EXPERIMENTAL AND CFD ESTIMATION OF HEAT TRANSFER IN HELICALLY COILED HEAT EXCHANGERS

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Abstract – *In present day shell and coil heat exchangers is the most common type heat exchangers widely used in oil refineries and other large chemical process, because it suits high pressure application. Enhancement in heat transfer due to helical coils has been reported by many researchers. While the heat transfer characteristics of double pipe heat exchangers are available in the literature, there exists no published experimental or theoretical analysis of a helically coiled heat exchanger using CFD package ANSYS 15.0. The objectives of the project is design of shell and coil heat exchanger with change in pitch and study the flow and temperature field inside the shell using ANSYS software tools. The experimental results are compared with the CFD calculation results using the CFD package. The CFD predictions match reasonably well with the experimental results within experimental error limits. Based on the confidence gained in the CFD predictions, the results generated under different conditions may be used further to obtain a generalized correlation, applicable to various coil configurations.*

***Key Words*: shell, shell cover, tubes, channel, channel cover, tube sheet, baffles.**

1.1 BRIEF DESCRIPTION ABOUT SHELL AND TUBE HEAT EXCHANGER

Heat exchangers are device that facilitate heat transfer between two fluids at different temperatures. In the majority of the heat exchangers, solid wall separates the two fluids so that they are not in direct contact with each other.

A shell and tube heat exchanger is a class of heat exchanger designs. As its name implies, this type of heat exchanger consists of a shell (a large pressure vessel) with a bundle of tubes inside the shell.

A shell and tube heat exchangers are probably most common type of heat exchangers applicable for wide range of operating temperature and pressure. They have larger ratio of heat transfer surface to volume than double pipe heat exchanger and they are easy to manufacture in large variety of sizes and flow configuration. Shell and tube heat exchangers find widespread use in refrigeration, power generation, heating and air conditioning, chemical processes, petroleum, medical applications.

Use of helical coils adds efficiency to the heat exchanger performance. Shell-and-coil heat exchangers have been used mainly in solar domestic hot water (SDHW) systems because of their high heat transfer and smaller space requirement, their use in heat recovery systems for space heating also has been reported [1]. Therefore, it is worthy to study heat transfer, pressure drop and thermal performance of the shell side of helical or spiral coil used in heat exchangers. In spite of numerical and experimental studies which have been carried out in relation to tube-side heat transfer coefficient, there are not many investigations on the shell-side mixed convection heat transfer coefficient of shell-and-coil heat exchangers.

1.2 Background of study

correlation based approaches can be used for sizing and can also be used iteratively to obtain general performance parameter (rating and pressure drop) of a heat exchanger. At a given iteration, if the performance of the considered design is calculated to be unsatisfactory, a better performing design can be obtained by changing the design parameters in the right direction. An experience heat exchanger designer knows what change in which direction. as the simplest example: if the tube side heat transfer coefficient comes out smaller than expected, one can guess that the velocities are low and try a configuration with a smaller cross sectional flow area in the next iteration. Although it is simple to adjust the tube side parameters, it is very hard to get the right combination for the shell side. If possible, an ability to visualize the flow and temperature field on the shell side can simplify the assessment of the weaknesses. The estimation for pressure loss for the fluids flowing inside tubes are relatively simple, but complex in shell side flow. Computational fluid dynamics (CFD) can be very useful tool to gain those abilities.

2. Inlet Velocity 1 m/s and Pitch 25 mm

The velocity and temperature profiles at the exit of the helical pipe for the constant and temperature dependent properties of the cooling medium are given in Fig. 6.25 In all the figures, the right side is the outer side of the coil. It can be readily seen that unlike for flow through a straight tube high velocity is on the outer side of the coil his is especially prominent in the inner side of the coil, as the velocity gradients at this location are higher.

Figure.6. 1 Mid Sectional Pressure Contoursof Shell Region

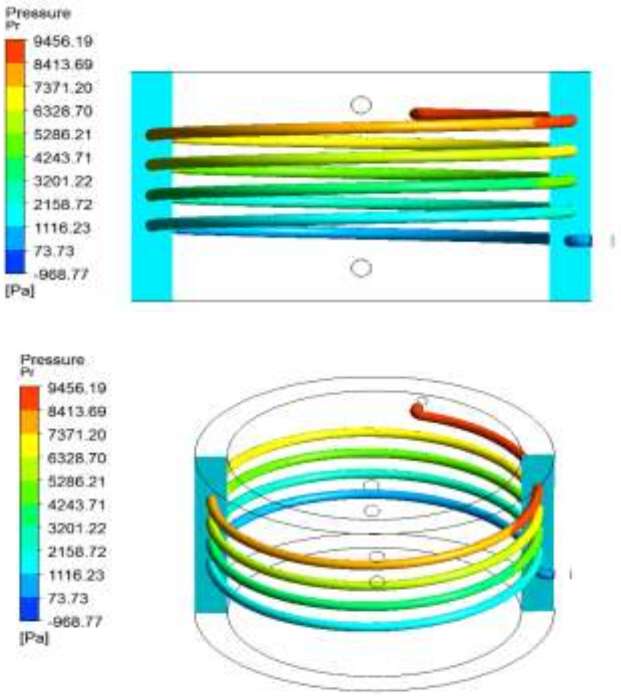

Figure.6. 2 Pressure Contours of Coil Region

Figure.6. 3 Mid-Sectional Temperature Contours of Coil Region

Temperature profile of the hot fluid for of he cases (inlet velocity = 1ms−1) is given in Fig. 6.1. The effect of cross flowin the shell region is visible from the temperature contours. Velocity profile along a section on the *YZ* plane is shown in Fig.6.27. This is the plane passing through the shell inlet/outlet. Irregularity of the flow in shell as compared to a double pipeheat exchanger is very dominant in this case. The velocity contours in the *XZ* plane are given in Fig. 6.8. The coil section at top left is hot fluid inlet, where a circular velocity contours are observed. As the fluid flows down, the flow gets developed due to the centrifugal and torsion effects induced by the helical nature of the pipe. This figure also0indicates the irregular velocity profiles existing in the shell side.

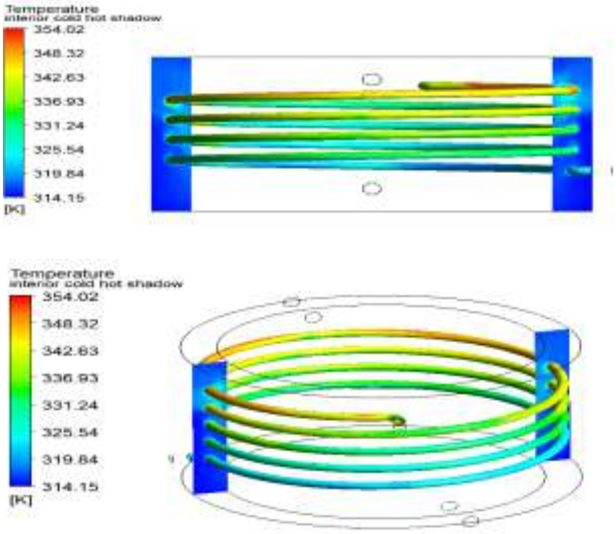

Figure.6. 4Temperature Contours of Coil Region

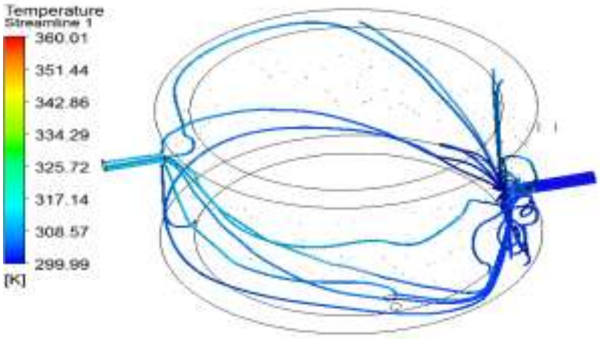

Figure.6. 5 Stream Line Contours of Shell Region

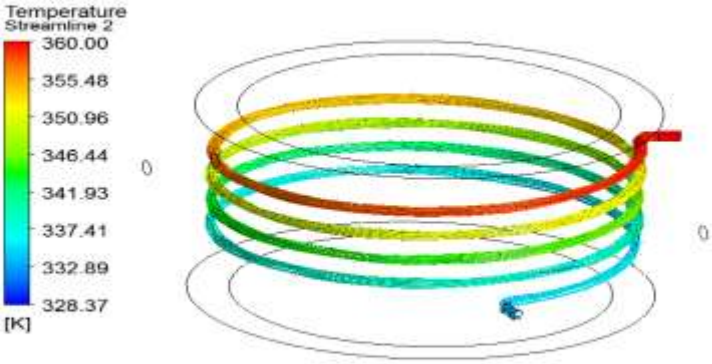

Figure.6. 6 Stream Line Contours of Coil Region

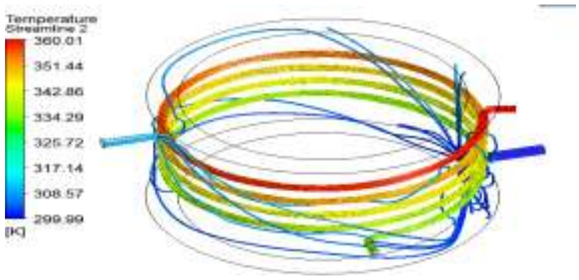

Figure.6. 7 Stream Line Contours of Shell & Coil Region

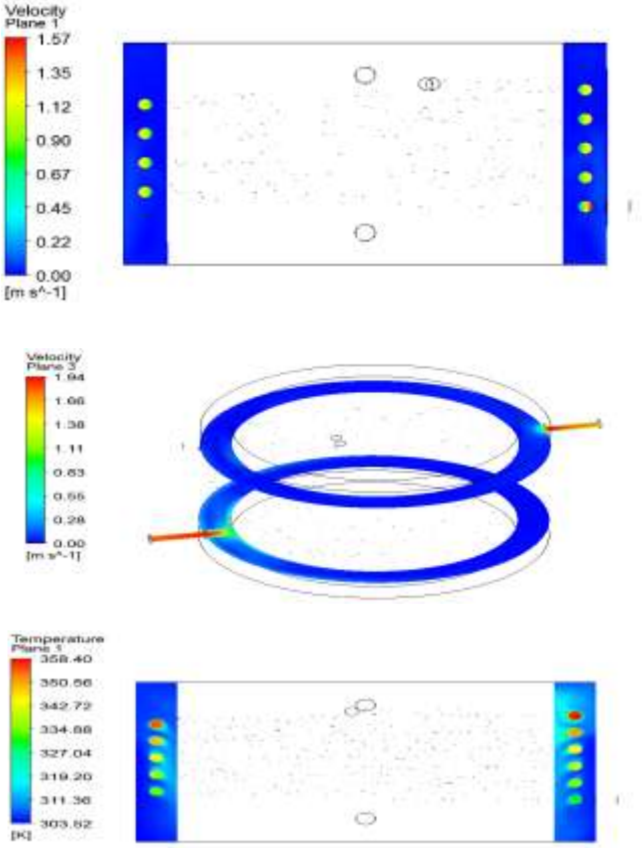

Figure.6. 8 Mid Sectional Velocity Contours of Tube and Shell Region

The results of the analysis of the CFD simulation are used to estimate the overall heat transfer coefficient. **Fig.6.33** gives a comparison of the overall heat transfer coefficients obtained from the experiment and those calculated using the CFD code. It is found that the values are well within 5%.During the experiments, care was taken to obtain non-oscillatory flow rates. For this, stabilised power supply was used for the experimental setup, which maintains speed of the pumps at a constant rpm. Proper thermal insulation was provided for the heating tank and the pipes. No insulation need to be provided to the test section as the cold water at ambient temperature was flowing on the shell side. Thus, enough care was taken to minimise uncertainties in the experiments. An error of 0.2 ◦C is expected in temperature measurements due the accuracy of the temperature sensors and indicators. Error due to accuracy of the rota meters was 3%.

The figure also shows overall heat transfer coefficient predicted by the CFD code when constant values are used for fluid properties.Thefigure also shows the overall heat transfer coefficient calculated from its components, viz., inside heat transfer coefficient, wall conductance and outside heat transfer coefficient. This value is found to be very close to the overall heat transfer coefficients calculated from overall energy balance. The inside Nusselt numbers reported by FLUENT for the case of helical pipe heat exchanger assembly are compared with those obtained for a helical pipe. The results are shown in Fig. 6.34.

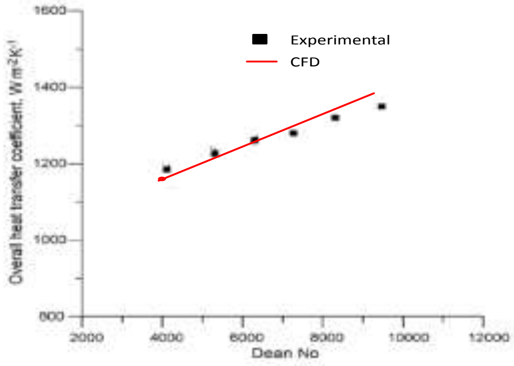

Figure.6.9Comparison of overall heat transfer coefficient.

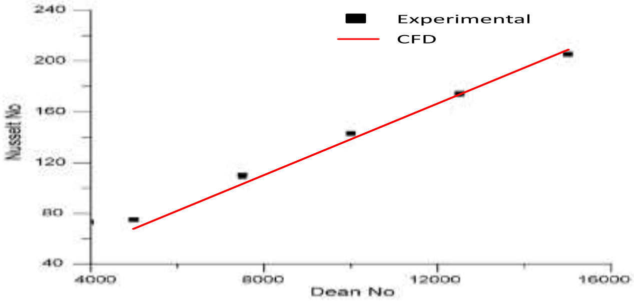

Figure.6. 10Comparison of Nusselt number

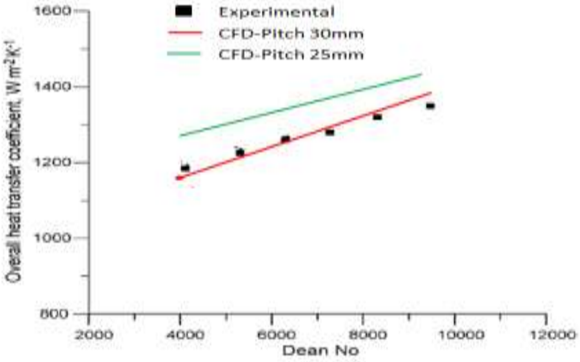

Figure.6. 11Comparison of overall heat transfer coefficient for different pitch

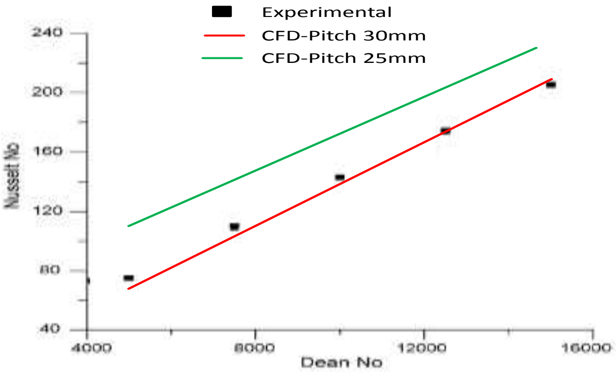

Figure.6. 12Comparison of Nusselt number for different pitch

The methodology for estimation of heat transfer for a helically coiled heat exchanger has been successfully validatedagainst experiments. As mentioned earlier, CFD analysis was carried out using Realizable k–ε model with standard wall functions. Applicability of this model with strong centrifugal and torsional effects predominant in the case of flow through helical coil needs to be further investigated. In addition, usage of a fixed set of model constants without considering the temperature effects on them, can result in uncertainties in the CFD predictions In future analysis, these factors need to be taken into account.

3. CONCLUSION

It is observed that the use of constant values for the thermal and transport properties of the heat transport medium results in prediction of inaccurate heat transfer coefficients Also for prediction of heat transfer in a situation of fluid-to fluid heat transfer, as it occurs in the case in a heat exchanger arbitrary boundary conditions such as constant wall temperature constant heat flux, etc., are not applicable. In this situation, it is essential to model the equipment considering conjugate heat transfer. An experimental setup is fabricated to study fluid–fluid heat transfer in a helically coiled heat exchanger. Heat transfer characteristics of the heat exchanger with helical coil are also studied using the CFD code FLUENT. The CFD predictions match reasonably well with the experimental results within experimental error limits. Based on the results a correlation was developed to calculate the inner heat transfer coefficient of the helical coil. Based on the confidence gained in the CFD predictions, the results generated under different conditions may used further to obtain a generalised correlation, applicable to various coil configurations.

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