HCHE) in icy condition in frigid periods of winter, a mathematical model is developed; simulations with different parameters are conducted to investigate the effects of variable parameters on the thermal performance, such as inlet temperature, intermediate medium’s flow rate, heat exchanger’s length and diameter, temperature of seawater. The study indicates that the developments of the mathematical model are very helpful in the designing of Heat exchanger used for the SWHP system.

Changnian Chen et. al. [13] studied the characteristics of Pressure Drop and Heat Transfer of coils Used in Solar collectors. He was found that under the experimental conditions of lower mass flow rate, the flow resistance pressure drop of coiled tube is larger than those of the other pipes, especially when the Reynolds number is more than 15000 under the high mass flow rate and the flow resistance pressure drop of bigger plate coil is smaller and the larger the mass flow rate is the grater difference will be. For heat transfer characteristics, the heat transfer coefficient of coiled tubes showed a trend of increase with increasing the curvature of spiral, and the length to diameter ratio on heat transfer coefficient of the influence for plane spiral tube. At the same time the experimental and simulation results found that length to diameter ratio of coiled tube has little effect under the experimental conditions and the effect of helical pitch on heat transfer coefficient is the least among all the factors.

Vinita Sisodiya et. al. [14]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.

Jaafar Albadr et. al. [15] has done experimental study on the forced convective heat transfer and flow characteristics of a nanofluid consisting of water and different volume concentrations of Al_2O_3 nanofluid (0.3–2) % flowing in a horizontal shell and tube heat exchanger counter flow under turbulent flow conditions are investigated. The Al_2O_3 nanoparticles of about 30 nm diameter are used in the present study. The results show that the convective heat transfer coefficient of nanofluid is slightly higher than that of the base liquid at same mass flow rate and at same inlet temperature. The heat transfer coefficient of the nanofluid increases with an increase in the mass flow rate, also the heat transfer coefficient increases with the increase of the volume concentration of the Al_2O_3 nanofluid, however increasing the volume concentration cause increase in the viscosity of the nanofluid leading to increase in friction factor.

N. K. Chavdaet. al. [16] has done an experimental investigation to determine the effect of various concentration of Al_2O_3 nano-dispersion mixed in water as base fluid on heat transfer characteristics of double pipe heat exchanger for parallel flow and counter flow arrangement. The volume concentrations of Al_2O_3 nanofluid prepared are 0.001 % to 0.01 %. The conclusion derived for the study is that overall heat transfer coefficient increases with increase in volume concentration of Al_2O_3 nano-dispersion compared to water up to volume concentration of 0.008 % and then decreases.

Problem Formulation

In the literature survey we found that so much work had been done to increase the heat transfer rate in heat exchanger. But there is no work has been done on heat transfer rate of comparing the fluid and nanofluid. In my work I am trying to showing the comparison of nanofluid and water fluid for the given helical coil heat exchanger keeping in mind that it nanofluid should produce maximum heat transfer rate with minimum power consummation. Because some times in the process of improving the heat transfer coefficient we consume more power without knowing the economic cost. Consider the helical coil heat exchanger of PCD 35 mm of length 1000 mm the pitch of the coil is 15 mm, the coil diameter is 8 mm & the material of coil is Copper & Aluminium. In my research I am using Water as a natural fluid, ZnO & TiO_2 as a Nanofluid. [3,7]

Table 2: Comparison Table of the work from the literature Survey

Author Name	Fluid Used	Type of Heat Exchanger	Pressure Drop
Vijaykant Pandey et. al	Water	Helical Coil	12100 Pa pressure drop Increased to other coil
M. Balchandaran et. al	Water	Helical & Straight Tube	Pressure Drop of Helical tube is more than Straight Tube
K. Abdul Hamid et. al.	EG & TiO_2 Nano Fluid	Helical Coil	Pressure Drop of TiO_2 is not Increased compared to EG nanofluid
Shiva Kumar et. al.	Water	Helical Tube & Straight Tube	Pressure Drop of Helical tube is more than Straight Tube
Fakoor et. al.	Water & Nano Fluid	Helical Coil	Pressure drop of Nanofluid is higher as compared to water fluid
Ahskan Alimoradi et. al.	Water	Helical Coil & Shell & Tube	-
Hemasunder Banka et. al.	Tic, TiN, ZnO	Shell & Tube	-
T. Srinivas et. al.	CuO Nano fluid	Shell & Tube, Helical Coil	Pressure Drop Increased as Volume Concentration Increased

Tushaar Sinha et. al.	ZnO & EG Nanofluid	SWCNT	-
J. S. Jayakumar et. al.	Water	Helical Coil	-
Amar Raj Singh Suri et. al.	Solar Energy	Tube with multiple square perforated twisted tapes with square wing	-
Wandong Zheng et. al.	Sea water	Helical Coil	-
Changnian Chen et. al.	Solar Collector	Coiled tube	Pressure drop of coiled tube is larger than pipes.
Vinita Sisodiya et. al	Al_2O_3 Nanofluid	Helical Coil	-
Jaafar Albadar et. al.	Water & Al_2O_3 Nanofluid	Shell and tube	Volume Concentration Increases then pressure drop increases.
N. K. Chavda et. al.	Al_2O_3 Nanofluid	Double Pipe	Volume Concentration Increases then pressure drop increases.

DISCUSSION

The different boundary conditions are taken for helical coil heat exchanger for the numerical simulations. The numerical study considers the effect of natural fluid that is water and nanofluid such as Zinc Oxide (ZnO) and Titanium Oxide (TiO_2) on the flow and heat transfer characteristics of tube. The thermal properties of fluid are lesser as compared to nanofluid. Nano fluids have Nano particles of solid materials which increase the thermal properties of Nano fluid also because of vortex flow the pressure drop will be increased. In all above literatures we found that normally the water fluid is used for analysis of helical coil only the geometries have been changed for calculation of pressure drop. We made a helical coil of 35 mm PCD and 8 mm tube diameter of length 1000 mm and the water fluid and Nano fluid is flow inside the tube by which the pressure drop is increased in helical coil which flows the Nano fluid and the fluid which has thermal conductivity higher that will give high pressure drop. [24]

CONCLUSION

Increase in centrifugal force due to increases in curvature ratio of coil, mass flow rate and tube diameter. This increases more generation of secondary flow inside helical coil. Secondary flow produces additional transport of fluid and strong mixing (advection – diffusion) in the fluid over the cross section of pipe. Addition of nanoparticles in base fluid increased pressure drop, which indicated higher heat transfer into the fluids. Thus nano fluids could be a promising replacement for pure water in heat exchanger where there is need to more efficient heat transfer.When the thermal conductivity in fluid is increases the temperature is also increases.

REFERENCES

1. Vijaykant Pandey, Dinesh Kumar Koli 2015, "CFD analysis of helical coil heat exchanger" International Journal of Engineering Associates, Volume 4, Page 95-99.
2. 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.
3. K. Abdul Hamid, W. H. Azmi, RIzalman Mamat, N. A. Usri and Gohalamhassan Najafi 2015, "Effect of Titanium Oxide Nanofluid Concentration on Pressure drop" ARPN Journal of Engineering and Applied Sciences, Volume 10, Page 7815-7820.
4. Shiva Kumar, K Vasudev Karanth 2013, "Numerical analysis of a Helical Coiled Heat Exchanger using CFD" International Journal of Thermal Technologies, Volume 3, Page 126-130.
5. 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.
6. Ashkan Alimoradi 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.
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. T. Srinivas, A. Venu Vinod 2015, "Heat Transfer Enhancement using CuO/Water Nanofluid in a Shell and Helical Coil Heat Exchanger" Elsevier, Volume 127, Page 1271-1277.
9. Tushar A. Sinha, Amit Kumar, Nikhilesh Bhargava and Soumya S Mallick 2014, "An Experimental Investigation into the Thermal Properties of Nano Fluid" Applied Mechanical Engineering, Volume 4, Issue 1.
10. Jayakumar J. S., S.M. Mahajani, J.C. Mandal, P.K. Vijayan, Rohidas Bhoi, 2008, "Experimental and CFD estimation of heat transfer in helically coiled heat exchangers" Chemical Engineering Research and Design, Volume 86, Page 221-232.
11. 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.
12. Wandong Zheng, Huan Zheng, 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.
13. 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.

14. Vinita Sisodiya, Dr. Ankur Geete 2016 "Heat Transfer analysis of Helical coil Heat Exchanger with Al_2O_3 Nanofluid" International Journal of Engineering and Technology, Volume 3, Page 366-370.
15. Jaafar Albadr, Satinder Tayal, Mushtaq Alasadi 2013 "Heat transfer through heat exchanger using Al_2O_3 nanofluid at different concentrations" Elsevier, Volume-1, Page 38-44.
16. 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.
17. Pramod Deshmukh, Vikram D Patil, Prof. Baviskar Devakant 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.
18. Amol Bari, Hemant Bhutte, Nirmal Waykole, Ajeet Yadav, 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.
19. 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.
20. Prof. Alpesh Mehta, Dinesh k Tantia , Nilesh M Jha , Nimit M Patel 2012 "Heat Exchanger using Nano Fluid" International Journal of Advanced Engineering Technology, Volume 3, Page 49-54.
21. Kevin Kunnassery, Rishabh Singh, Sameer Jackeray 2017 "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.
22. Vishwas M. Palve, Prof. Rajesh V. Kale 2015 "Computational analysis of helical coil Heat exchanger for Temperature and Pressure drop" International Research Journal of Engineering and Technology, Volume-2, Page 162-166.
23. Amitkumar S. Puttewar , A.M. Andhare 2015 "Design and thermal evaluation of Shell and Helical coil Heat exchanger" International Journal of Research in Engineering and Technology,Volume-4, Page 416-423.
24. Ramdas Anant Rao Gadekar, Sanjay Kumbhare 2015 "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.
25. Cengiz Y, Yasar B, Dursun P. 1995, "Heat transfer and pressure drops in rotating helical pipes" Appl Energy Volume 50, Page 85–94.
26. Sarit Kumar Das, Stephen U. S. Choi, Hrishikesh E Patel 2006, "Heat Transfer in Nano fluids -A Review" Heat Transfer Engineering, Volume 27.
27. http://thermalscienceapplication.asmedigitalcollection.asme.org/data/journals/jtsebv/930692/tsea_006_03_031001_f001.png
28. http://engg-learning.blogspot.in/2011/03/helical-spring.html