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Studies on Helical Coil Heat Exchanger

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ABSTRACT

The present work is mainly focused on the behavior of helical coil heat transfer equipment by subjecting to various process conditions. These variations usually are the alterations in the speed of the impeller, heat energy provided to the bath liquid and thereby changing the temperature of that liquid, and the volumetric flow rate of the coolant that is being circulated inside the helical coil. The variations mentioned above are used for every arbitrarily chosen different type of impeller in combinatorial fashion of pre-fixed impeller speeds (RPM) and volumetric flow rates. The effect of system behavior is also characterized for two different bath liquids such as Water and Motor Oil, by circulating coolant being Water. The results are analyzed in order to calculate the Heat Transfer Coefficients in the above mentioned both the cases experimentally from the data generated. The analysis is followed by conclusions and possible explanation of the equipment behavior.

Keywords – Helical coil, Water, Motor Oil, Heat Transfer Coefficient, Impeller

I. INTRODUCTION

Heat transfer in the process industries is an essential unit operation. Almost all of the process employs the transfer of heat energy in one way or the other. For the process heat transfer to take place, the equipment or the comprising unit part of the entire process should be able to remove or add heat from a certain source by conduction, convection or radiation modes of heat transfer.

These heat transfer entities are known as "Heat Exchangers". Depending on the requirements at hand the heat transfer is directed. Heat is removed from hot substances or heat can be added to a cold substance as per the demands of the process that is being carried out.

One such heat exchange apparatus that is chosen for study is "Helical Coil Heat Exchanger". Coil heat exchangers are used for heating and cooling fluids in a variety of industries. Coils are commonly used in chemical reactors, agitated vessels and storage tanks to heat and cool materials ranging from chemicals to dairy products, vegetable and fruit juices and process oils. They are used for heat recovery from waste liquors, vapors and gases.

Tube coils afford one of the cheapest means of obtaining heat transfer surface. They are usually made by rolling lengths of copper, steel or alloy tubing into helixes or double helical coils in which the inlet and exit are conveniently located side by side.

Helical coils of either type are frequently installed in vertical cylindrical vessels with or without an agitator, although free space is provided between the coils and the vessel wall for circulation. When such coils are used with mechanical agitation, the vertical axis of the agitator usually corresponds to the vertical axis of the cylinder. Double helical coils may be installed in shells with the coil connections passing through the shell or shell covers. Such an apparatus is similar to a tubular exchanger, although limited to smaller surfaces.

Curved coils can be classified into those with a constant curvature and with a variable curvature. The former is referred to as helices and the latter curved pipes as spirals. The rolling of the coils, particularly with diameters above one inch requires a special winding technique to prevent the tube from flattening into an elliptical cross section, since distortion reduces the flow area.

Compared to the relatively simple case of steady flow in a straight tube, the flow in a curved tube is so exceptionally complicated that even the details of the mean flow are not yet known. Here in this project work the steady state operation of helical coil heat exchange equipment is adopted. The overall behavior and performance of such apparatus is determined in the steady state batch operation.

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The variations in the no. of mechanisms employed for carrying out the process involves the changes in RPMs of the impellers, flow rates of the coolants and bath liquids at different reference temperatures. This enables the sufficient difference exhibition in the performance and at the point of time where all the values become fixed i.e., when system attains steady state the desired functioning and predictions can be obtained from the generated data. The batch operation is often chosen rather than continuous operation because of the feasibility of study at certain conditions intact all the way during the course of the experimental procedure.

II. EXPERIMENTAL SETUP

2.1: Helical Coil Heat Transfer Equipment

The apparatus as shown in the figure above is equipped with a helical coil housed inside the vessel. The ends of the coil are provided with grooves for checking the inlet and outlet coolant temperature respectively. The vessel is attached to the stand bearing the motor rig and the control system. This system houses the dimmerstat for invoking variations in the temperatures and changes in the impeller speeds. The thermostat is inserted into the bath vessel for temperature regulation at desired ranges. The apparatus has one valve at the bottom for draining the bath liquid. The motor directly above the vessel is fitted with an impeller shaft and the motor RPM is controlled by auto transformer connected in series with an ammeter.

2.2: Materials of Construction

The material used for the construction of bath vessel is stainless steel. The helical coil is made up of copper, which is a known for its low resistance to heat flow. The impellers used for experimentation are also of stainless steel make. Iron shaft is used for impeller holding purposes.

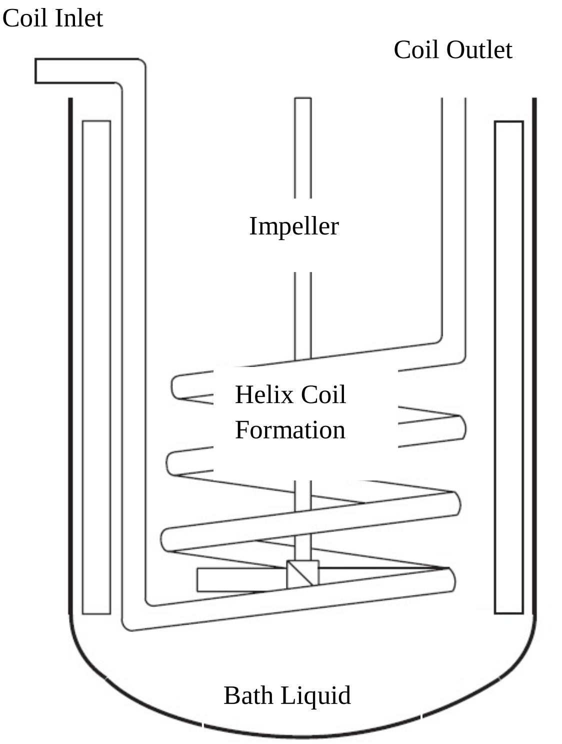

Fig. 1. Sketch of Helical coil heat exchanger.

2.3: Specifications

- Material of construction of the bath vessel: Stainless steel
- Diameter of the vessel : 30 cm
- Capacity of bath : 25 Liters
- Internal diameter of the coil: 9.6 mm
- External Diameter of the coil: 12.5 mm
- Coil Diameter: 200 mm
- Number of coil turns: 7
- Power of the Heating element: 2KW
- Motor : ¼ HP connected to auto transformer (for variable speed)
- Paddle, Mixer and Mincer grinder blade for agitation
- Thermometers: 0-110 ^{o}C

III. SYSTEM OF CHOICE

The choice of system that is being used in the experiment is purely speculative. Depending on the resources the system is adopted. Water which is easily available in surplus is chosen to be the primary component. Motor oil is chosen to the

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other component, attributing to its substantial contrast in viscosity when compared to water. The

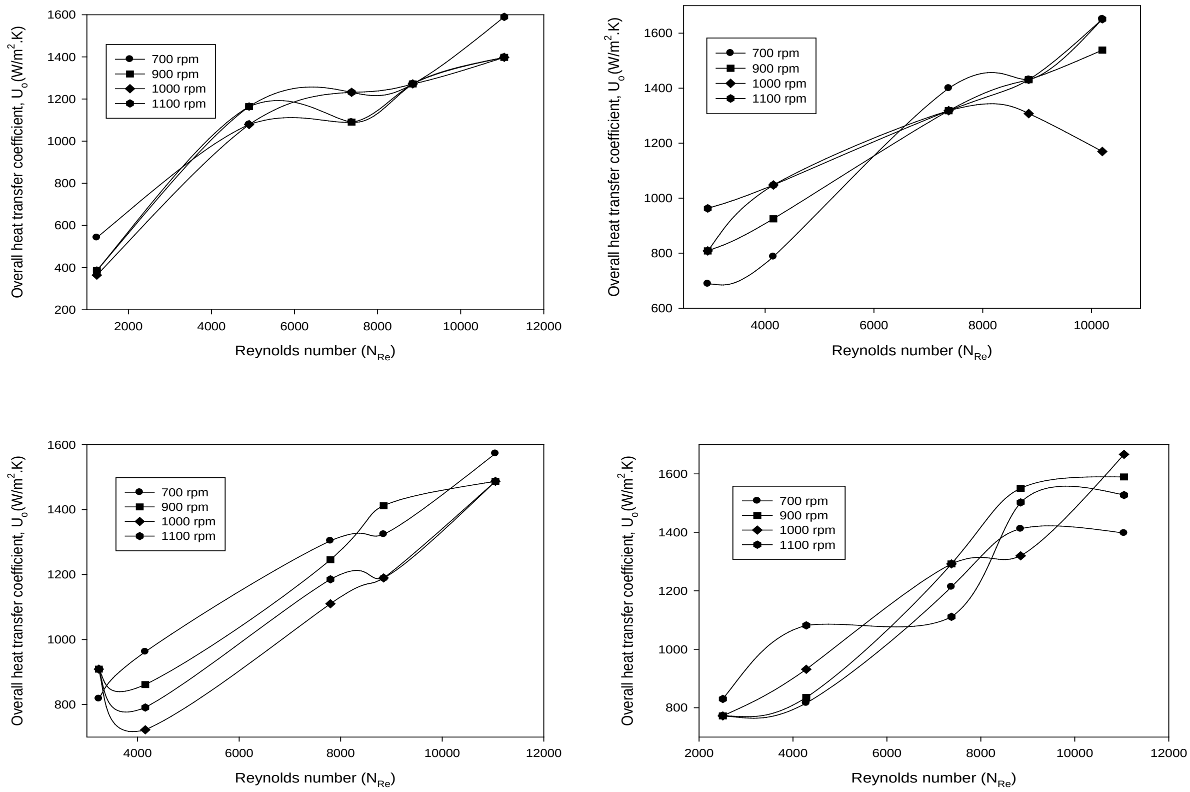

Fig.2. Graphs drawn between overall heat transfer coefficient, U_o (W/m^2.K) and Reynolds number (N_{Re}) for paddle at different temperatures i.e., 40°C (Top left), 50°C (Top right), 60°C (Bottom left), 70°C (Bottom right) with varying speed.

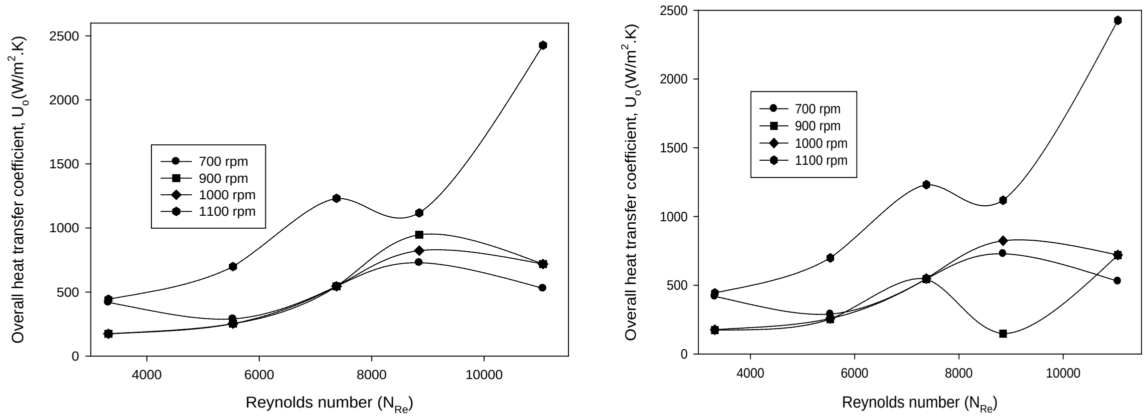

Fig.3. Graphs drawn between overall heat transfer coefficient, U_o (W/m^2.K) and Reynolds number (N_{Re}) for paddle (left) and mixer blade (right) at 40°C temperature with varying speed.

coolant that is used of removing the heat from the bath liquids (Water & Motor oil) is also water.

The above choices are replaced with any alternative type of flowing materials subjected to the limitations of the apparatus.

3.1: System Properties

System 1: Water – Water

The system 1 is assumed like water acting like bath liquid as well as a coolant. The properties mentioned below are at ambient temperature.

Density of water (ρ) = 1000 kg/m^3

Viscosity of water (μ) = 10^{-3} Pa.s

Thermal conductivity of water (K) = 0.625 W/m K

Specific heat capacity (Cp) = 4.18 kJ/kg K

System 2: Motor Oil – Water

The system 2 is assumed like Motor oil is the bath liquid and water as coolant. The properties mentioned below are at ambient temperature.

Density of Motor Oil (ρ) = 876 kg/m^3

Thermal conductivity of Motor Oil (K) = 0.145 W/m K

Specific heat capacity (Cp) = 2 kJ/kg K

IV. EXPERIMENTAL PROCEDURE

After the initial trail run of the experiment is done, the bath vessel is filled with the bath liquid of choice i.e., Water or Motor Oil till all the coils inside the vessels are submerged.

Heat input is given to the bath liquid using the dimmerstat provided, by turning the knob to a desired value of temperature, say 40 ^{0}C. Allow the bath liquid to gain temperature gradually. Using the auto transformer put the motor into motion by fixing a value of rotation on the scale. This motor rotation allows the impeller to turn inside the liquid.

The inlet of the coil is provided with coolant stream and the volumetric flow rate is regulated as per the need. Using a stopwatch and a measuring jar the flow rate of the liquid is measured. Wait till the steady state is reached. Measure the temperature values of the inlet and outlet coolant streams at the respective provisions provided as shown in the fig.1.

Take notes of the bath, inlet and outlet temperatures. Also measure the RPM of the motor using a Tachometer. Carry out the experiment at different temperatures with different pre fixed flow rates using chosen impeller. Repeat the experiment with different impellers mentioned earlier at those pre fixed flow rates and temperatures. The entire process is carried out with different bath liquid i.e., Motor Oil.

V. RESULTS & DISCUSSIONS

From the above plotted graphs i.e., Fig.2 and Fig.3 between Overall Heat Transfer Coefficient and Reynolds Number it can be asserted that the overall heat transfer coefficient varies with change in speed of impeller and the flow rate of the coolant.

As from the Water-Water system graphs at different pre chosen temperatures i.e., 40^{0}C, 50^{0}C, 60^{0}C, 70^{0}C using different impellers it can be understood that the heat transfer coefficient attains higher magnitudes with the impeller speed increments and gradual raise in temperature.

The speed of impeller has no direct consequence on the local inner heat transfer coefficient. The variation inside the coil in the H.T. C. is due to the secondary flow existence at the curves of the coil which regulates the effective heat transfer.

But in the case of Oil-Water system the overall heat transfer coefficient values are not greatly promoted in comparison with water as bath liquid.

This might be due to the constrained impeller impact on the high viscous bath and lesser turbulence which will be hurdle for the heat transfer to be more productive.

The property depend function like heat transfer coefficient is sensitive towards various features of the chosen bath liquid. In this case water which has higher thermal conductivity, heat capacity and lower viscosity will be a good medium for better heat transfer mechanism. In contrast Motor Oil is highly viscous and has lower thermal conductivity.

The impeller speed has effect over the film thickness formation over the solid-fluid interface. So outer local heat transfer coefficient is effected by the RPM with which impeller is rotating.

The difference obtained in the readings at same conditions can be attributed to the foul formation inside the coil and on the outer surface. The irregular flow conditions can also have certain measure of effect on the overall outcome.

Assuming the liberty of taking constant values for speed, volumetric flow and the ambient temperature, the experimentation yield is acceptable with quarter of an error and deviation from its original behavior. Inherent defects like impeller pitch, coil curvature, thermostat effective temperature regulation and shaft load on the motor are negligible.

VI. CONCLUSIONS

As per the expected values, the deviations are appreciably low. In Water-Water system the heat transfer is more effectively done in comparison with Oil-water system.

The Overall Heat Transfer Coefficient U as expected increases with Reynolds Number N_{Re}. As the flow rates increases the molecular movement increases so the film thickness reduces due to turbulence creation.

The correction factors are to be associated to the existing correlations to account for deviated behavior of the apparatus.

The variations of fall and raise in the H. T. C values from the graphs and observations notes that the predictable values are yet to arrive only if further study at different speeds which are intermediate to the original ones is done.

Helical coil heat exchangers are not studied extensively so there is gap for any forward comments on the effects of Reynolds number in tube side and consequent changes due to secondary flow. Hence for higher flow rates also the study is supposed to be done.

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