EXPERIMENTAL INVESTIGATION OF HEAT TRANSFER IN HELICAL COIL HEAT EXCHANGER BY VARYING ANGLES WITH CFD ANALYSIS

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Abstract: Helical loop heat exchangers are a standout amongst the most well-known hardware found in numerous modern applications. Helical loop heat exchanger is one of the gadgets which are utilized for the recuperation framework. The helical curl heat exchangers can be made as a shell and cylinder heat exchangers and can be utilized for mechanical applications, for example, control age, atomic industry, process plants, heat recuperation frameworks, refrigeration, sustenance industry and so forth. The helical coil has a bent surface or turns, hence when the fluid flow through the bends, pressure drop occurs and at the point or surface contact heat transfer maximizes, helical coil gives larger surface area contact the fluids flowing and if the number of turns in coil is more, more accurate the heat transfer rate can be obtained. Here a single helical coil is used and the angles are varied as follows, 0°, 45° and 90°. The effectiveness, heat transfer rate, overall heat transfer co-efficient is done through the mathematical calculation. The process is carried out by keeping cold water at 1.5 lpm and hot fluid at 1 lpm. By tabulated values the effectiveness of individual coil is determined and compared in graph.

Keywords – Helical coil heat exchanger, CFD analysis, varying angles.

1. INTRODUCTION

A warmth exchanger is a gadget that is utilized to exchange warm vitality (enthalpy) between at least two liquids, between a strong surface and a liquid, or between strong particulates and a liquid, at various temperatures and in warm contact. In warmth exchangers, there are typically no outside warmth and work cooperations. Normal applications include warming or cooling of a liquid stream of concern and dissipation or buildup of single-or multicomponent liquid streams.

In different applications, the target might be to recoup or dismiss heat, or disinfect, purify, fractionate, distil, concentrate, take shape, or control a procedure liquid. In a couple of warmth exchangers, the liquids trading heat are in direct contact. In most warmth exchangers, heat exchange between liquids happens through an isolating divider or into and out of a divider in a transient way. In many warmth exchangers, the liquids are isolated by a warmth exchange surface, and in a perfect world they don’t blend or break. Such exchangers are alluded to as roundabout exchange type, or essentially recuperators. Interestingly, exchangers in which there is irregular warmth trade between the hot and cold liquids—by means of warm vitality stockpiling and discharge through the exchanger surface or network—are alluded to as roundabout exchange type, or essentially regenerators. Such exchangers ordinarily have liquid spillage from one liquid stream to the next, because of weight contrasts and grid revolution/valve exchanging. Regular instances of warmth exchangers are shell-and-cylinder exchangers, car radiators, condensers, evaporators, air preheaters, and cooling towers. Helical geometry permits the successful dealing with at higher temperatures and extraordinary temperature differentials with no exceptionally prompted pressure or development of joints. Helical curls are utilized for different procedures, for example, heat exchangers since they can suit an expansive warmth move zone in a little space, with high warmt transfer coefficients.

The radiating powers are following up on the moving liquid because of the ebb and flow of the cylinder results in the improvement of auxiliary stream which upgrades the warmth exchange rate. This wonder can be helpful particularly in laminar stream. Helical curled cylinders are utilized in an assortment of uses including sustenance preparing atomic reactors, minimized warmth exchangers, heat recuperation frameworks, synthetic handling and therapeutic hardware.

APPLICATIONS

Use of helical coils for heat transfer applications:

1) Helical coils are used for transferring heat in chemical reactors and agitated vessels because heat transfer coefficients are higher in helical coils. This is particularly significant when substance responses have high warm of response are done and the warmth created (or devoured) must be exchanged quickly to keep up the temperature of the response. Likewise, because helical loops have a reduced design, more warmth exchange surface can be given per unit of room than utilizing straight cylinders. Because of the compact configuration of helical coils, they can be readily used in heat transfer application with space limitations, for example, in steam generations in marine and industrial applications.

2) The helically coiled tube is eminently suited for studying the characteristics of a plug flow reactor in reaction kinetic studies because the secondary motion present in the helical coil destroys the radial concentration gradient.
II. LITERATURE REVIEW

1. W. Witchayanuwat, S. Kheawhom introduced a point by point examination on heat exchange from fumes particulate quality of cleanser splash drying tower to water by helical curled heat exchanger. It was found that the effect of coil pitch on the tube side and shell side heat transfer coefficient. The exchanger duty, overall heat transfer coefficient are investigated as function of the tube surface geometry, the flow pattern (parallel and counter) and tube Reynolds number. The outcome demonstrates that the expanding of the wound cylinder pitch diminishes within Nusselt number.

2. Salimpour researched three heat exchanger with various loop pitches and found that the shell-side heat exchange coefficient of curls with bigger pitches is higher than those with littler pitches for the counter-stream arrangement. Likewise, two connections were created to foresee the internal heat exchange coefficients and the external warmth exchange coefficients of the wound cylinder heat exchanger.

3. Prabhanjan experimentally investigated the natural convection heat transfer from helically coiled tubes in water. They reported that different lengths were used to correlate the outside Nusselt number to the Rayleigh number. Models were developed to predict the outer temperature fluid flow through the helical coiled heat exchanger. The best correlation employed the total height of the coil as the characteristic length. They built up a model to anticipate the outlet temperature of a liquid moving through a helically wound warmth exchanger, given the gulf temperature, shower temperature, curl measurements, and liquid stream rate.

III. PROBLEM STATEMENT

Extensive trial work has been done on buildup heat exchange coefficient through helical loops of round cross area. But few, rest all investigations have created relationships dependent on exploratory information. To simulate the effect of variable tilt angle of helical coil heat exchanger on heat transfer rates by using CFD

IV. EXPERIMENTAL SETUP

Fig 1. Line diagram of the setup [4]
The above shown block diagram represents the experiential setup of the unit used for investigation of heat transfer using helical coil heat exchanger, the components used are thermometer, rotometer, Electrical heater, Helical coil.

Fig 2. Helical coil at 0˚ angle
Fig 3. At 45˚ angle
Fig 4. At 90˚ angle

V. THEORETICAL APPROACH

5.1 Reynolds number: The Reynolds number can be defined for several different situations where a fluid is in relative motion to a surface. These definitions by and large incorporate the liquid properties of thickness and consistency, in addition to a speed and a trademark length or trademark measurement. This measurement involves show - For instance, span and distance across are similarly legitimate to depict circles or circles, however one is picked by show. For flying machine or ships, the length or width can be utilized. For stream in a pipe or a circle moving in a liquid the inner measurement is commonly utilized today. Different shapes, for example, rectangular channels or non-circular items have a proportionate breadth characterized. For liquids of variable thickness, for example, compressible gases or liquids of variable consistency, for example, non-Newtonian liquids, unique guidelines apply. The velocity may also be a matter of convention in some circumstances, notably stirred vessels. For flow in a pipe or tube, the Reynolds number is generally defined as:

\[ Re = \frac{\rho v D}{\mu} = \frac{QD_H}{vAD_H} \]

where,

- \( D_H \) is the hydraulic diameter of the pipe; its characteristic travelled length, \( L \), (m).
- \( Q \) is the volumetric flow rate (m\(^3\)/s).
- \( A \) is the pipe cross-sectional area (m\(^2\)).
- \( \mu \) is the dynamic viscosity of the fluid (Pa·s = N·s/m\(^2\) = kg/(m·s)).
- \( v \) is the mean velocity of the fluid (SI units: m/s).
- \( \rho \) is the density of the fluid (kg/m\(^3\)).

For shapes such as squares, rectangular or annular ducts where the height and width are comparable, the characteristic dimension for internal flow situations is taken to be the hydraulic diameter. \( D_H \) defined as:

\[ D_H = \frac{4A}{P} \]

5.2 Nusselt Number: In heat transfer at a boundary (surface) within a fluid the Nusselt number (Nu) is the ratio of convective to conductive heat transfer across (normal to) the boundary. In this context, convection includes both advection and diffusion. The convection and conduction heat flows are parallel to each other and to the surface normal of the boundary surface, and are all perpendicular to the mean fluid flow in the simple case.
Where,

- \( L \) = characteristic length
- \( k \) = thermal conductivity of the fluid
- \( h \) = convective heat transfer coefficient of the fluid

### 5.3 Dean number:

The Dean number (D) is a dimensionless group in fluid mechanics, which occurs in the study of flow in curved pipes and channels. The Dean number is typically denoted by the symbol \( D \). For flow in a pipe or tube it is defined as:

\[
D = \frac{\rho V d}{\mu} \left( \frac{d}{2R} \right)
\]

where,

- \( \rho \) is the density of the fluid
- \( \mu \) is the dynamic viscosity
- \( V \) is the axial velocity scale
- \( d \) is the diameter (other shapes are represented by an equivalent diameter, see Reynolds number)
- \( R \) is the radius of curvature of the path of the channel.

The Dean number is therefore the product of the Reynolds number (based on axial flow \( V \) through a pipe of diameter \( d \)) and the square root of the curvature ratio.

### 5.4 Prandtl Number:

The Prandtl number is a dimensionless number; the ratio of momentum diffusivity (kinematic viscosity) to thermal diffusivity.

It is defined as:

\[
Pr = \frac{\nu}{\alpha} = \frac{\text{Viscous Diffusion Rate}}{\text{Thermal Diffusion Rate}} = \frac{C_p \mu}{k}
\]

where,

- \( \nu \) : kinematic viscosity, \( \nu = \frac{\mu}{\rho} (m^2/s) \)
- \( \alpha \) : thermal diffusivity, \( \alpha = \frac{k}{\rho C_p} (m^2/s) \)
- \( \mu \): dynamic viscosity, \( (Pa \ s = N \ s/m^2) \)
- \( k \): thermal conductivity, \( (W/(m \ K)) \)
- \( C_p \): specific heat, \( (J/(kg \ K)) \)

- Hot water flow rate \( (Q_h) = M_h \times C_{ph} \times (T_1-T_2) \) ------KW
- Cold water flow rate \( (Q_c) = M_c \times C_{pc} \times (t_1-t_2) \) ------KW
- Logarithmic mean temperature difference \( (LMTD) = (T_1-t_2)-(T_2-t_1)/\ln(T_1,t_2)/(T_2-t_1) \)
- Discharge \( (Q) = Q_h+Q_c/2 \)
- Overall heat transfer coefficient \( (U) = Q/A_o \times LMTD \)
- Area of shell \( (A_o) = \pi dL \)
- Capacity rate of hot fluid \( (C_h) = M_h \times C_{rh} \)
- Capacity rate of cold fluid \( (C_c) = M_c \times C_{pc} \)
- NTU = \( U_o A_o / C_{min} \)
- Capacitance \( (C) = C_{min} / C_{max} \)
- Effectiveness = \( 1-e(-N(1+c))/1-e(-N(1+c)) \)
VI. RESULTS AND DISCUSSION

Fig 5. Nu v/s θ

Fig 6. Re v/s θ

Fig 7. Effectiveness v/s ΔT

Fig 8. Nusselt Number (Nu) v/s Dean Number (De)
Fig 9. Effectiveness v/s $\Delta t$

Fig 10. CFD analysis at 0° angle

Fig 11. CFD analysis at 45° angle
VII. CONCLUSION

In the process, the investigation is operated by varying angle with the constant pitch corresponding at defined length the process is done for counter flow. It is came to know that effectiveness in counter flow increases as the angle of all increases. It is found that Deans, prandlts, Nusselts numbers increases as the angle of all increases.

The graph for overall Nusselt number v/s Reynolds number, Dean number v/s Reynolds number, Effectiveness v/s T, Nusselt number v/s Dean number, Effectiveness v/s t, shows the heat transfer rate for different inclination is increasing with the angle of tilt. The graph Dean numbers Reynolds number shows a linear variation. Dean number is the property of fluid flowing in curved tubes and shells which signifies the extent of turbulence due to secondary flow. Greater will be the turbulence higher will be the heat exchange. As the Dean number increases with Reynolds number, the heat transfer also increases with Reynolds number.

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