

An Experimental Investigations of Twisted Tape Inserts in Square and Circular Geometry Helical Coil Heat Exchanger

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Abstract - This study mainly examine helical coil heat exchanger was performed by using two differently shaped heat exchangers, square and circular pattern with twisted tape inserts. The empirical Nusselt number correlation of circular pattern helical coil compared with the square pattern helical coil. Also investigates the heat transfer rate of both coils comparatively.

The performance of helical coil heat exchanger will be evaluated by measuring heat transfer coefficient of coil geometries differently by using Wilson plot method. Also study the effect of twisted tape inserts.

Also calculate tube side Nusselt number for various mass flow rates. This tube side Nusselt number were developed for both the coil geometries and compared with the available existing correlations. Also study two helical coils for Nusselt number variation with Reynolds number for circular and square helical coiled pattern.

Keyword – Helical coil heat exchanger, Nusselt Number, Heat transfer coefficient.

1. INTRODUCTION

Heat exchangers are devices that can be used to transfer heat from a fluid stream (liquid or gas) to another fluid at different temperatures. Heat Exchanger is a device in which the exchange of energy takes place between two fluids at different temperature.

Heat exchangers are extensively used in the industries for a variety of industrial applications like, refrigeration and air-conditioning, steam power plants, nuclear reactors, chemical and food processing industries, and medical equipment [3-11].

Enhancement (augmentation or intensification) in heat transfer coefficient improves the performance of a heat exchanger and reduces surface area required for heat transfer. In general these heat transfer enhancement techniques are of three types viz. active, passive and compound techniques.

2. LITERATURE REVIEW

Most of researchers have done numerical and experimental studies on helical coil heat exchanger in circular pattern. Salimpour et al. [6] investigated Correlation

between the tube-side Nusselt number and Dean number, Prandtl number, and dimensionless coil pitch is obtained using least square analysis Rennie et al. [2] investigated heat transfer rates were much higher in the counterflow configuration due to the larger average temperature difference between the two fluids than parallel flow configuration. Shokouhmand et al. [5] analyses experimental results indicate that as coil pitch increases, tube side Nusselt number decreases. Rane et al. [3] investigated, serpentine layout tube in tube heat exchanger with seven bend has shown optimum performance, with overall heat transfer coefficient 17% higher than straight tube in tube in tube heat exchanger. Nobari et al. [8] analyses Effects of governing non-dimensional parameters, such as torsion, curvature, aspect ratio, Reynolds and Dean Numbers on the fluid flow characteristics involving axial flow, secondary flow and friction factor. Choosing superior twisted tape configurations is the high value of thermal performance factor.

3. PROBLEM IDENTIFICATION

Most of the investigations on heat transfer coefficients are for of helical coil heat exchanger with circular geometry only. None has reported reliably optimal layout, it is beneficial to investigate more coil geometries experimentally such as square, elliptical, rectangle etc. Less work was done in heat transfer augmentation technique such as twisted tape inserts in helical coil heat exchanger.

So in present work we Investigates twisted tape inserts in square and circular pattern helical coil heat Exchanger experimentally.

4. SCOPE AND OBJECTIVE

- [1] Comparative analysis will be conducted for heat transfer analysis on two separate helical coil geometries. Under counter flow setup, square and circular coil patterned geometries with twisted tape were tested.
- [2] To study the performance of both coil, variation of tube side Nusselt Number (Nu) versus tube side Dean Number (De) are observed graphically.
- [3] Tube side Nusselt number (Nu) calculated for different mass flow rates to suggest correlation. For both the coil geometries, the tube side Nusselt number (Nu) correlations were developed and compared with existing correlations available.

- [4] To study performance of two helical coils, experimentally investigates Nusselt number (Nu) variation with Reynolds number (Re) for both coils.
- [5] To analyses the effect of twisted tape inserts in HCHE.

5. DESIGN & DEVELOPMENT OF HELICAL COIL HEAEXCHANGER

5.1 Geometric dimensions and working conditions selected for analysis

The literature review shows that most research has been done on helical coil heat exchangers with circular geometry of the coil. Thus, in these investigations, we analyze helical coil heat exchanger with two different geometries, such as circular and square, in no pitch condition. Geometry of both helical coil heat exchangers is shown in Figure 5.1.

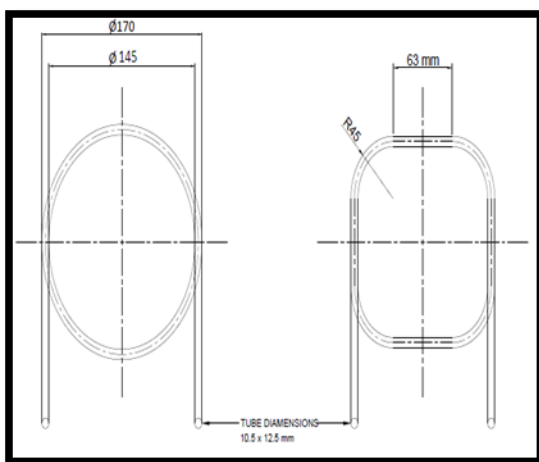


Figure 5.1. Geometry of helical coils

Table 5.1: Geometric parameters selected for analysis

Sr. No.	Parameters	HCHE	
		Circular Coil	Square coil
1	Tube Dimensions: I.D. X O.D. ($d_i \times d_o$) mm	10.5 × 12.5	10.5 × 12.5
2	Coil diameter (R_c), mm (D_c)	170	Avg. 170
3	Curvature radius, mm	85	NA
4	Corner Radius, mm	NA	45
5	Tube length (L), mm	3204	3204
6	Number of Turns	6	6
7	Coil Pitch (b), mm	12	12

Geometry of twisted tape is shown in Fig. 5.2.



Figure 5.2. Geometry of twisted tape

Table 5.2: Geometric parameters selected for twisted tape

Sr. No.	Parameter	Dimension
1	Twist pitch	20 mm
2	Width	6 mm

Table 5.3: Range of working parameters

Sr. No.	Working Parameters	Range
1	Tube side / cold fluid flow rate	0.0167-0.0833 kg/s
2	Shell side / hot fluid flow rate	0.0167-0.0833 kg/s
3	Tube side / cold fluid inlet temperature	40-60°C
4	Tube side / cold fluid outlet temperature	37-55°C
5	Shell side / hot fluid inlet temperature	27-33°C
6	Shell side / hot fluid outlet temperature	32-45°C

5.2 Square and circular geometry helical coil heat exchanger test rig

Test rig set included

1. Square and Circular geometry HCHE
2. Tube side / hot water supply system with in-built heater, pump.
3. Constant temperature cold water source
4. Rotameter for flow measurement
5. Control panel include Pump On/ OFF switch, Heater ON / OFF switch, Temperature indicator.

Figure 5.3 shows flow diagram of Square and circular geometry HCHE test rig investigated experimentally.

The performance was taken on the setup shown in figure 5.3, with two different geometries of helical coil. A hot water tank provides tube side hot fluid flow and overhead tank provides shell side cold fluid flow. Two rotameters were used to measure mass flow rate on both tube side and

shell side. The indicator panel used to record all inlet and outlet temperature of both coil alternatively.

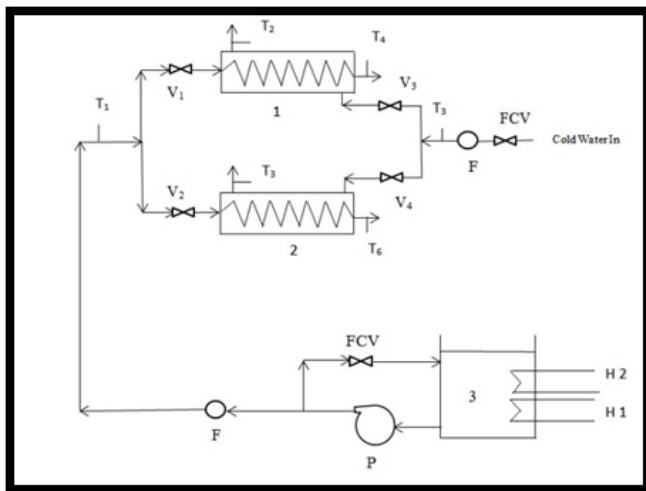


Figure 5.3 Block diagram of test rig

5.3 Experimental procedure

The first calibrate all rotameter & thermocouple. Adequate quantity of working fluids was collected in both tanks i.e. hot water tank and overhead cold water tank. Overhead tank started the flow of cold water on the shell side. Maintain the temperature of hot water at 40 °C by using a heater and then start supplying hot water to the tube side. Simultaneously supply cold water at constant temperature on the shell side. By adjusting the flow control valve and bypass valve maintains the tube side flow rate. For taking Square geometry HCHE readings, valves of circular geometry HCHE be closed and vice versa. Using the temperature indicator, take the tube side and shell side temperature readings, the steady state was confirmed by no improvement in time temperature readings. Repeat the process for different cold water flow rates of 1, 2 and 3 LPM and cold water flow rates of 1, 1.5, 2, 2.5, 3, 3.5, 4 and 4.5 LPM.

6. RESULT, GRAPH AND DISCUSSION

In present work heat transfer coefficient of both coils were calculated by using Wilson plot method,

Heat absorbed by cold water,

$$Q_c = mc \times C_{p_c} \times (T_{in} - T_{out})$$

Heat rejected by hot water,

$$Q_h = mh \times C_{p_h} \times (T_{in} - T_{out})$$

The performance was taken on the setup shown in figure 5.3, with two different geometries of helical coil. A hot water tank provides tube side hot fluid flow and overhead tank provides shell side cold fluid flow. Two rotameters were used to measure mass flow rate on both tube side and

shell side. The indicator panel used to record all inlet and outlet temperature of both coil alternatively.

$$Q_{avg} = \frac{(Q_c + Q_h)}{2}$$

The outer Heat transfer Area of both coiled heat exchanger was same,

$$A_o = \pi d_o L = 0.1258 \text{ m}^2$$

Overall heat transfer coefficient is given by,

$$U_o = \frac{q_{avg}}{A_o \text{ LMTD}}$$

The overall heat transfer coefficient was calculated by following equation,

Outside convective heat transfer coefficient,

$$\frac{1}{U_o} = \frac{A_o}{A_i h_i} + \frac{A_o \ln\left(\frac{d_o}{d_i}\right)}{2\pi KL} + \frac{1}{h_o}$$

Inside heat transfer coefficient,

$$h_i = C \times V h^n$$

Reynolds Number

Reynolds Number for tube side,

$$Re_i = \frac{\rho h V_i d_i}{\mu}$$

Reynolds Number for Shell side,

$$Re_o = \frac{\rho c \cdot V_o \cdot d}{\mu}$$

Nusselt Number

Nusselt Number for tube side,

$$Nu_i = \frac{h_i d_i}{k_h}$$

Nusselt Number for shell side,

$$Nu_o = \frac{h_o d_h}{k_c}$$

Effectiveness

$$Q_{max} = m \min \times C_{p \min} \times (T_{hi} - T_{ci})$$

$$\text{Effectiveness } (\epsilon) = (Q_{avg} / Q_{max})$$

Dean Number (D_e)

$$D_{e_i} = Re_i (d_i / 2R_c)^{0.5}$$

$$D_{e_o} = Re_o (d_i / 2R_c)^{0.5}$$

Friction factor

$$\frac{7.2}{\sqrt{Re_i}} \left(\frac{d_i}{D_c}\right)^{0.25}$$

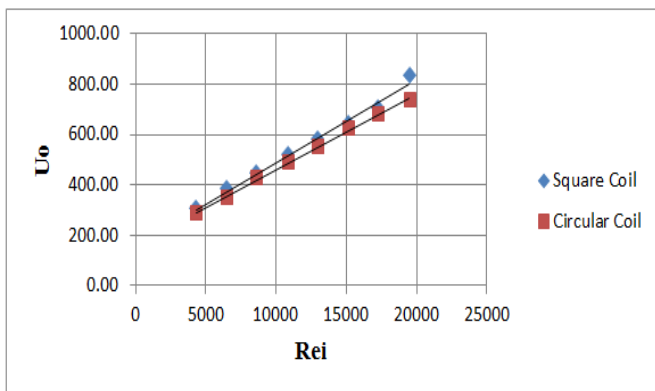
Pressure drop,

$$\Delta P = 2fL\rho Vh^2 / d_i$$

The literature analysis shows that extensive work in the helical coil heat exchanger. Among them we choose the following correlation because Dean Number ranges from $500 < De < 5000$ and Dimensionless Pitch ratio is 0.02247.

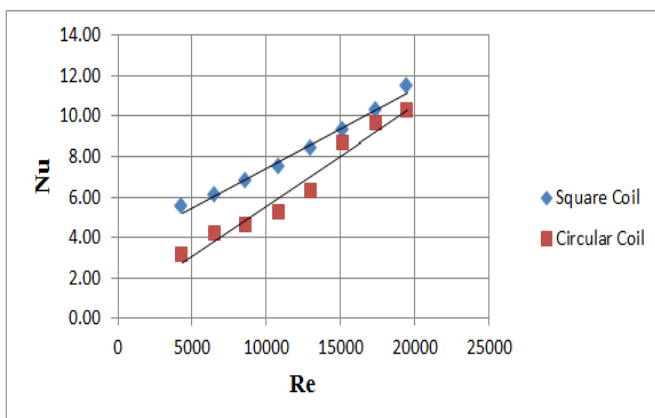
$$Nu_i = 0.152 Re_i^{0.431} Pr^{1.06} \gamma^{-0.277} \quad [6.1]$$

$$Nu_o = 19.64 Re_o^{0.513} Pr^{0.129} \gamma^{-0.0938} \quad [6.2]$$



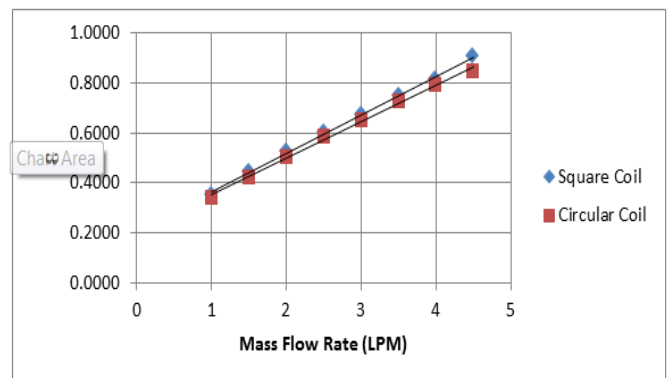
Graph 6.1 Effectiveness (ε) vs. tube side flow rate

Graph 6.1 shows comparison of effectiveness of helical coil heat exchanger with shell side flow rate for both geometries of coil separately. As the tube side flow rate increases the heat exchanger effectiveness increases, when shell side flow rate remains constant. It was observed that, Square coiled heat exchanger has greater effectiveness than circular coiled heat exchanger.



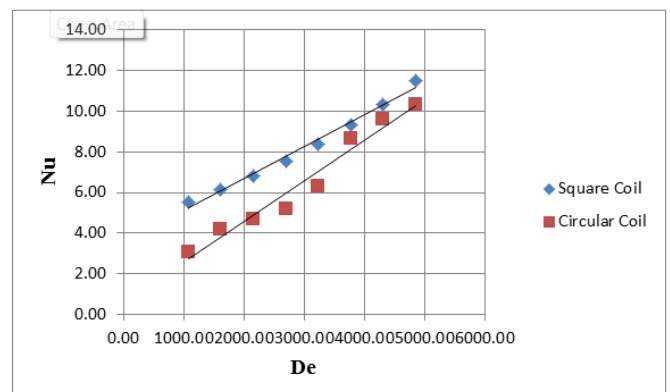
Graph 6.2 Overall heat transfer Coefficient [U_o] vs. inside Reynolds Number [Re]

Graph 6.2 shows comparison of overall heat transfer coefficient [U_o] of helical coil heat exchanger with inside Reynolds Number [Re] for both geometries of coil separately. As Reynolds number [Re] increases the overall heat transfer coefficient [U_o] of heat exchanger increases, when shell side flow rate remains constant. Square coiled heat exchanger has greater heat transfer coefficient than circular coiled heat exchanger. From result table shows that the overall heat transfer coefficient [U_o] of the square coil heat exchanger was approximately 8% higher than the circular coiled heat exchanger.



Graph 6.3 Tube side Nusselt Number [Nu] vs. tube side Reynolds Number [Re]

Graph 6.3 shows comparison of tube side Nusselt Number [Nu] of helical coil heat exchanger with tube side Reynolds Number [Re] for both geometries of coil separately. Square coiled heat exchanger has greater Nusselt Number [Nu] than circular coiled heat exchanger. Also tube side Nusselt Number [Nu] calculated by using existing correlation between the Prandtl Number [Pr], Dean Number [De] and Dimensionless pitch ratio [γ] was nearly same as experimental Nusselt Number [Nu].



Graph 6.4 Tube side Nusselt Number [Nu] vs. tube side Dean Number [De]

Graph 6.4 shows comparison of tube side Nusselt Number of helical coil heat exchanger with tube side Dean Number for both geometries of coil separately. As tube side

Dean Number [De] increases the tube side Nusselt Number [Nu] of heat exchanger also increases, when shell side flow rate remains constant. Square coiled heat exchanger has greater Nusselt Number [Nu] than circular coiled heat exchanger for given range Dean Number [De] $500 < De < 5000$.

7. CONCLUSION

Experimental investigation of helical coil heat exchanger with square and circular coil geometry was studied in counter-flow configuration. The design, development and investigation was done and has following conclusions,

- [1] As the tube side flow rate increases the heat exchanger effectiveness increases, when shell side flow rate remains constant. Square coiled heat exchanger has greater effectiveness than circular coiled heat exchanger.
- [2] As Reynolds number [Re] increases the overall heat transfer coefficient [Uo] of heat exchanger increases, when shell side flow rate remains constant. Square coiled heat exchanger has greater heat transfer coefficient than circular coiled heat exchanger.
- [3] From the result table, the overall heat transfer coefficient [Uo] of the square coil heat exchanger was approximately 8 % higher than the circular coiled heat exchanger.
- [4] Square coiled heat exchanger has greater Nusselt Number [Nu] than circular coiled heat exchanger.
- [5] Also tube side Nusselt Number [Nu] calculated by using existing correlation between the Prandtl Number [Pr], Dean Number [De] and Dimensionless pitch ratio [γ] was nearly same as experimental Nusselt Number [Nu].
- [6] As tube side Dean Number [De] increases the tube side Nusselt Number [Nu] of heat exchanger also increases, when shell side flow rate remains constant. Square coiled heat exchanger has greater Nusselt Number [Nu] than circular coiled heat exchanger for given range Dean Number [De] $500 < De < 5000$.

REFERENCES

- [1] Prabhanjan DG, Raghavan GSV, Kennic TJ. Comparison of heat transfer rates between a straight tube heat exchanger and a helically coiled heat exchanger. Heat and mass transfer (2002); 29 (2): 185-191.
- [2] Rennie T J, Raghavan VGS. Experimental studies of a double-pipe helical heat exchanger. Experimental Thermal and Fluid Science (2005); 29: 919-924.
- [3] Rane M V, Tandale M S. Water-to-water heat transfer in tube-tube heat exchanger: Experimental and analytical study. Applied Thermal Engineering (2005); 25: 2715-2729.
- [4] Naphon P. Thermal performance and pressure drop of the helical-coil heat exchangers with and without helically crimped fins. International Communications in Heat and Mass Transfer (2007); 34: 321-330.

- [5] Shokohmand H, Salimpour MR, Akhavan-Behabadi MA. Experimental investigation of shell and coiled tube heat exchangers using Wilson plots. International Communications in Heat and Mass Transfer (2008); 35: 84-92.
- [6] Salimpour MR. Heat transfer characteristics of a temperature-dependent-property fluid in shell and coiled tube heat exchangers. International Communications in Heat and Mass Transfer (2008); 35: 1190-
- [7] N. Jamshidi, M. Farhadi*, D.D. Ganji, K. Sedighi. Experimental analysis of heat transfer enhancement in shell and helical tube heat exchangers; Applied Thermal Engineering 51 (2013) 644-652.

BIOGRAPHIES



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