Numerical Analysis of Overall Heat Transfer Co-Efficient in Tube in Tube Helical Coil Heat Exchanger

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Abstract - *Heat exchanger are important engineering system with wide range of applications. Working towards the goal of saving energies and concise design, heat transfer plays a major role in heat exchanger. Conventional heat exchangers are large and heat transfer is less. In conventional heat exchangers, a dead zone is produced which reduces the heat transfer rate. Helical coil heat exchangers (HCHE) are compact in size, eliminates the dead zone, more turbulence and offers better heat transfer rate. A tube in tube helical coil heat exchanger is designed/modeled and analyzed using a commercial available software FLUENT19.1. This paper deals with the variation of mass flow rate and pitch, and its effect on overall heat transfer coefficient.*

Key Words: **HCHE, Heat Exchanger, Heat Transfer, CFD, Helical Coil**

1. INTRODUCTION

A heat exchanger is a system used to transfer heat between two or more fluids. Heat exchangers are in use for both cooling and heating processes. A solid wall to prevent mixing may separate the fluids or they may be in direct contact. There are three primary classifications of heat exchangers according to their flow arrangement. In parallel-flow heat exchangers, the two fluids enter the exchanger at the same end, and travel in parallel to one another to the other side. In counter-flow heat exchangers, the fluids enter the exchanger from opposite ends. The counter current design is the most efficient, in that it can transfer the most heat from the heat (transfer) medium per unit mass because the average temperature difference along any unit length is higher. In cross-flow heat exchanger, the fluids travel roughly perpendicular to one another through the exchanger. Types of heat exchangers are shell and tube heat exchanger, plate heat exchanger, plate and shell heat exchanger, adiabatic wheel heat exchanger, plate fin heat exchanger, pillow plate heat exchanger, fluid heat exchanger, etc. Double-pipe heat exchangers are the simplest to design but the helical-coil heat exchangers (HCHE) have following advantages. The centrifugal force due to the curvature of the tube results in the development of secondary flows (flows perpendicular to the axial direction) which assist in mixing the fluid and enhance the heat transfer. HCHE are compact in size, highly efficient use of space, no formation of dead zones, greater turbulence etc. These HCHE finds applications in nuclear industry, power generation, process plant, chemical process industries etc.

2. ABBREVIATIONS AND ACRONYMS

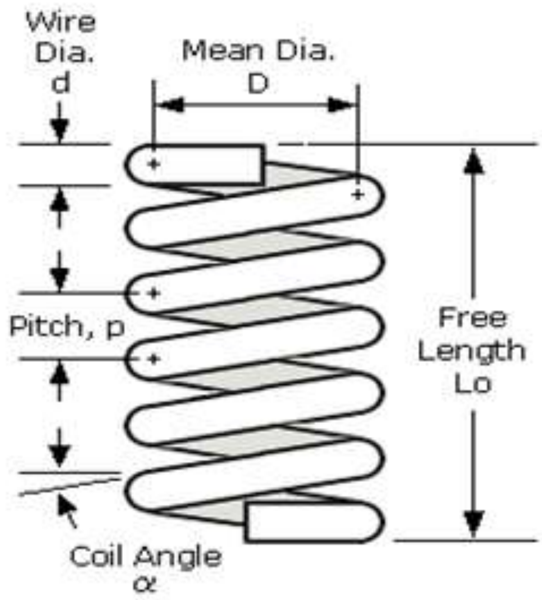

Fig -1: Name of the figure

di - Inner tube inner diameter
do - Inner tube outer diameter
Di - Outer tube inner diameter
Do - Outer tube outer diameter
P - Pitch Lo - Free length
D - Mean diameter
α - Helix Angle
CFD - Computational Fluid Dynamics
HCHE - Helical Coil Heat Exchangers

3. MODELING OF HEAT EXCHANGER

The tube in tube helical coil heat exchanger is modeled/designed using ANSYS Geometry. The inner tube diameter is 12 mm, diameter of outer tube is 21 mm, and thickness is 0.5 mm for both the tubes. Material used is copper. Working fluid used is water with constant properties. Pitch is consider depending on the analysis. Length of the heat exchanger is 500 mm. Else parameters are shown in table-1.

Table -1: Dimensional Parameters

Dimensional Parameters (mm)		Heat Exchanger
di		12
do		12.5
Di		21
Do		21.5
Length		500
Pitch	Case 1	50
	Case 2	50 , 75

4. GOVERNING EQUATIONS

Heat transfer rate (q): $\dot{m}C_p\Delta T$

Average heat transfer (q_{avg}): $\frac{q_{i+}\ q_o}{2}$

Area (A): $\pi(D_i - d_o)L$

Logarithmic mean temperature difference (ΔT_m): $\frac{\Delta T_i - \Delta T_o}{\ln\frac{\Delta T_i}{\Delta T_o}}$

Overall heat transfer co-efficient (h): $\frac{q_{avg}}{A \times \Delta T_m \times C}$

C=Correction factor, 0.9

5. MESHING

Mesh is created using ANSYS Mesh module. Edges of the heat exchanger is meshed using edge sizing. For the flow near the walls, inflation of five layers is used. With element size of 30.417 mm, coarse mesh is used. Physics preference is CFD and solver preference is Fluent. Growth rate given is 1.2. Smoothing is medium.

6. ANALYSIS

Computational Fluid Dynamics approach, along with a commercial available software ANSYS FLUENT19.1 used for analysis. K-ω SST model is used. The boundary conditions used for analysis, shown in table-2. For the first case, the mass flow rate of fluid of the inner tube varied keeping the pitch constant and in second case the mass flow rate is kept constant and the pitch is varied. The overall heat transfer co-efficient of the heat exchanger is analyzed for both the cases.

Table -2: Boundary Conditions

Inner tube fluid inlet temperature (K)		323
Outer tube fluid inlet temperature (K)		298
Outer wall condition		Adiabatic
Inner walls condition		Coupled
Material		Copper
Inner fluid		Water
Outer fluid		Water
Mass flow rate (Kg/s)	Case 1	0.003 , 0.005
	Case 2	0.005

7. RESULTS AND CONCLUSIONS

The overall heat transfer co-efficient is plotted with mass flow rate. From the chart-1, as the mass flow rate increases the overall heat transfer co-efficient increases.

The overall heat transfer co-efficient is plotted with pitch. From the chart-2, as the pitch increases the overall heat transfer co-efficient decreases.

A tube in tube helical coil heat exchanger is modeled and analyzed. From the results obtained it can be seen that as the mass flow rate increases the overall heat transfer co-efficient increases and as the pitch increases the overall heat transfer co-efficient decreases. Therefore, it is necessary to choose an optimum pitch or any other parameter for designing a heat exchanger with good overall heat transfer co-efficient.

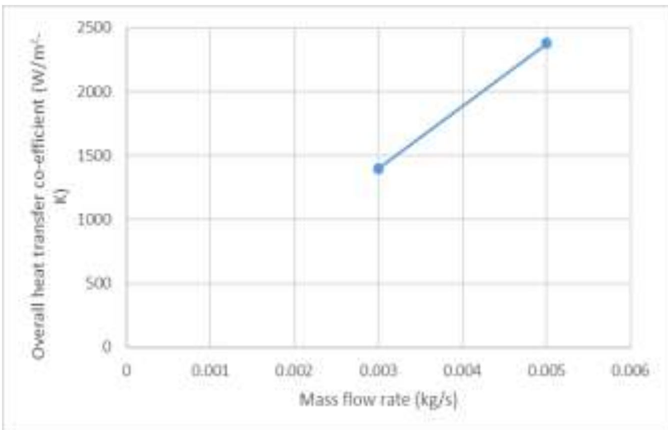

Chart -1: Variation of overall heat transfer co-efficient with mass flow rate with pitch constant

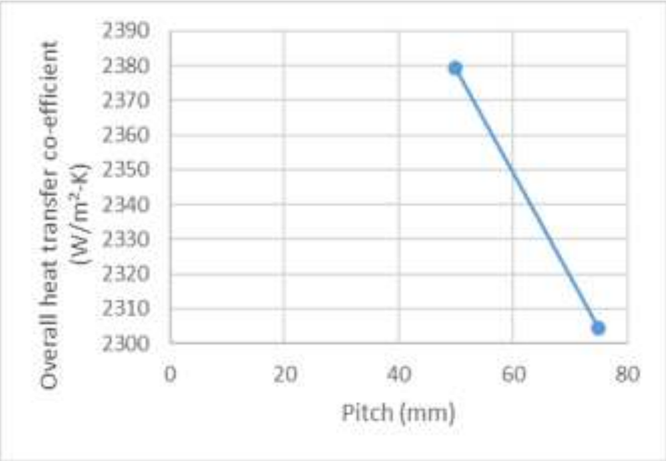

Chart -2: Variation of overall heat transfer co-efficient with pitch keeping mass flow rate constant

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