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INVESTIGATIONS USING NUMERICAL AND OBSERVATION ON THE ENERGY TRANSFER AND FLOW PROPERTIES OF A HELICAL COIL HEAT EXCHANGER

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ABSTRACT

A helical coil twin pipe heat exchanger's flow and heat transfer characteristics have been examined through experimental and numerical research. The Dean number and torsion are two crucial variables that influence convective heat transfer. The Wilson plot is used to calculate the overall heat transfer coefficients and to determine the heat transfer coefficients. The experimental data from the current work and those from previous research are used to validate the numerical scheme. The findings demonstrated that using helical coil heat exchangers rather of straight tube types improves the Nusselt number. However, helical coils have a high friction factor. The Nusselt number in the inner tube and annulus rises along with the Dean number, and the annulus is where the effect of the Dean number on the Nusselt number is most pronounced. There is an ideal pitch value, and the overall heat transfer coefficient varies with pitch. It is suggested to estimate the Nusselt number using a correlation between the Dean number, Prandtl number, and dimensionless pitch.

Kew Words- Helical coils, heat transfer, Nusselt number, Dean number

INTRODUCTION

Helical coils are frequently employed in systems for heat recovery, food processing, and refrigeration. Helical coils have higher heat transfer rates than straight pipes, especially in the laminar regime. Centrifugal forces brought on by the pipe's curvature act on the fluid in motion, creating a second flow pattern that is perpendicular to the primary axial flow. This secondary flow pattern often consists of two vortices that transport fluid from the inner wall of the tube to the outer wall, across the tube's centre, and back to the inner wall in a wall-following motion. Heat transfer coefficient and friction factor are higher in a curved pipe than in a straight one due to the secondary flow motion caused by the curvature effect and the resulting centrifugal force. Additionally, the temperature and velocity fields are made more complicated by the torsion of helically coiled tubes. Yildiz et al. (1995) and Xin et al. (1997; helical pipes) showed an increase in pressure drop and heat transfer rate. Lin et al. (1997) examined the three-dimensional laminar forced flow and heat transfer in the entry region of helical pipes using a completely elliptic numerical technique. In comparison to laminar flow at lower Reynolds numbers, laminar flow at higher Reynolds numbers produces a less oscillation of the average friction factor. In order to calculate the heat transfer coefficient, Ali (1998) investigated the natural convection heat transfer from horizontally oriented, uniformly heated helical tubes. Thermal radiation can speed up overall heat transmission, according to research by Zheng et al. (2000) on its impact on convective heat transfer. The benefit of a helically coiled heat exchanger over a straight tube heat exchanger for heating liquids was demonstrated by Prabhanjan et al. in 2002. The turbulent and transitional flow zones were used for the experiments. An experimental study on the heat transmission from helical coiled tubes submerged in water was conducted by Prabhajan et al. in 2004. They compared the Rayleigh number to the outer Nusselt number and decided that coil height was the best illustration of a vertical coil. Moawed (2005) presents an experimental analysis of steady state natural convection heat transfer from uniformly heated helicoidal pipes that are oriented both vertically and horizontally. The findings shown that for vertical helicoidal pipes, the ratios of coil diameter to pipe diameter (D/do), pitch to pipe diameter (p/do), and length to pipe diameter (L/do) all rise with increasing values. In the laminar regime, Rennie et al. (2006) performed numerical simulations on a double pipe helical heat exchanger. Both parallel flow and counter flow total heat transfer coefficients were estimated, and a link between annulus Nusselt number and modified Dean number was found. The heat transfer parameters of a tube-in-tube heat exchanger were investigated experimentally and numerically by Kumar et al. (2006) while operating in the counter-current mode. In their experiments on a helical coil heat exchanger using air and water as the heat transfer fluids, Shokouhmand and Salimpour (2007) suggested a correlation for calculating the heat transfer coefficient. In order to comprehend forced laminar flow in rectangular coiled pipes with circular cross sections, Conte and Peng (2008) carried out numerical investigation. Conical coils performed better in terms of heat transmission. In parallel and counterflow arrangements, Chen and Dung (2008) studied twin tube heat exchangers numerically. Oval-cross section inner tubes demonstrated superior heat transfer properties. According to Xiaowen and Lee (2009), using a helical heat exchanger improved the coefficient of performance of a household water-cooled air conditioner. Mandal and Nigam (2009) looked at the fluid-to-fluid heat transfer properties of compressed air with turbulent flow in a two pipe helical heat exchanger. Correlations between the Nusselt number and friction factor in the inner and outer tubes were suggested. A correlation for the heat transfer coefficient for flow between concentric helical coils was developed by Kharat et al. in 2009. CFD simulations of vertically oriented helical coils with turbulent water flow were performed by Jayakumar et al. in 2010. They suggested correlations for estimating the average Nusselt number under the boundary conditions of constant wall temperature and constant wall heat flux. Ghorbani et al. (2010) conducted an experimental investigation on the mixed convection heat transfer in a coil-in-shell heat exchanger. Both laminar and turbulent flow experiments were carried out inside coils. Chen et al. (2011) performed crucial heat flux tests in horizontal helically coiled tubes using R134a as the heat transfer fluid. It has been stated that a correlation can be used to estimate the critical heat flux and that the coil to diameter ratio is more significant than the length to diameter ratio. Experimental research on forced convection heat transfer from a constant heat flux helical coil tube was done by Moawed (2011). Studies with different coil characteristics were done to determine the relationship between Reynolds number and geometric parameters for the heat transfer coefficient. Ice slurries' flow and heat transmission characteristics in a helically-coiled pipe were investigated by Haruki and Horibe in 2013. The interaction of the centrifugal and buoyant forces caused by secondary flow significantly affects the flow resistance. The latent heat of the ice particles, on the other hand, had an impact on the heat transmission coefficient. According to Mahmoudi et al.'s (2017) investigation of the forced convection heat transfer and pressure drop in helically coiled pipes employing TiO2/water nanofluid, Dean number significantly affects heat transfer for a given Reynolds number. Experimental research on the heat transfer properties of supercritical CO2 in helically coiled tubes with continuous wall heat flow was conducted by Xu et al. (2018). They looked into how diameter, heat flow, and mass flux affected the destruction of exergy without regard to dimensions. According to the findings, for supercritical CO2, the irreversibility of heat transfer results in a far greater loss of energy than flow friction. An experimental examination of a diabatic flow of R-600a through a concentric-configured helically coiled capillary tube suction line heat exchanger was provided by Dubba and Kumar (2018). To forecast the mass flow rate of R-600a passing through an adiabatic helical coiled capillary tube, a semi-empirical correlation was proposed. Izadpanah et al. (2018) investigated the heat transfer by natural convection over a helically coiled heat exchanger's exterior surface inside a water tank. A power law correlation for the Nusselt number was shown after studying the impact of coil diameter, pitch, turns, and mass flow rate.

This study's primary goal is to offer pertinent information about the thermal and flow properties of double pipe helical coil heat exchangers. The solid-fluid interfaces in the numerical study have interface boundary conditions applied to them, and Fluent's conjugate heat transfer method is used to compute the heat transfer. The data from our experimental research are compared to the outcomes of numerical studies. The association between the Nusselt number and the Dean number, Prandtl number, and dimensionless pitch is suggested by this study.

SECTION SNIPPETS

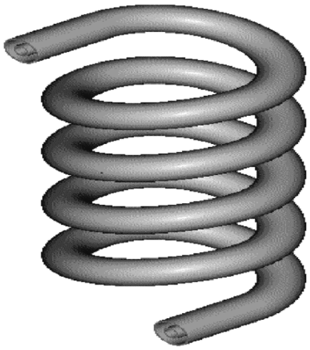
GEOMETRICAL DETAILS OF THE HEAT EXCHANGER

Table 1 shows the dimensions of the helical coil tube in tube heat exchanger considered for the study.

Parameter	Value(mm)
Outside diameter of inner tube (d_o)	9.5
Inside diameter of inner tube (d_i)	7.9
Wall thickness of both inner and outer tubes (t)	0.8
The outside diameter of the outer tube (D_o)	15.9
Inside diameter of outer tube (D_i)	14.3
The radius of curvature of the helical coil (R)	235.9
Pitch of the helical coil varied from (P)	16 - 144
Length of the coil (L)	2960

EXPERIMENTAL SETUP

The schematic diagram of the experimental setup is shown in the Fig. . The test section i.e. the helical coil heat exchanger is made of copper tubes. In order to prevent the heat loss from the heat exchanger to the surroundings two layers of insulations are provided on the outer surface of the heat exchanger. The first layer is polyurethane foam (PUF) insulation and the second layer is.



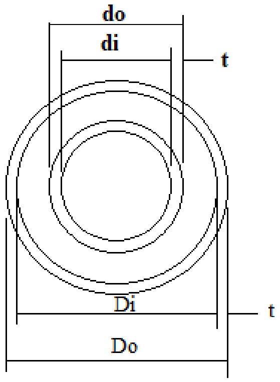


Figure 1 Tube in tube helical coil heatexchanger

Figure 2 Cross-section of the heatexchanger

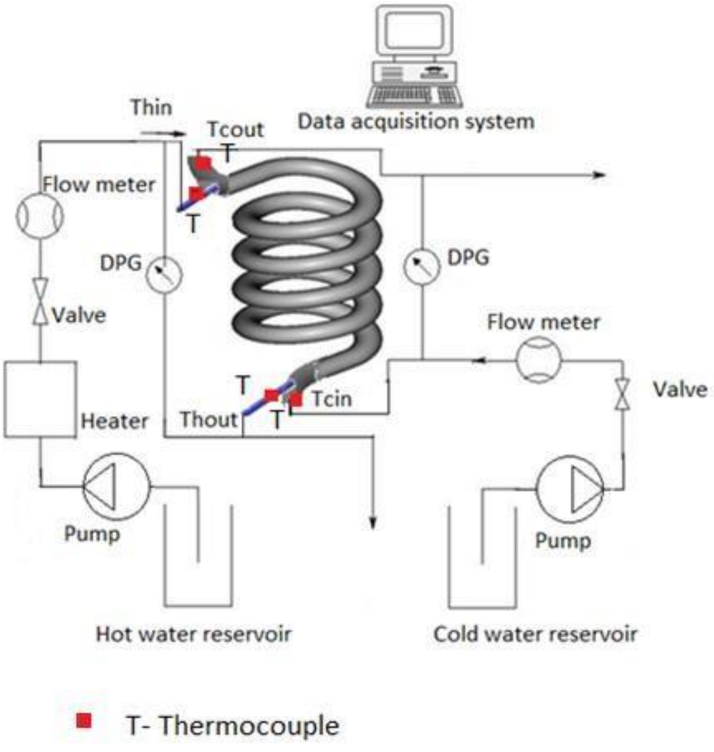


Figure 3 Experimental setup

NUMERICAL SETUP

The 3D-geometry of the double tube helical coil heat exchanger is modeled using AutoCAD 14.0 and ANSYS 14.5 Design Modeler. The mesh was created using meshing module of the ANSYS 14.5 workbench. Initially a relatively coarser mesh is generated. This mesh contains mixed cells (Tetra and Hexahedral cells) having both triangular and quadrilateral faces at the boundaries. Care is taken to use structured hexahedral cells as much as possible. It is meant to reduce numerical diffusion as much as.

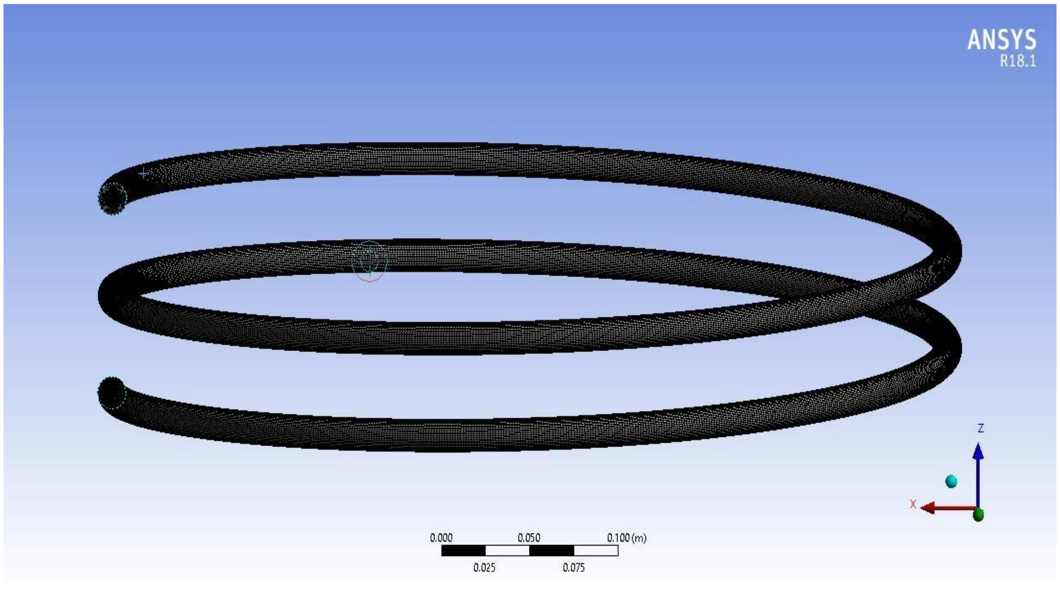
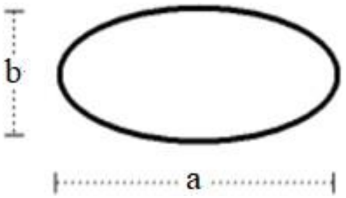


Figure 4 Computational domain

Table 2 Dimensions for the study of the effect of inner tube diameter

	do (mm)	di (mm)	t (mm)	Do (mm)	Di (mm)	R (mm)	p (mm)
Case 1	12.7	11.1	0.8	15.9	14.3	235.9	15.9
Case 2	9.5	7.9	0.8	15.9	14.3	235.9	15.9
Case 3	6.35	4.75	0.8	15.9	14.3	235.9	15.9

Table 3 Major and minor diameter dimensions of three configurations of ellipticalcross-section



Major diameter, a (mm)	Minor diameter, b (mm)
10.6	4.60
9.6	5.99
8	7.9

RESULT AND DISCUSSION

The impact of Reynolds number, Dean number, and torsion on the heat transfer and flow properties in a twin tube helical coil heat exchanger has been studied through experimental and numerical analyses. Both the inner tube and the annulus have laminar flows with a counter-flowing arrangement. Pitch in the numerical analysis is changed from 16 mm to 144 mm while keeping the curvature's length and radius constant.

EFFECT OF INNER DEAN NUMBER ON OVERALL HEAT TRANSFER OEFFICIENT

Figure indicates the variation of the overall heat transfer coefficient with theinner Dean number for various flow rates through the annulus. The graph shows that theDean number has a significant effect on the overall heat transfer coefficients when the outer flow rate is high. For a flow rate of 0.3 lpm, the overall heat transfer coefficient increases by 25 % when the Dean number increases from 172 to 584, and the corresponding increase for the flow rate of 0.9 lpm is 29%. At higher annulus flow rates,the flow rate in the inner tube is the limiting factor of the overall heat transfer coefficient;hence any change in the inner flow rate will have a significant effect. At low inner flow rates, the overall heat transfer coefficient depends on the inner heat transfer coefficient. At higher inner flow rates, it depends on the annulus heat transfer coefficient. Hence anychange in inner flow rate will have a significant effect

EFFECT OF INNER DEAN NUMBER ON INNER NUSSELT NUMBER

In the experimental studies, the Wilson plot is used to estimate the heat transfer coefficients. Figure 3.11 indicates the variation of the inner Nusselt number with the innerDean number. The data obtained from numerical studies are also shown for comparison. There is good agreement between the data obtained from experiments and numerical studies. The increase in inner Nusselt number is 50 % when the Dean number is varied from 170 to 585.

CONCLUSIONS

Experimental and numerical research is done on the convective heat transfer of fully developed laminar flow in a helical tube in tube heat exchanger. Two important parameters, Dean number and torsion, have a substantial impact on the heat transfer behaviour in a helical heat exchanger. The secondary flow becomes more powerful as the Dean number rises. The study's findings are as follows: (i) the numerical model is capable of forecasting the heat transfer and flow properties of the heat.

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