Heat Transfer and Pressure Drop variation in Helical Coil Heat Exchanger with varying pitch using Water-based Tio$_2$ Nanofluid

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Abstract

In this study of heat transfer rate in heat exchanger comprising of helical coils has been studied. It is found that there is fewer publications has been produced on heat exchanger with varying pitch is investigated using horizontal helically coiled tube and water based TiO_2 as Nanofluid of volume fractions of 0% ,0.1% ,0.2% ,0.3% ,0.4% and 0.5% prepared by two step method. Heat transfer variable and friction factor studies were experimentally conducted for 3 different helical coil tubes of same diameter and pitch variations of 25 mm, 30 mm, and 35 mm with a curvature ratio $\delta = 0.0667$. The study is conducted under turbulent flow condition (Re = 7713–8153). The combined effects of nanofluids, pitcHE's, flow rate on inner Nusselt number, Dean Number, inner heat transfer coefficient and friction factor are investigated. The finding shows that the use of TiO_2 nanofluid with DI water increases the heat transfer rate with increase in nanofluids volume concentrations. The rate of heat transfer in helical tubes enhances for lowest pitch of P =20mm.With Increase in nanofluid volume fraction the Pressure drop increases and the rate of heat transfer coefficient increases with decreasing friction factor. The higHE'st rate of heat transfer coefficient of 7720 W/m^2 K is observed for helical coil tube of pitch 25mm and for 0.5 % volume concentration of TiO_2 nanofluid with Dean Number of 2464. The higHE'st Nusselt number of 138 also observed for 0.5% volume fraction of nanofluid with friction factor of 0.0362.

Keywords: *Nusselt Number, Heat Exchanger, varying pitch, Nanofluid, Dean Number, friction factor, helical coil*.

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Nomenclature

P	Pitch
k_c	Temperature sensitivity of copper coil (W/m K)
k_i	Temperature sensitivity of cold water (W/m K)
k_o	Temperature sensitivity of hot water (W/m K)
N	Number of turns of coil tube
R_c	Mean helical radius of the helical coil in mm
r	Inner radius of the helical coil tube in mm
d_o	Outside diameter of the helical coil tube in mm
d_i	Inside diameter of the helical coil tube in mm
a_o	Outside surface area of the helical coil tube in m^2
a_i	Inside surface area of the helical coil tube in m
L	Overall length of the helical coil tube in mm
Q	Rate of Discharge in m^3/sec
A_i	Area of the Cross sectional of inside helical coil tube in
V_i	Inside helical coil tube velocity in m/sec
D_e	Dean number
R_e	Reynolds Number
ΔT_{lm}	Log Mean Temperature Difference in ^oC
$\dot{m}_h$	Hot water flow rate in kg /sec
$\dot{m}_c$	Cold water Flow rate in kg /sec
c_{ph}	Specific heat of hot fluid constant pressure in kJ/kg K
c_{pc}	Specific heat of cold fluid constant pressure in kJ/kg K
C_h	$\dot{m}_h c_{ph}$= hot fluid capacity rate in kW /K
C_c	$\dot{m}_c c_{pc}$ = cold fluid capacity rate in kW /K
C	Capacity ratio

U_o	Overall coefficient of heat transfer of outside coil tube W/m^2 °C
U_i	Overall coefficient of heat transfer of inside coil tube W/m^2 °C
h_o	Coefficient of heat transfer of outside coil tube W/m^2 °C
h_i	Coefficient of heat transfer of inside coil tube W/m^2 °C
NTU	Number of Transfer units
HCHE	Helical Coil heat exchanger
HE	heat exchanger
ΔP	Pressure drop
TiO_2	Titanium Dioxide
Nu	Nusselt Number

Greek letters

δ	Curvature ratio
ρ	Density of water in kg/m^3
μ	Dynamic viscosity of fluid in N-sec/ m^2
ε	Effectiveness
ϕ	volume concentration
f	Friction Factor

Subscripts

h_1	Inlet of hot fluid
h_2	Outlet of hot fluid
c_1	Cold fluid inlet
c_2	Cold fluid outlet
p	Metallic oxide particles
f	Base fluid density
nf	Nanofluid

1. INTRODUCTION

In industrial environments, heat exchanges are frequently used to cool or heat the equipments. With different enhancing methods, the effectiveness of HE has increased. Heat transfer improvement technique adopted and currently being utilized extensively in cooling, automotives, process industries and chemical manufacturing, etc. More efforts are made up to reduce the dimensions and cost of HE's. In addition, since the heat transfer rate in plain tubes is often low, heat transfer methods for enhancement is essential for turbulent flow condition. Bhanvase et.al. [1] found that when the temperature rises, the heat transfer coefficient increases in the volume concentration of nano fibers in nanofluid and Anbu et.al. [2] experimentally carried out for five helically corrugated tubes of different heights and pitcHE's was conducted under turbulent flow .The results found that the addition of Tio_2 nanoparticles in base fluid water upsurges the rate of heat transfer. According to the results of Prabhanjan et.al, [3] Geometry of the HE and the temperature of the water bath surrounding it both had an impact on the heat transfer coefficient. Pathipakka et.al, [4] for both plain tubes and tubes fitted with helical tape inserts, the data collected through modeling are in accord with the value published in the research with a discrepancy of less than 10%. Kumar et.al, [5] discovered that significant agreement between the simulation and the experimental findings. The Nu and ΔP in experimental results, the CFD data are discovered to be varying by 7.2% and 8.5%, respectively. Ali et.al, [6] discusses new developments in the uses of nanofluid that improve heat transmission in addition to earlier investigations. Also the most recent developments in preparation and stability enhancement have been reviewed. Prakash et.al, [7] studied experimental data and earlier studies are utilised to validate the numerical scheme. The results showed that upgrading to HE's with helical coils from straight tube types increases the Nu. Pawar et.al, [8] study of correlation was compared with the work of earlier investigators and was found results to be in good agreement. Jayakumar et.al, [9] experimental setup fabricated for the estimate heat transfer characteristics. The outcomes of the experiment are contrasted with the CFD calculation results using the CFD package FLUENT 6.2. A correlation is created to calculate the inner heat transfer coefficient of the helical coil based on the experimental results. Pak et.al, [10] Compared under the assumption of a constant average velocity, it was discovered that the convective heat transfer coefficient of the dispersed fluid at a volume concentration of 3% was 12% smaller than that of pure water. Xuan et.al. [11] Investigated using nanofluids for enhancement of heat transfer mechanism. This article suggests there are two ways for determining the nanofluids heat transfer correlation, presuming that it behaves more fluidly than a typical solid-fluid mixture. Kahani et.al, [12] used distilled water as a host fluid and Nanofluids of aqueous TiO_2 nanoparticles (50nm) suspensions were prepared in various volume concentrations of 0.25–2 %. The coefficient of heat transfer nanofluids is obtained for different nanoparticles concentrations for various Res. The experiments were conducted with Res between 500 and 4,500. The findings demonstrate a significant improvement in heat transfer rate. This is caused by nanoparticles present in the fluid. By increasing the both the flow rate and the volume concentration of nanoparticles, the coefficient of heat transfer increases.

In the current study, the characteristics of the heat transfer rate in HE's using helical coils have been examined. In HE with a helically coiled tube using water-based TiO_2, it was discovered that few research articles available on HE's with varying pitch. Though most research focuses on helical coiled tubes, there is a significant gap in the literature when it comes to estimating effect of nanofluids, Pitch of HE's, flow rate affect on De, inner heat transfer coefficient, Nu and friction factor by considering pitch, fluid and flow rate are taken into consideration. The majority of studies on the convective heat transfer of nanofluids are not satisfied the preparation and characterization of the nanofluids using HCHE's. With the addition of a small volume fraction of nanoparticles, heat transfer is significantly improved. The advantages of nanofluid and the mechanisms underlying this improvement in heat transfer are still being studied by researchers.

The aim of this research is to investigate effect of flow rate on HCHE heat transfer characteristics. The creation of an experimental setup that can accommodate a helical pipe with a manually adjustable pitch depending on the pipe's composition. To investigate the heat transfer properties of nanofluid TiO_2 with various volume concentrations in helical coil tube HE's for varying pitch.

2.EXPERIMENTAL

The line diagram and image of the experimental setup as in Figs. 1 and 2. The test section's image is depicted in Fig. 3. Two loops comprise the experimental setup. The first one handles nanofluids and has a helically coiled tube side. The second loop is on the side of the shell that deals with cold water. A storage tank, a heater with a 2KW capacity, and a pump are in connection with first loop. A 0.5 horsepower pump, a valve to control the flow on the tube side, and a test section are in connection with helical coiled tube loop side. Glass wool is used to protect the shell's exterior to stop heat loss. The geometry of the three helical coiled tubes used in this research work is shown in Table 1.

The proposed experimental setup consisting of helical coil tube heat exchanger

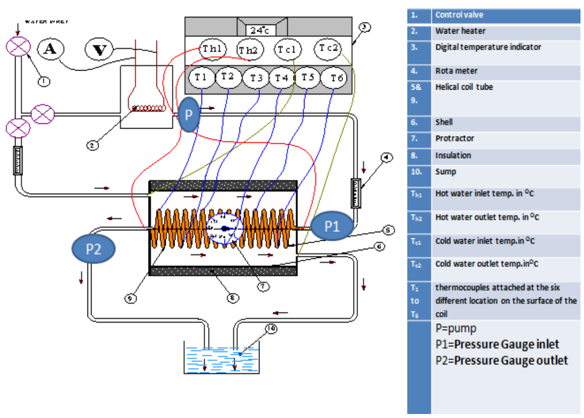

Figure 1 Line diagram of the Experimental setup

Figure 2 Picture of the testing environment

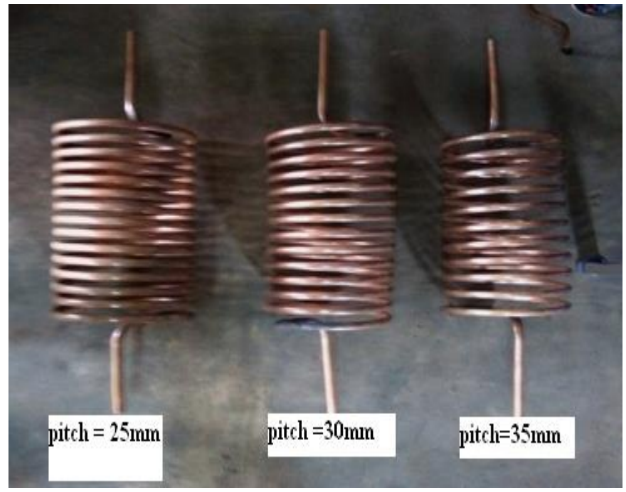

Figure 3 Pitch-variable helical coils

Table 1 Geometry of helical coils used.

Helical coils	Coil -1	Coil -2	Coil -3
P(mm)	25	30	35
Material Type	Copper		
k_c at atmospheres	386		
N	15	13.5	11
R_c(mm)	74.9	74.9	74.9
r(mm)	5.537	5.537	5.537
δ	0.0739	0.0739	0.0739
d_o (mm/inch)	12.7(1/2″)	12.7(1/2″)	12.7(1/2″)
d_i (mm)	11.074	11.074	11.074
L (m)	7.409	6.706	5.531
$a_o(m^2)$	0.2956	0.2675	0.2206
a_i (m^2)	0.2577	0.2333	0.1924

2.1.Experimentation

Evaluation of heat transfer characteristics water based Nano fluid Titanium Dioxide (TiO_2) using different volume concentrations (0-0.5%) of in a varying pitch of 35mm, 30mm and 25mm helical coil tube. The effect of the coefficient of heat transfer, De, friction factor, ΔP and Nu on the heat transfer in a helical coil tube HE has carried out through experimental research. Turbulent flows with a counter flow condition are present in helical coil tubes. TiO_2 is used in this experimental study on its properties as a water-based nano fluid at various volume concentrations (0.0 to 0.5%) in helical coil tubes with varying pitch HE's that are 25 mm, 30 mm and 35 mm.

The following presumptions are used when analysing the HCHE's heat transfer characteristics because of HE's perfect insulation, there is minimum heat loss to the environment in the flow condition studied, during the heat transfer, the fluid also does not change phase, the thermal sensitivity and specific heat capacity of the helically coiled tube are constant, the changes in potential and kinetic energy are insignificant, and the heat resistance of the liquid film is disregarded.

2.2.Experimental procedure

Water is allowed to flow in the experimental setup check for any fitting leaks. After inspection the regular water is allowed to flow through the shell side and hot water is permitted to flow through the helical coil tube. The water in the water heater is heated to about 48°C when the control panel is turned on. The temperature of the cold water is kept at 24±1 ^{o} C. Once the exchanger was turned on, the coil's pitch was set to 25 mm. Control valves are used to regulate fluid flow, and rotameters are used to measure flow rates. A constant flow rate of 4.5 LPM of cold water is maintained to the shell's inlet. For all studies, hot water is allowed to flow through the coil tube. For all tests, hot water flow rate is maintained at different flow rates varying from 3.6 to 4.2 LPM. For each test, Different volume concentrations varying from 0-0.5% of TiO_2 nanoparticles suspensions based on distilled water were created. Cold water is supplied to the shell side and nanofluids with volume concentrations of 0%, 0.1%, 0.2%, 0.3%, 0.4%, and 0.5% are supplied for the helically coiled tube.

Following that, temperatures and mass flow rates readings of the both fluids are recorded. Experiment is repeated at flow rates of 3.6, 3.8, 4.0, and 4.2 LPM. Using nanoparticles, the corresponding temperatures and flow rates for volume concentrations 0%, 0.1%, 0.2%, 0.3%, and 0.5% are noted. Experiments were conducted for other helical coil tubes of 30mm and 35mm pitch HE's were inserted inside the shell while maintaining a constant curvature ratio.

2.3. Data reduction

a. **L** Required to perform N turns:

$$L = (l + \left(N\sqrt{(2\pi R_C)^2 + P^2}\right)) \quad \text{...(1)}$$

l = both sides of an extended straight tube measure 340mm.

b. Log mean temperature difference,

$$\text{LMTD} = \Delta T_{lm} = \frac{(\Delta T_2 - \Delta T_1)}{(\frac{\Delta T_2}{\Delta T_1})} \quad \text{......(2)}$$

c. Thermophysical properties of nanofluids

The density of TiO_2 nanofluids is found using (Pak and Cho)equation

$$\rho_{nf} = \phi\rho_{p+(1-}\phi)\rho_f \quad \text{...(3)}$$

Heat capacity, viscosity, and thermal conductivity are the three main factors that go into calculating the nanofluids rate of heat transfer; these 3 factors may vary significantly from the pure fluid's original.

(Xuan and Roetzel)Equation is used to calculate the specific heat

$$(\rho C_p)_{nf} = (1-\phi)(\rho C_p)_f + \phi\,(\rho C_p)_p. \quad \text{.....(4)}$$

The fluid's nano scale viscosity is measured using this equation.

$$\mu_{nf} = \mu_f(1+2.5\phi) \quad \text{......(5)}$$

d. The rate of heat transfer

$$Q_h = \dot{m}_h C_h (T_{h1} - T_{h2}) \quad \text{......(6)}$$

$$Q_c = \dot{m}_c C_c (T_{c2} - T_{c1}) \quad \text{......(7)}$$

$$Q_{actual} = \frac{Q_h + Q_c}{2} = U_o a_o \Delta T_{lm} = U_i a_i \Delta T_{lm} \quad \text{......(8)}$$

$$a_i = \pi d_i L \text{ and } a_o = \pi d_o L \quad \text{......(9)}$$

e. The heat transfer coefficient calculated by using following relationship:

$$h_i \frac{Q}{a_i(T_{h(avg)} - T_{is})}, \quad \text{..........(10)}$$

$$h_o \frac{Q}{a_o(T_{os} - T_{c(avg)})}$$

$$T_{h(avg)} = \frac{T_{h1} + T_{h2}}{2} \quad \text{.............(11)}$$

$$T_{c(avg)} = \frac{T_{c1} + T_{c2}}{2} \quad \text{..............(12)}$$

T_{os} is the mean temperature of the outside coil surface (calculated as the mean of six thermocouple readings taken at six different coil surface locations), T_{is} the coil's average interior surface temperature can be estimated using the formula below.

$$Q = \frac{2\pi k_c L(T_{is} - T_{os})}{\ln(\frac{\frac{d_o}{2}}{\frac{d_i}{2}})} \quad \text{......(3)}$$

f. Thermal conductivity of nanofluid is measured by Maxwell equation

$$\frac{k_{nf}}{k_f} = \frac{k_p + 2k_f - 2\phi(k_f - k_p)}{k_p + 2k_f + \phi(k_f - k_p)} \quad \text{.......(4)}$$

g. **Nusselt Number**: The ratio of temperature gradients by conduction and convection at the surface.

$$\text{Inside Nusselt number} = N_{ui} = \frac{h_i d_i}{k_{nf}} \quad \text{...(5)}$$

$$\text{Outside Nusselt number} = N_{uo} = \frac{h_o d_o}{k_{nf}} \quad \text{...(6)}$$

h. A stream's flow rate is determined by multiplying its cross-sectional area by its flow velocity (speed).

$$V_i = \frac{\dot{m}_h}{\rho nf \times A_i} \quad \text{.......(7)}$$

i. **Reynolds Number (Re):** a dimensionless number used in fluid mechanics to represent the steady or turbulent nature of fluid flow past a body or in a duct.

$$\text{Re} = \frac{d_i V_i \rho nf}{\mu nf} \quad \text{......(8)}$$

j. **Dean number (De)**: A dimensionless group in fluid mechanics, which occurs when researching flow in arched pipes and HE's.

In order to describe the flow in a helical pipe, one uses the De.

$$De = Re\sqrt{r/R_c} \quad \text{..........(19)}$$

k. **Friction factor** (f): The following relation is used to calculate the friction factor under isothermal conditions from the pressure drop.

The Darcy –Weisbach equation

$$f = (\Delta P/0.5\rho v^2)(d/L) \quad \text{.....(20)}$$

In a cylindrical pipe of uniform diameter D, flowing full, the pressure loss due to viscous effects Δp is proportional to length L and can be characterized by the Darcy–Weisbach equation.

l. The Blasius equation for turbulent flow consider is used to validate it:

$$f = \frac{0.316}{Re^{0.25}} \quad \text{..............(21)}$$

(3000≤Re≤20000) the flow is turbulent

3. RESULTS AND DISCUSSION

Discussions of the heat transfer properties of TiO_2 in a water-based nano fluid using various volume concentrations (0-0.5%) in helical coil tubes with varying pitch HE's that is 25 mm, 30 mm, and 35 mm. The effect of the De, flow rate, coefficient of heat transfer, pressure drop, friction factor, and Nu on the transfer of heat in a helical coil tube HE has been carried out. The inner helical coil's shell (annulus) and flow are both turbulent, and the flow direction is counter-flow. TiO_2 is used in this experimental study on its properties as a water-based nano fluid at various volume concentrations (0.0 to 0.5%) in helical coil tubes with varying pitch HE's that are 25 mm, 30 mm, and 35 mm in diameter.

3.1. Validation of experimental results

Tests are conducted using nano fluid volume concentration changing from 0-0.5% in pitch of 25mm, 30mm, and 35mm in order to compare the results and validate the experimental apparatus. Figure.4 compares experimental data from turbulent flow scenarios with results from the Blasius equation.

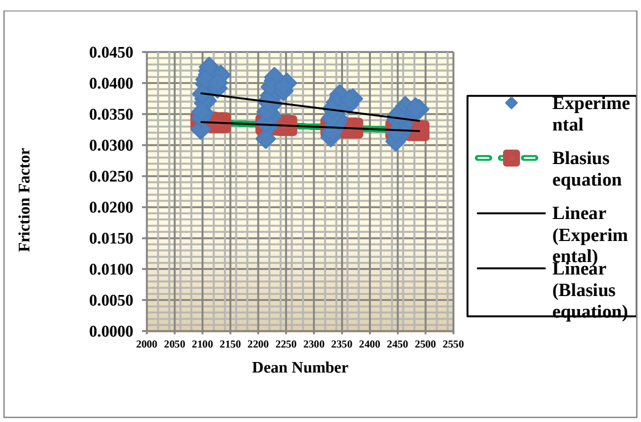

Figure 4 Blasius equation comparison with experimental friction factor in turbulent flow conditions.

The experimental readings of friction factor found to concur strongly with the theoretical values predicted from the Blasius equation within deviation of ± 8.322%.

3.2. Friction factor Characteristics

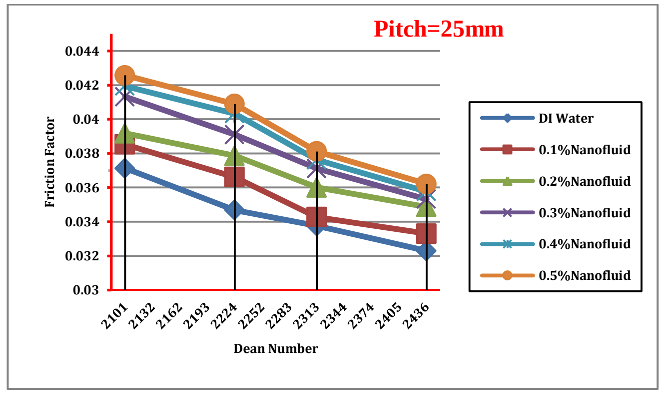

Figure 5 De Vs friction factor in nanofluid volume fractions, Pitch=25mm

The friction factor of a HE made of 25mm-pitch helical coil tubes under steady-state flow conditions is shown in Fig. 5. There is less friction when the hot fluid inside's De rises. For helical coil tube of Volume fraction 0.5% Nanofluid an average value of Friction factor is higher 1.35%, 3.13%, 6.26%, 9.55% and 12.63% than the reaming Volume fraction 0.4%, 0.3%, 0.2%, 0.1% and 0% DI Water respectively.

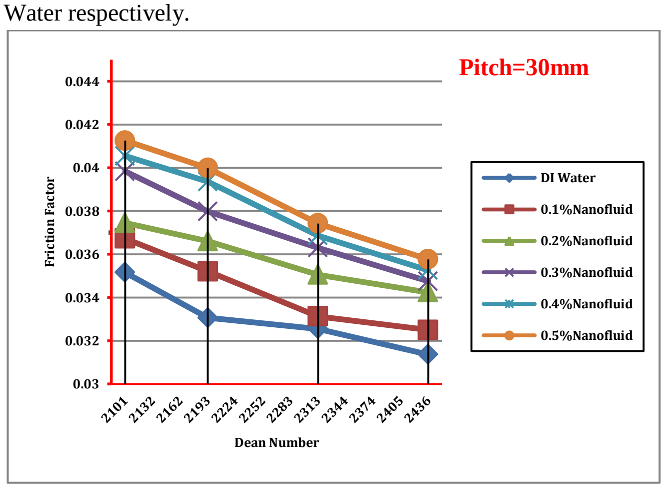

Figure 6 Friction factor Vs De in a nanofluid volume fractions, Pitch=30mm

The friction factor of a HE made of 30mm-pitch helical coil tubes under steady-state flow conditions is shown in Fig. 6. As the There is less friction when the hot fluid inside's De rises Less friction is observed. For helical coil tube of Volume fraction 0.5% Nanofluid an average value of Friction factor is higher 1.56%, 3.6%, 7.18%, 10.92% and 14.44% than the reaming Volume fraction 0.4%, 0.3%, 0.2%, 0.1% and 0% DI Water respectively.

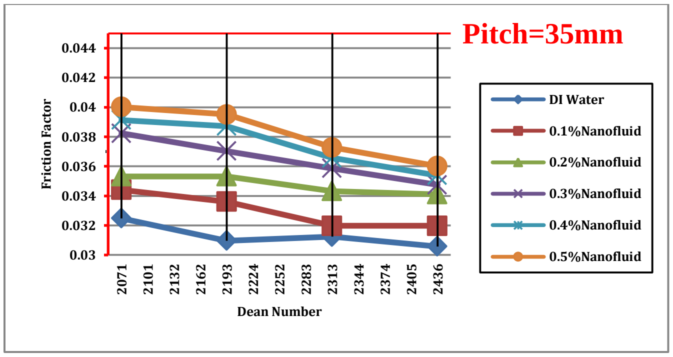

Figure 7 Friction factor Vs De in a nanofluid volume fractions, Pitch= 35mm

Figure 7 illustrates the friction factor of a HE made of 35 mm-pitch helical coil tubes under steady-state flow conditions. As the There is less friction when the hot fluid inside's De rises. For helical coil tube of Volume fraction 0.5% Nanofluid an average value of Friction factor is higher 1.97%, 4.55%, 8.99%, 13.65% and 18.03% than the reaming Volume fraction 0.4%, 0.3%, 0.2%, 0.1% and 0% DI Water respectively.

Figures 5, 6 and 7 shows the friction factor of a HE made of helical coil tubes with varying pitch HE's of 25 mm, 30 mm, and 35 mm in steady state flow conditions. It has been noted that for all study pitch HE's, the friction factor of the HE decreases as the De of the internal hot fluid increases. The average friction factor for helical coil tubes with a pitch of 25mm is higher than that of tubes with a pitch of 30mm and 35mm, respectively, by 2.9% and 5.6%. The coil tube with a pitch of 25 mm and a volume fraction of 0.5% nanofluid had the highest friction factor, and DI water had the lowest. For a fixed De of the hot fluid inside a 35mm pitch helical coil tube. As the Re increases, the friction between the hot fluid decreases because De is directly linked to Re of the fluid.

3.3.Experimental Nusselt Number

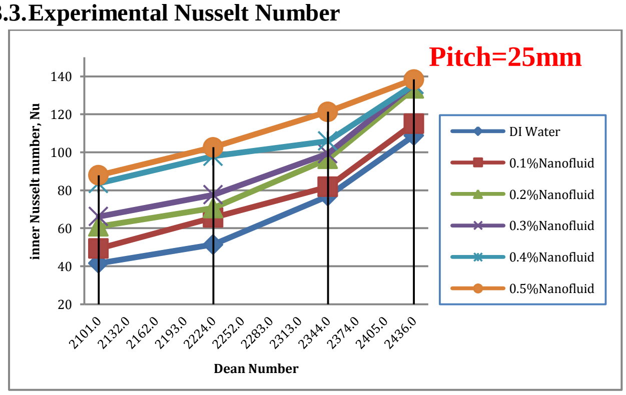

Figure 8 Inner Nu Vs De in a nano fluid volume fractions, pitch= 25mm

In Fig. 8, the HE's inner Nu was of 25 mm-pitch helical coil tubes is shown under steady-state flow conditions. It's been discovered that the De of the hot fluid inside grows as the Nu increases. For helical coil tube of Volume fraction 0.5% Nanofluid an average value of Nu is higher 6.1%, 15.8%, 19.7%, 30.7% and 38.1% than the reaming Volume fraction 0.4%, 0.3%, 0.2%, 0.1% and 0% DI Water respectively.

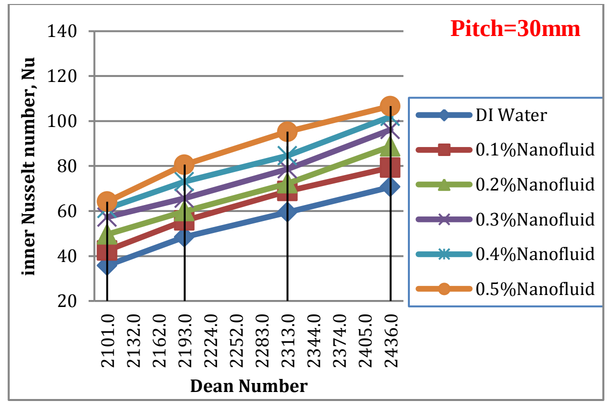

Fig 9 Nu Vs De in nano fluid volume fractions, pitch= 30mm

In Fig. 9, the inner Nu of a HE made of 30 mm-pitch helical coil tubes is shown under steady-state flow conditions. It has been found that the De of the hot fluid inside grows as the Nu increases. For helical coil tube of Volume fraction 0.5% Nanofluid an average value of Nu is higher 7.5%, 14.1%, 22%, 28.9% and 38.1% than the reaming Volume fraction 0.4%, 0.3%, 0.2%, 0.1% and 0% DI Water respectively.

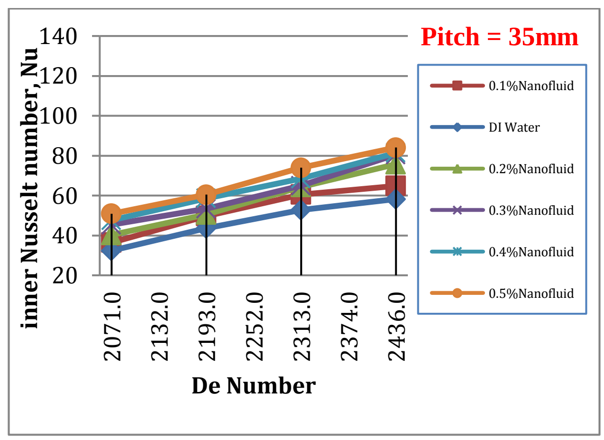

Fig 10 Inner Nu Vs De in a nano fluid volume fractions, Pitch= 35mm

In Fig. 10, the inner Nu of a HE made of 35 mm-pitch helical coil tubes is shown under steady-state flow conditions. The found that the De of the hot fluid inside grows as the Nu increases. For helical coil tube of Volume fraction 0.5% Nanofluid an average value of Nu is higher 4.9%, 9.3%, 14.3%, 21.4% and 30.6 % than the reaming Volume fraction 0.4%, 0.3%, 0.2%, 0.1% and 0% DI Water respectively.

Figures 8, 9, and 10 show the inner Nu of a HE with helical coil tubes of varying pitch (25mm, 30mm, and 35mm) and steady-state flow conditions. For all pitch consider HE's taken into consideration for the study, it has been observed that as the De of internal hot fluid raises, so does the Nu of HE's. The average inner Nu for helical coil tubes with a pitch of 25mm is higher by 23% and 36% than it is for tubes with a pitch of 30mm and 35mm, respectively. For helical coil tubes with a pitch of 25 mm and a volume fraction of 0.5% nanofluid, the maximum Nu was discovered; the minimum was DI water. As a fluid's Re increases, the Nu between the hot fluids also rises because De is directly proportional to that number.

3.4. Pressure Drop Characteristics

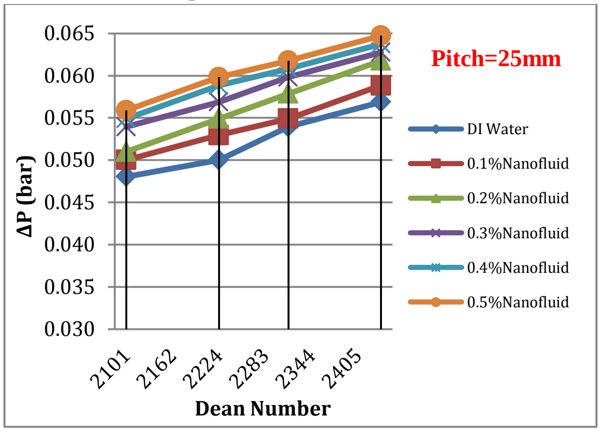

Figure 11 ΔPVs De in a nano fluid volume fractions, Pitch= 25mm

Figure 11 illustrates the ΔP of a HE made of 25 mm-pitch helical coil tubes under steady-state flow conditions. It's been observed that ΔP increases as De of internal hot fluid increases. For helical coil tube of Volume fraction 0.5% Nanofluid an average value of ΔP is higher 1.6%, 3.6%, 6.9%, 10.5% and 13.8 % than the reaming Volume fraction 0.4%, 0.3%, 0.2%, 0.1% and 0% DI Water respectively.

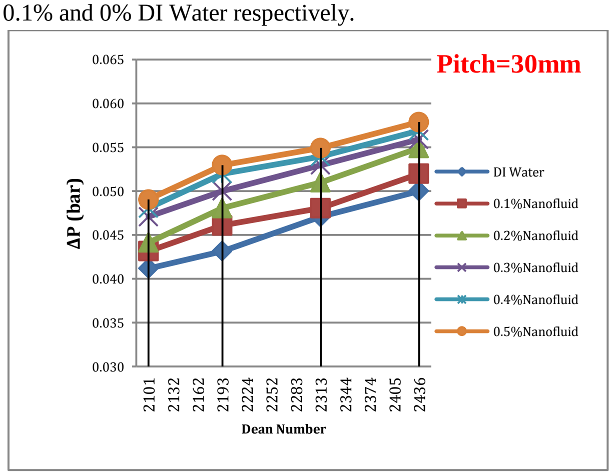

Figure 12 ΔP Vs De in a nanofluid volume fractions, Pitch= 30mm

Figure 12 illustrates the ΔP of a HE made of 30 mm-pitch helical coil tubes under steady-state flow conditions. It has been noted that ΔP increases as De of internal hot fluid increases. For helical coil tube of Volume fraction 0.5% Nanofluid an average value of ΔP is higher 1.8%, 4.1%, 7.8%, 11.9% and 15.5 % than the reaming Volume fraction 0.4%, 0.3%, 0.2%, 0.1% and 0% DI Water respectively.

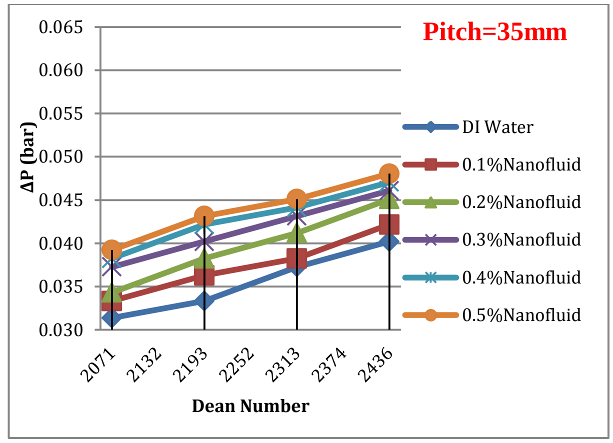

Figure 13 ΔP Vs De in a nanofluid volume fractions, Pitch= 35mm

Figure 13 depicts the ΔP of a HE made of 35 mm-pitch helical coil tubes under steady-state flow conditions. It is noted that ΔP increases with increasing De of hot fluid inside. For helical coil tube of Volume fraction 0.5% Nanofluid an average value of ΔP is higher 2.2%, 5.0%, 9.5%, 14.5% and 19.0 % than the reaming Volume fraction 0.4%, 0.3%, 0.2%, 0.1% and 0% DI Water respectively.

Figures 11, 12, and 13 shows the ΔP number for a HE made of helical coil tubes with varying pitches of 25 mm, 30 mm, and 35 mm in steady state flow conditions. For all pitches taken into consideration for the study, it has been observed that the De of internal hot fluid increases with the ΔP of the HE. The average ΔP for helical coil tubes with a pitch of 25mm is higher than for tubes with a pitch of 30mm and 35mm, respectively, by 12.1% and 29.3%. The helical coil tube with a pitch of 25 mm was found to have the highest pressure drop, and it contained the least amount of DI water and 0.5% nanofluid. Since De and fluid Re are directly proportional, ΔP between hot fluids raises as the fluid's Re rises.

3.5. Characteristics of Heat transfer

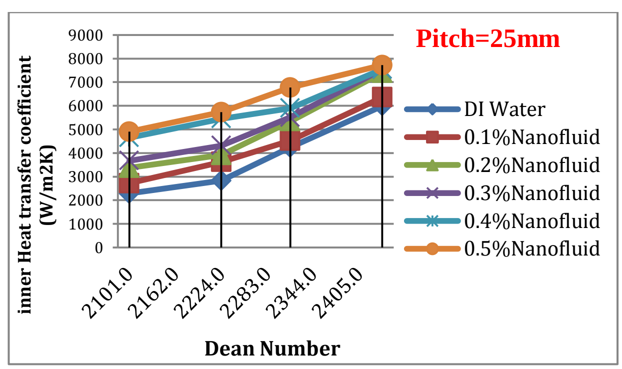

Figure 14 Inner coefficient of Heat transfer Vs De in a nano fluid volume fractions, Pitch= 25mm

Figure 14 shows the inner heat transfer coefficient of a HE made of 25 mm-pitch helical coil tubes under steady-state flow conditions. It found that the De of internal hot fluid rises as the coefficient of heat transfer rises. The average coefficient of heat transfer for helical coil tubes with volume fractions of 0.5% nanofluid is more than for reaming tubes with volume fractions of 0.4%, 0.3%, 0.2%, 0.1%, and 0% DI water, respectively, by 6.3%, 16.29%, 20.32%, 31.45%, and 38.92%.

Figure 15 illustrates the inner heat transfer coefficient of a HE made of 30mm-pitch helical coil tubes under steady-state flow conditions. It has been found that the De of internal hot fluid rises as the heat transfer coefficient rises. The average heat transfer coefficient for helical coil tubes with a volume fraction of 0.5% nanofluid is higher than that for reaming tubes with volume fractions of 0.4%, 0.3%, 0.2%, and 0% DI Water, respectively, by 6.49%, 13.45%, 21.57%, 28.74%, and 38.15%.

Figure 16 shows the inner coefficient of heat transfer of a HE made of 35 mm-pitch helical coil tubes under steady-state flow conditions. Found that the De of internal hot fluid rises as the coefficient of heat transfer rises. In comparison to remaining volume fractions of 0.4%, 0.3%, 0.2%, and 0.1% DI Water, the average coefficient of heat transfer for helical coil tubes filled with 0.5% nanofluid is higher at 5.14 percent, 8.59 percent, 13.85 percent, 21.2 percent, and 30.5 percent, respectively.

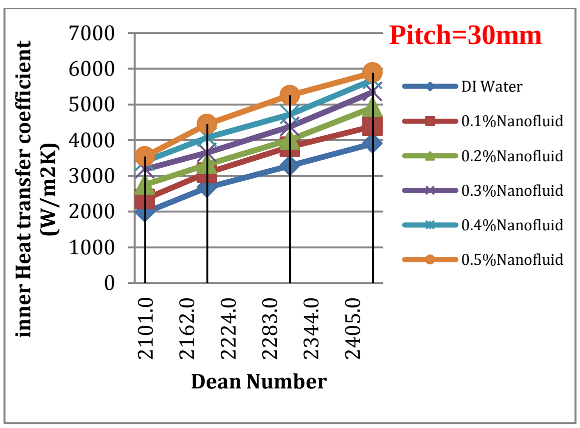

Figure 15 Inner coefficient of Heat transfer versus De in a nano fluid volume fractions, Pitch= 30mm

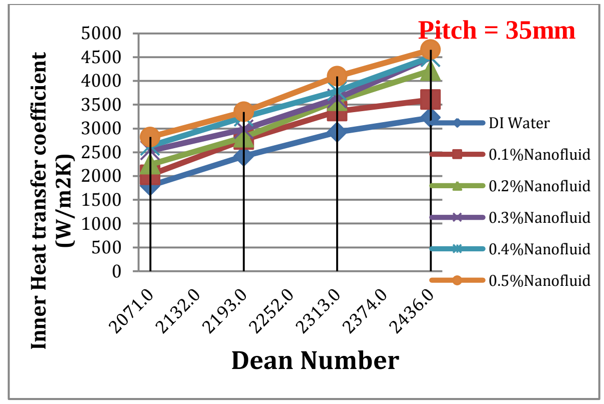

Figure 16 Inner Heat transfer coefficient Vs De in a nanofluid volume fractions, Pitch= 35mm

The rate of heat transfer HE's is observed to increase for all study pitches as the De of hot fluid inside rises. With the furthermore of nano particle, the coefficient of heat transfer also showed a rising trend. For 0.5% vol. concentration, the convective coefficient of heat transfer was more noticeable. For a fixed De of inside hot fluid, the heat transfer rate was found to be maximum for helical coil tubes with a pitch of 25 mm and to be minimum for helical coil tubes with a pitch of 35 mm. Since De and fluid Re are directly proportional, the heat transfer rate of between the hot fluid raises as the Re rises. The hot fluid particles' kinetic energy produces more heat Additionally, it can be seen from the results that, turbulence in a steady state flow conditions, the average value of heat transfer rate for helical coil tubes with a pitch of 25 mm is found to be 23.05% more than that for helical coil tubes with a pitch of 30 mm and 36.49% more than that for helical coil tubes with a P= 35 mm. With more in the hot fluid's De inside the helical tube for the various pitches taken into consideration for the study, the rate of heat transfer the helical coil tube HE increases.

4. CONCLUSION

The experimental investigation of Heat transfers properties of HCHE's with variable pitch is being carried out in the current study. Using water-based TiO_2 nanofluid in a HCHE, the effect pitch on De, coefficient of heat transfer, pressure drop, friction factor and Nu characteristics are studied. The experiment was conducted in HCHE with various nano particle volume concentrations and pitches in turbulent flow conditions. As per the experimental study's findings, the following conclusions were drawn:

a. When of nanofluid with 0%, 0.1%, 0.2%, 0.3%, 0.4% and 0.5% volume concentrations in DI water.

i. Increasing in the concentration of the nanoparticles results in greater improvements in rate of heat transfer when added to the base fluid.
ii. The HCHE's maximum improvement in Nu and friction factor observed for 0.5% volume concentration.

b. When using helical coils of pitches 25mm, 30mm and 35mm.

i. The average friction factor for HCHE with a pitch of 25mm is more than the average values for tubes with a pitch of 30mm and 35mm, respectively, by 2.9% and 5.6% in percentages.

ii. The average inner Nu for helical coil tubes with a pitch of 25mm is found to be higher by 23% and by 36% as compared to pitch of 30mm and 35mm respectively.

iii. The average Pressure drops experienced for helical coil tube of pitch 25mm is higher by 12.1% and by 29.3% as compared to pitch of 30mm and 35mm respectively.

iv. For turbulent flow condition it is discovered that the average value of rate of heat transfer for helical coil tubes with a pitch of 25 mm is 23.05% more than that of helical coil tubes with a pitch of 30 mm and 36.49% more than that of helical coil tubes with a pitch of 35 mm.

Future research is required to examine the heat transfer and friction factor using TiO_2 water nanofluids at various helically coil diameters and different volume concentrations.

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