International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 09 Issue: 08 | Aug 2022 www.irjet.net p-ISSN: 2395-0072

CONVECTIVE HEAT TRANSFER ANALYSIS IN A HELICAL COIL

[1]Mr. Ankush J. Kakode, [2] Dr A.T. Autee

[1]M.E. Scholar, Department of Mechanical Engineering, Maharashtra Institute of Technology, Aurangabad India
[2]Professor, Department of Mechanical Engineering, Maharashtra Institute of Technology, Aurangabad India

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Abstract- *Twisted pipes are classified on the base of curve as constant curve and variable curve pipes. The former are called as "helices" i.e. spiral coil & the ultimate as ' spirals ". When a fluid flows in a helically curled tube centrifugal forces causes secondary fluid stir, which gives rise to increase heat transfer rate. At veritably short distances from the launch of heat transfer zone, the thermal boundary subcaste is too thin to be affected by the secondary inflow field, which reaches its maximum intensity at some distance down from the tube wall. thus, near the tube inlet the rate of heat transfer measure in a curled tube to that in a straight tube varies only as NDe1/6 and Coil tube offers little advantage over a straight tube. The present work involves fabrication of a setup for spiral coil of ID8.04 mm & OD9.70 mm and 3800 mm length. The coil consists of a tank of ID 305 mm with a bath result like water. The face temperature of spiral coil at different positions, bath temperature are measured on digital temperature archivist. The water bay and outlet temperature are measured by thermometer. The work involves analysis of heat transfer between bath result and water flowing through the spiral coil. The convective heat transfer will be anatomized for with and without agitation. The ideal of this discussion work is to gain a better and further quantitative sapience into the heat transfer process that occurs when a fluid flows in a spiral coils tube.*

Keywords--Heat Transfer1, Helical coil2, copper Coil 3

1. INTRODUCTION

Spiral coils are compact in size and provides distinct benefit like advanced film measure, more effective application of available pressure drop, which results in effective and less precious design. spiral coil permits running of high temperature and extreme temperature differentials without high convinced stresses or expensive expansion joints. spiral coil offers advantages over straight tubes due to their conciseness and increased heat transfer measure. The increased heat transfer portions are a consequence of the curve of the coil, which induces centrifugal forces to act on the moving fluid, performing in secondary inflow. A Flow through Helical Coil When a fluid flows through a straight tube the haste is maximum at the tube centre, zero at the tube wall and symmetrically distributed about the axis. still when a fluid flows through a twisted tube, the primary haste profile shown in Fig -1.1 is distorted by the addition of secondary inflow pattern. The secondary inflow is generated by the centrifugal action and acts in the Aeroplan

vertical to the primary inflow. Since the haste is maximum at the tube centre the fluid at the centre is subordinated to maximum centrifugal action, which pushes the fluid towards external wall. The fluid at the external wall moves inward along the tube wall to replace the fluid ejected outwards. This results in the conformation of two maelstroms symmetrically about a vertical aeroplane through the tube center.

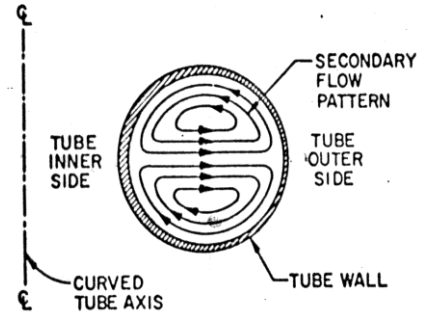

Fig-1 Basic Geometry of Helical Coil

1.2.1 Heat Transfer in Helical coil: - The heat and mass transfer are advanced in a twisted pipe than in an original straight tube at the same inflow rate, due to actuality of superimposed secondary inflow (5).

Flow in twisted path is a complex miracle because of the presence of centrifugal forces acting on rudiments of liquid flowing through similar pipes. To balance this centrifugal force, a pressure grade across the pipe is formed. The pressure is maximum at external wall and minimum at the inner wall. This results in a secondary inflow, in which the fluid near the top and nethermost moves inward and the fluid in the middle moves outward. The secondary inflow is the cause of high heat transfer rates and disunion losses in a pipe.

operation of Helical Coil- Helical coils are considerably employed for heat transfer operation in the process and power diligence.

Some of the operations are listed as

1. spiral coils are used for transferring heat in a chemical reactor and agitated vessel because heat transfer portions are advanced in spiral coils. This is especially important when chemical reactors having high heat of response are carried out and the heat generated(or consumed) has to be transferred fleetly to maintain the temperature of the response. Also because of spiral coils have a compact configuration further heat transfer face can be handed per units of space than by use of straight tube.

2. Due to conciseness, it's used for brume generation in marine and artificial operation.

3. The actuality of tone- convinced acceleration field in spiral coil makes spiral coil most desirable for heat transfer and fluid inflow operation in the absence of a graveness field, similar as for spaceships in external space.

4. spiral coils have lately being studied for possible operation inbio-engineering. Weissman and Mockero's lately studied the use of spiral coils to compound mass transfer in membrane blood- oxygenerators. Their study demonstrated, both theoretically and experimentally that by curling a membrane tube into a spiral coil, they could mainly increase the mass transfer rate of oxygen and carbon dioxide to and from the blood flowing inside the tube.

5. spiral coils have been considerably used in the cryogenic assiduity for the liquefaction of feasts. The single pressure mixed refrigerant (SPMR) process for the liquefaction of the natural gas is a current illustration. Recent emphasis on the increased product of thawed natural gas will call for an increased use of curled tube heat exchangers.

1.3 Scope of Work: -Helical coils are widely used in all fields of engineering, so a thought is given to experimentally suggest the values of heat transfer coefficients, the various numbers associated with heat transfer phenomenon and suggest a fluid which gives maximum overall heat transfer coefficient.

The dissertation consists of selection and fabrication of various components required for the experimental analysis of flow inside a helical coil. The setup for the analysis consists of copper helical coils of inner diameter 8.04 mm and length 3800 mm. The set up required a tank or vessel of internal diameter as 30.5 cm to accommodate the helical coil along with a heating element of 1500 watt. The work involves the analysis of results obtained for fluid like water. The work carried out for the both with and without agitation condition for all fluids.

2. EXPERIMENTAL SETUP

2.1 Introduction: The convective analysis of helical coil, requires the experimental set up to record various temperature along the length of coil at different heat input and at different mass flow rate. The setup requires fabrication & selection of different component for the analysis purpose.

2.2 Experimental setup :

Fig - 2.1 Shows the schematic arrangement of the various components required for the experimentation.

1. Fill the cylindrical tank with water such that the entire setup of helical coil immersed in liquid.
2. Adjust the heat supplied to setup by properly adjusting dimmer. Heat input should be recorded from the values of voltage and current.
3. Adjust the flow rate of water entering in helical coil in a way to maintain constant flow rate after enough heating of liquid.
4. Note down the various thermocouple reading with the help of temperature indicator at steady state.
5. Carry out the experimentation for the various values of heat input and by changing the mass flow rate.

2.3 Component used: The list of components along with material & specification for experimentation is given in table no.3.1

Table 3.1 : Different component used for the experimental setup.

Sr. No.	Name of component	Material	Specification
1.	Helical coil	Copper	ID 8.04 mm, OD 9.70mm & length 380cm
2.	Cylindrical	GI sheet	ID 30.5 cm

	tank		Height 41 Cm Wall thickness 25 mm
3.	Thermo couple and digital temperature indicator	-----	A digital temperature indicator with 6 point selector switch and thermo couple wire & junction.
4	Dimmer stat	-----	6 Amp Dimmer stat with a range of 0-230 Volt
5	Stirrer	-----	¼ HP cooler motor pump of RPM 1360, amp 0.36, 50 Hz and 45 watt.
6.	Flow measuring Device	Glass	A glass biker of 1 liter marking
7	Heating coil	Copper	1500-watt drum heating coil

The various thermocouples mounted along the length of coil are worked as per the distance specified and are enlisted in table no.2.1

2.4 Criteria for selection *of* component:

2.4.1 Helical Coil: The material selection for the spiral coil is similar that, it must have high thermal conductivity. At the same time material should be easy to bend in the form of spiral structure, so the material named for the spiral coil which has both these parcels & it's fluently available. The dimension of spiral coil like inner dia. & length are named grounded on the vacuity of material and at the same time to accommodate the number of thermocouples along the length. To achieve proper heat transfer five turns of spiral coils of bobby material is named grounded on length of coil as shown iffig.3.2

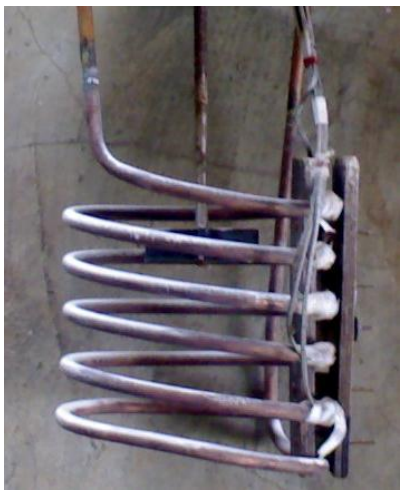

Fig - 3.2 Helical coil

2.4.2 Cylindrical Tank: The criteria for selection of spherical tank should be similar that, the spiral coil arrangement, the heater and stirrer for agitation must accommodate in it. Considering the proper sizes, height of coil & the distance of spiral coil from the heater, a spherical tank of dimensions30.5 cm inner periphery, height41.0 cm with a consistence of 25 mm is named as shown in fig3.3. The tank named is of material GI & is the same used for water heater purpose in the home operation.

Fig - 3.3 Cylindrical tank

2.4.3 Thermocouple and Digital Temperature Indicator To record the colorful temperature of water inside the coil at colorful distances 5 Cr- Al thermocouples

are named. To record the temperature, a digital temperature index as shown in fig3.4., of least count0.10 c and the range of 0- 5000 C is named.

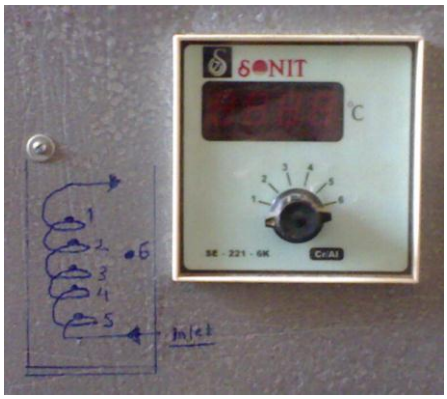

Fig - 3.4 Digital temperature indicator

2.4.4 Dimmerstat: A dimmerstat of range(0- 1500 W) is named to fulfill the demand of varying heat input to assay the performance of heat transfer between water & colorful result as shown in fig3.5..

Fig - 3.5 Dimmerstat

2.4.5 Stirrer: For proper mixing of various solution & to increase the turbuance a stirrer is required. In this setup, a ¼ HP cooler motor pump of 1360 rpm is used as stirrer.

2.4.6 Flow Measuring Device: To measure the quantity of water flowing through the helical coil, a 1 lit glass measuring jar is used.

2.4.7 Heating Coil: A 1500-watt drum heating coil is used to heat the bath solution in the tank.

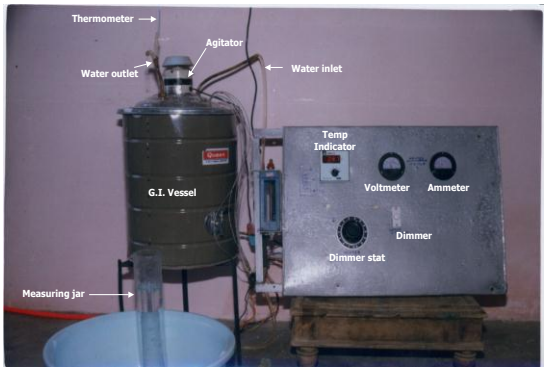

Fig - 3.6 Photograph of Experimental Setup

2.5 Testing procedure: The convective heat transfer analysis of spiral coil is principally heat transfer between the bath liquid & fluid flowing through spiral coil i.e. water. The bath liquid used for the analysis purpose are water. To find out the colorful parameters needed for the analysis certain procedure must be espoused. So a testing procedure is designed and the same as followed during this trial.

To avoid any leakages, originally a leak test of the experimental setup is assured at outside inflow rate of fluid. The testing procedure is listed as follows.

1. Fill the spherical tank with proper liquid(viz. watersuch that the entire setup of spiral coil immersed in liquid.

2. Acclimate the heat supplied to setup by duly conforming dimmer. Heat input should be recorded from the values of voltage and current.

3. Acclimate the inflow rate of water entering in spiral coil in a way to maintain constant inflow rate after enough heating of liquid.

4. Note down the colorful thermocouple reading with the help of temperature index at steady state.

5. Carry out the trial for the colorful values of heat input and by changing the mass inflow rate.

1. Instruments Used for Performance

The colorful instruments used for testing purpose are as follows

1. Ammeter (0 – 10 A)
2. Voltmeter (0- 230 V)
3. Thermocouple

4. Measuring jar and stop watch(due to attainability of Rotameter)

5. Tachometer

3. RESULTS AND DISCUSSION

The measure readings recorded in table 3.3 - 3.8 are used for calculation of heat transfer coefficient, over all heat transfer coefficient, the convective analysis governed with various non dimensional numbers and Nusselt number correlation. Depending upon the flow conditions the analysis requires numbers like Re number, Nusselt number, Pr number, De number..

3.2 Calculation:

3.2.1 Calculation for Deciding Type of Flow : In helical coil flow of fluid is a function of Reynold number and Prandtl number.

For deciding laminar and turbulent flow following equation are used (3),

For laminar flow

$$Nu = \frac{0.364}{A}(De)^{\frac{1}{2}}\left\{1+\frac{2.35}{(De)^{\frac{1}{2}}}\right\} \quad ...(4.1)$$

For turbulent flow,

$$Nu = \frac{1}{41}x\,\mathrm{Pr}^{0.4}\,x\,\mathrm{Re}^{\frac{5}{6}}\left(\frac{d_i}{D_c}\right)^{\frac{1}{12}}\{1+\frac{0.061}{\left[\mathrm{Re}\left(\frac{d_i}{D_c}\right)^{2.5}\right]^{\frac{1}{6}}}\} \quad ...(4.2)$$

Sample calculation for water at head input 0.6 kw and mass flow rate of 5.75 gm/sec,

Pr = 4.92 > 1 & Re= 0.621 > 0.4

∴ Flow is turbulent

3.2.2 Calculation for Heat Transfer Coefficient:

Heat transfer coefficient in helical coil is calculated by using equation are used (3), Sample calculation for water at heat input Q_i = 0.6 kw and mass flow rate of 5.75 gm/sec,

From equation 4.5,

Pr = 4.92 Re = 1170

d_i = 8.04 mm De = 259

Nu = 13.74

$$Nu = \frac{h_i d_i}{k}$$

Where, k = 0.626 W/m^2 ^{0}k = Thermal conductivity which is taken from thermo physical properties of water at 34.5^{0}c (22)

∴ hi = 1.069 Kw/m^2 ^{0}k

3.2.3 Calculation for Over All Heat Transfer Coefficient :

The overall heat transfer coefficient is calculated by using the relation stated as per (3) by equation

$$U = \frac{Q}{A(T_b - T_m)} \quad ...(4.3)$$

Where,

U – Overall heat transfer coefficient

Q – Heat flow rate

A – Area of the helical coil at outside

T_b – Bath temperature

T_m – Mean temperature of the helical coil

Sample calculation for water at head input 0.6 kw and mass flow rate of 5.75 gm/sec,

$$U = \frac{Q}{A(T_b - T_m)} = 0.505 \text{ Kw/m}^2\,^0\text{k}$$

Appendix A-D shows the calculated values of Re number, Nu number, h_i, and U for water for without agitation and with agitation at a different concentration.

4 CONCLUSION

To analyses the convective heat transfer miracle in a spiral coil fluids like water is used during the trial. Water is used as a fluid flowing through spiral coil whereas fluid stated above are allowed to compass the entire spiral coil. Grounded on the trial the number of parameters is studied. On the base of below results and discussion following conclusion are drawn.

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