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Design and Analysis of Spiral Plate Heat Exchnager for Cooling Applications

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ABSTRACT

One of the most widely used device in heat transfer application is heat exchanger, a device transfer heat from one body to another due to difference in temperature. In this research work a Spiral plate heat exchanger is designed for 7 kW using the basic dimensions taken from Milton. The theoretical analysis and numerical analysis showed that for smaller spacing, the larger plate width to be used to meet our heat and pressure duty. The results showed that the plate width required is H= 301.92 mm to meet both the heat duty and pressure duty for 7 kW spiral plate heat exchanger.

KEY WORDS: Spiral plate heat exchanger, CFD analysis, Heat transfer, cooling applications.

1. INTRODUCTION

Heat exchangers are used in the process, power, petroleum, transportation, air conditioning, refrigeration, Cryogenic, heat recovery, alternate fuels, and other industries. A heat exchanger is the process to transfer heat from one fluid to another fluid. Spiral plate heat exchanger has excellent heat exchanger because of far compact and high heat transfer efficiency. In single-phase applications, it is wide-ranging for the hot stream to enter the exchanger through the central part of the exchanger and to exit at the periphery. The cold fluid, on the other hand, enters the unit from the outermost part of the unit and circulates to eventually exit the exchanger from the center, thus the two fluids flow counter-currently the channels are curved and have a uniform cross section, which creates spiralling motion within the fluid. The constant change in direction of the fluid that is spiraling creates a high shear stress that eliminates stagnant zones, resulting in increased heat transfer coefficients, and maintains suspended solids in motion preventing sedimentation and fouling. The spiral path followed by each of the fluids induces a secondary flow effective in increasing the heat transfer coefficient, especially in laminar flow, and in reducing fouling deposits. It can handle high viscous, fouling liquids and slurries more readily because of a single passage. In spiral plate heat exchanger, problem of thermal expansion is not probably occurring and self-cleaning is also possible.

Literature Review: Naphon (2006) investigated experimentally the effect of curvature ratios on the heat transfer and flow developments in the horizontal spirally coiled tubes. The spiral tube of 8 mm diameter with five turns for three different curvature ratios of 0.02, 0.04, 0.05 under constant wall temperature. The secondary flow caused by the centrifugal force has important effect on the developments and distributions temperature and flow in the spirally coiled tube. Due to the centrifugal force, the Nusselt numbers for the spirally coiled tube are 1.49 times higher than straight tube.

Nueza (2007), developed a new methodology for the sizing of spiral plate heat exchangers. The approach consists of an iterative process where physical dimensions like plate width and external spiral diameter are given initial values. The process to be continued until the convergence is achieved to meet the heat duty and pressure duty requirements. They also perform a numerical study using computational fluid dynamics shows that the differences between the numerical and analytical temperature profiles. In these temperature along the length for hot fluid is decreases and for cold fluid are increases.

Rajavel and Saravanan (2008), investigated experimentally the heat transfer coefficients of benzene in a spiral plate heat exchanger. They used Alfa Laval heat exchanger of model type− P5 VRB PLATE. The mass flow rate of water (Hot fluid) is varying from 0.5 kg sec-1 to 0.8 kg sec-1 and the mass flow rate of benzene (cold fluid) varies from 0.4 kg sec-1 to 0.7 kg sec-1.By varying the mass flow rate, temperature, and pressure of cold fluid, keeping the water mass flow rate as constant. When the mass flow rate of water is increases the heat transfer coefficient also increases, while the length of the plate increases leads to decreases in heat transfer coefficient.

Akhavan (2012), investigated experimentally the heat transfer enhancement of a nanofluid flow inside vertical helically coiled tubes. In this study the effects of a wide range of different parameters such as Reynolds and Dean Numbers, geometrical parameters and nanofluid weight concentrations of 0.1, 0.2 and 0.4% have been studied. By using nanofluids instead of base fluids lead to increases in Nusselt number increased up to 45%, and corresponding increment in heat transfer coefficient up to 80%.By using both techniques such as adding additives and change in flow passage shows the nanofluid used in helical coil is 10 times higher than base fluids used in straight tube.

Fakoor (2012), investigated experimentally on the thermo-physical properties and overall performance of suspending MWCNT with heat transfer oil nanofluids flow inside vertical helically coiled tubes. Pure heat transfer oil and nanofluids with particle weight concentrations of 0.1%, 0.2% and 0.4% are used as working fluids. They introduce a term called performance index η, heat transfer technique is more in favour of heat transfer enhancement rather than in favour of pressure drop increasing when it is greater than 1.The maximum performance of η= 6.4 for nanofluids used in helical coil, while η = 1.5, for nanofluids used in straight tubes, and η=5.1 for base fluids used in helical coil, shows using helical coil with base fluids have high heat transfer when compared to using nanofluids in straight tube.

Jay (2013), study the performance of spiral tube heat exchanger using a coil by bending a 12 mm diameter of straight copper tube into a spiral coil tube of four turns. The exit temperature of hot fluid (oil) decreases with increase in mass flow rate of cold fluid (water) while exit temperature of hot fluid (oil) increases with increase in mass f low rate of hot fluid (oil).The exit temperature of cold fluid is decrease with increase the mass flow rate of cold fluid. When the mass flow rate of cold fluid increase, then the effectiveness of the heat exchanger decreases.

Designing of Plate Heat Exchanger: The spiral plate heat exchanger has basic dimensions such as plate width, flow spacing for hot fluid and cold fluid. The basic dimensions are to be assumed in order to determine outer diameter, length of the passage and number of turns. The hot fluid enters at the center and leaves in periphery while cold fluid enters at the periphery leaves in center in order to obtained counter-current direction.

Basic dimensions: The basic dimensions used for designing the spiral plate heat exchanger are,

- Width of the plate = 304.8mm
- Channel spacing = 4.7625mm
- Thickness of the plate = 3.175mm
- Core or inner diameter = 203.2mm

Theoretical analysis: The graphical design tool developed for compact type heat exchanger used to predict the given heat exchanger dimensions will meet the heat duty within the limitations of pressure drop. For spiral plate heat exchangers the basic dimension involves such as plate spacing of the two streams, plate width, inner diameter, outer diameter and passage length. The plate length that meets the heat duty for a given plate width is called thermal length and length that meets the pressure drop is called hydraulic length. The dimension of spiral heat exchangers is varied simultaneously in order to obtain the design parameters that fulfill the process heat duty and pressure duty. The graph is plot between plate width on x-axis and length on y-axis. The intersection between the curves indicates the given heat exchanger dimensions for which the thermal length equals the hydraulic length. Then the basic dimensions are finalized by taking the standard dimensions available for design.

Graphical representation for design:

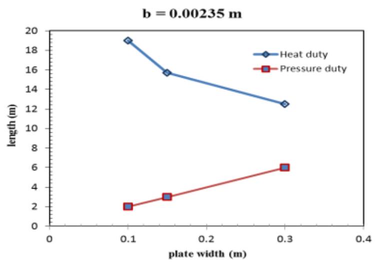

Figure.1. Heat transfer duty and pressure duty for plate width 0.00235 m

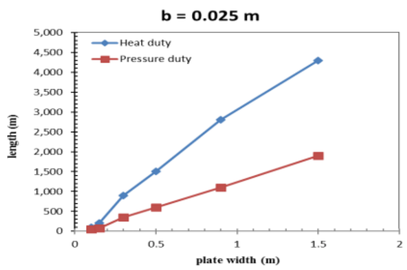

Figure.2. Heat transfer duty and pressure duty for plate width 0.025 m

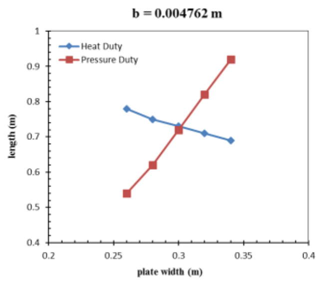

Figure.3. Heat transfer duty and pressure duty for plate width 0.004762 m

From the fig.1, .2 and .3, it's clearly showed that the heat transfer duty and pressure duty is not satisfied in first two cases due to the geometric variation in dimensions. But while we choosing the plate width of 4.762 mm our requirement of both pressure drop and heat duty is achieved.

2. METHODS & MATERIALS

Numerical Analysis: The 3-D modeling of the spiral heat exchanger was done by using CATIA and created the IGES file for analysis. The construction of spiral plate heat exchanger has consists of two plates and two flow sections, in order to obtain the counter-current arrangement. The exchanger geometry model was analyzed by using ANSYS FLUENT-13. The number of computational cell was 140074 and using k-ε model turbulent model

Analysis Condition for Simulation:

Air state = Steady state condition
Turbulent model = k-ε model
No. of cells = 140074
Hot water inlet temperature = 50˚C
Cold water inlet temperature = 30˚C
Mass flow rate of hot water = 0.44 kg/s
Mass flow rate of cold water = 0.52 kg/s

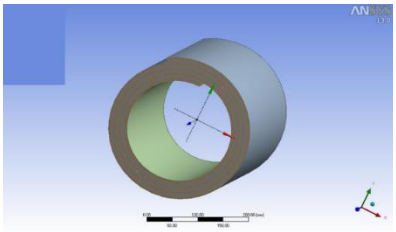

Figure.4a. 3D view of spiral plate heat exchanger

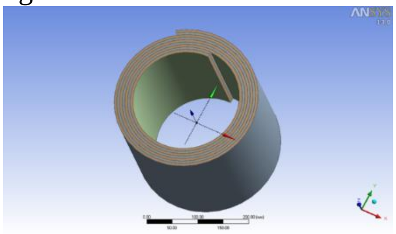

Figure.4b. 3D view of spiral plate heat exchanger

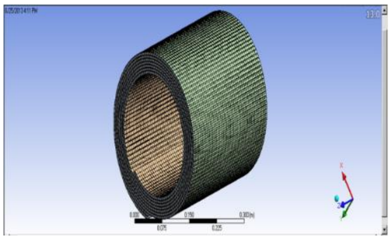

Figure.5. Messing of spiral plate heat exchanger

Figs.4 and 5 shows the modelling and messing of the spiral plate heat exchanger. Fig.6 showed that the temperature of hot fluid decreases with increases in temperature of cold fluid along the spiral flow.

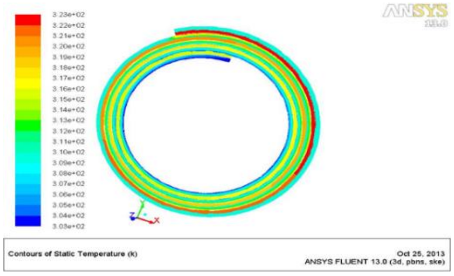

Figure.6. Temperature Variation

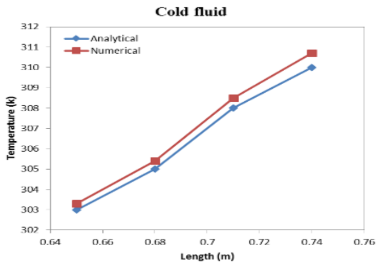

Figure.7. Temperature variation of cold body along the spiral plate heat exchanger

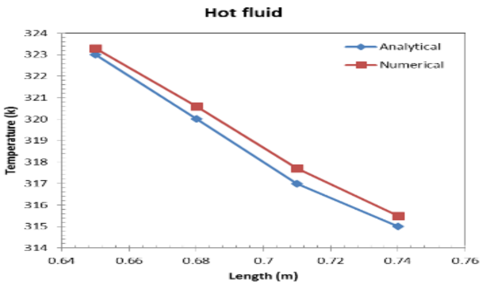

Figure.8. Temperature variation of hot body along the spiral plate heat exchanger

Figs.7 and 8 compares the theoretical analysis with numerical analysis, showed that little deviation occurred due to variation in temperature effects and pressure duty. The temperature along the length of cold plate is increases and temperature along the length of hot plate is decreases. The temperature along the length of cold plate is increases and temperature along the length of hot plate is decreases

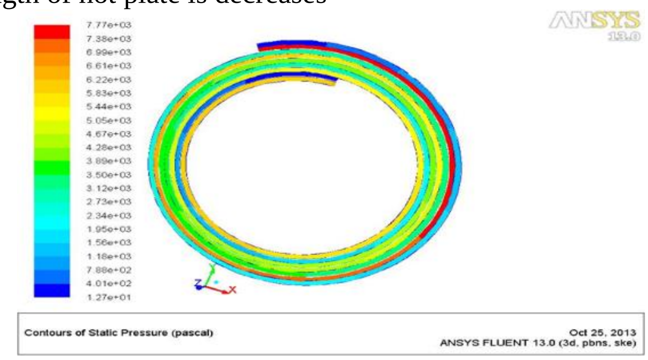

Figure.9. Pressure variation of hot body along the spiral plate heat exchanger

Table.1. Comparison of initial and final design with final dimensions.

Parameter	**Initial design for utilization of pressure duty**	**Final design with standard dimension**
Plate width, (mm)	301.92	304.8
Re (hot fluid)	5103	5055
Re (cold fluid)	4086	4048
Heat load, (W)	7000	7000
Heat transfer coefficient, hot side (W/m^2K)	2547.21	2529.28
Heat transfer coefficient, cold side (W/m^2K)	2463.27	2445.93
Over all heat transfer coefficient, (W/m^2K)	965.73	960.48
Heat transfer area, (m^2)	0.439	0.442
Passage length, (mm)	726.21	726

3. RESULTS

From the analysis we clearly know that, for a small spacing value, a larger plate width required to meet the heat duty and pressure duty. For a large spacing value, a smaller plate width required to meet the heat duty and pressure duty. The basic dimension which required to meeting the process duty as plate width of 301.92 mm. The temperature of the cold fluid is increased while the hot fluid is decreased along the length of the plate.

4. CONCLUSION

For enhancing the heat exchanger performance passive techniques is used to increases in heat transfer coefficient as well as reducing its cost and size. For designing a spiral plate heat exchanger of 7KW, the plate width required is H= 301.92 mm to meet both the heat duty and pressure duty. At this particular plate width the process duty is achieved at which the thermal length is equal to hydraulic length. Then for a small spacing value, a larger plate width required to meet the heat duty and pressure duty and vice versa.

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