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EFFECT OF PITCH NUMBER IN OVERALL HEAT TRANSFER RATE IN DOUBLE PIPE HELICAL HEAT EXCHANGER

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Abstract: The aim of the following research to study the tube in tube helical coil heat exchanger where with increase in the pitch will increase the overall heat transfer rate. Since that tube in tube, helical coil often taken small area and the height of the tube in tube helical coil heat exchanger can be configured by the relation index proposed in the following paper. The heat transfer rate in the heat exchanger depended on the heat transfer coefficient, surface area and temperature difference. Geometry of the heat transfer area and the turbulence factor plays a major role in the enhancement of the heat transfer rate, In this paper numerical analysis of a tube in tube helical coil heat exchanger is done using Ansys Fluent as a counter flow arrangement. The pitch of the helical tube is varied for the constant length of the coil and the overall heat transfer rate is calculated. Results have shown that as the pitch is reduced the heat transfer rate is increased.
Keywords: Pitch number , Helical coil heat exchanger, Overall Heat Transfer.

1. Introduction

Heat exchanger is the device that helps to transfer heat from the hot body to cold body. There are many types of the heat exchanger available based upon the TEMA. There is some rare type of the heat changer available like double pass and tube in tube helical coil heat exchanger, which comes to tubular type of heat exchanger. The tube in tube helical coil type of heat exchanger offers a wide option for the design in which liquid to liquid heat transfer can be incorporated along with the refrigerant to liquid and implementation of Nano fluids can be applied. The steep curvature's in the tubes introduces the secondary flow that is normal to the primary flow, which leads to form the transitionflow, with the turbulent conditions increases the heat transfer.Assuch, number of turns, which is responsible for the increase in the curvatures that induced in increase in the Dean Number, which is associated by the heat transfer with the curvature's, with increase in the Dean Number the increase in the Turbulence is caused by curvature which is directly depended on the pitch of the helical coil. Which is modeled as the k-e model, So any fluctuations in the pitch index will show immense effect on the Overall heat exchange value. The implementation's and usage of double pipe helical tube heat exchangers is in the recovery of CO_2, cooling the hydrocarbons and in polymer industries for cooling, since they are compact in nature they can be used in the space limitation places like space and steam generation and marine and industrial application. Extensive usage of this type of exchangers are used in low temperature "cryogenic" research.

2. Literature Review

The experimental comparison between tube in tube and helical coil heat exchangers have been made by the Ruchal G.Humbare ,Suraj R.Gurav et al 2015[1]. The analysis of helical coil heat exchanger is done by Amol Andhare and V.M Kriplani et al 2014 [2] correlations were proposed to calculate shell side and tube side heat transfer coefficients for different curvature ratios and pitch ratios. Wale l.A.Aly et al 2014[3]has performed CFD study to investigate the 3-D turbulence flow and heat transfer of coiled tube in tube heat exchangers results shown that Gnielinski correlation was used extensively for predicting nusselt number as the function of prandtl number and the convective co-efficients in inner coil tube and annular coil tube. J.S Jaykumar S.M Mahajani et al 2008[4] have performed CFD simulations for vertical and horizontal oriented helical coils by varying pitch circle diameter and tube pitch and pipe diameter and study the influence on heat transfer by varying this parameter a correlation was presented to predict the local values of nussult number as the function of angular location of the point. Timothy J.Rennie et al 2006[5]has performed the experimental study on the tube in tube helical coil heat exchanger by varying flow rates within the turbulent region in inner tube and in the annulus results have shown that the experimental data fit well with the numerical values for larger heat exchangers but some differences between numerical and experimental data for smaller coil.

3. Methodology

From the overall heat transfer rate, it is proven that the area is the possible terms in adjusting the parameter where the pitch come into play a possible change. To prove the pitch is the possible parameter for the heat transfer rate the following derivation has been made.

The following are the notation taken for the derivation

L is the length of the helical coil. =1.5 m
N is the number of turns of the coil.
R is the base radius if the helical coil. =0.15m
p is the pitch of the helical coil.
Q_{avg} is the average heat transfer rate.
U is the overall heat transfer rate.
d_{o-i} is the annulus thickness.
Δt_c is the corrected log mean temperature difference.

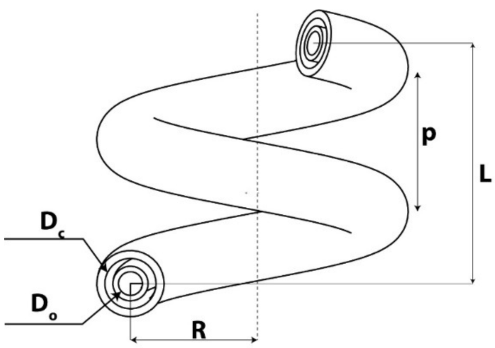


Figure 1. The design nomenclature of the Double pipe helical coil heat exchanger

$$\rightarrow L = N \cdot \sqrt{(2\pi R)^2 + p^2} \text{ Eq. (1)}$$

$$\rightarrow A = \frac{Q}{U \cdot \Delta t_c} \text{ Eq. (2)}$$

$$\rightarrow U = \frac{Q_{avg}}{A \cdot \Delta t_c} \text{ Eq. (3)}$$

$$\rightarrow U = \frac{Q_{avg}}{\pi \cdot d_{o-i} \cdot L \cdot \Delta t_c} \text{ Eq. (4)}$$

$$\rightarrow U = \frac{Q_{avg}}{\pi \cdot d_{o-i} \cdot N \cdot \sqrt{(2 \cdot \pi R)^2 + p^2} \cdot \Delta t_c} \text{ Eq. (5)}$$

$$\rightarrow U = f\left[\frac{1}{p}\right] \text{ Eq. (6)}$$

$$\rightarrow U \alpha \frac{1}{p} \text{ Eq. (7)}$$

From the eq 7 it is proved that the change in the heat transfer rate has the effect by the change in the pitch if the spiral. For increase in the heat transfer take place for decrease in the pitch and for the pitch it cannot be zero and cannot be equal to length of the helical coil. Since the study was not on the overall design of the tube in tube helical coil heat exchanger but specified to the pitch of it so the numerical simulation was made by varying the pitch in two cases by 0.09m and 0.20 m. the type of flow made was counter flow type. In order to verify the above equation numerical simulation was made on the Anysys Fluent tool where the solver used was k-ε type and with the turbulent intensity of 5% and Hydraulic length as 10mwith boundary conditions of fluid as follows.

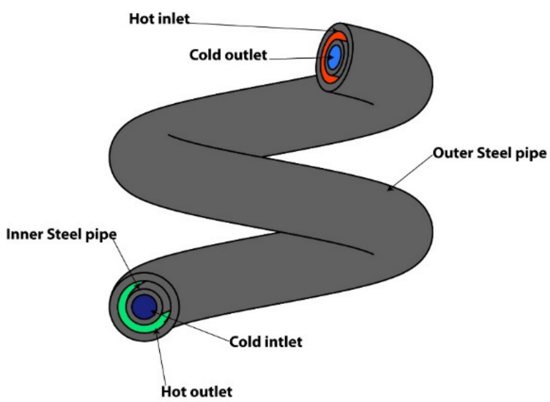


Figure 2. boundary conditions of the numerical simulation of the double pipe helical heat exchanger

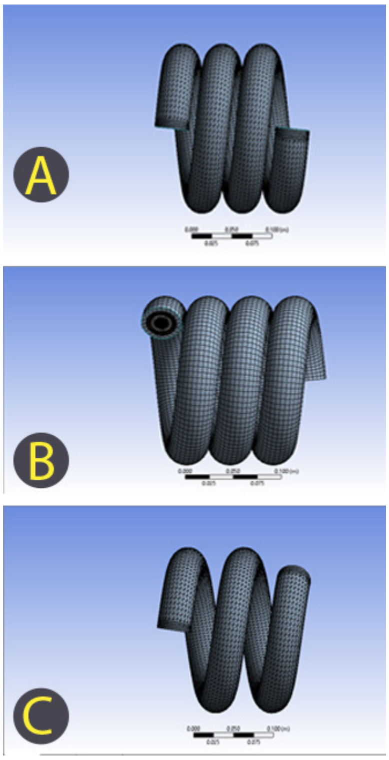


Figure 3. the different mesh modelsof tube in tube helical coil heat exchangers A is of pitch 0.045 m B is of pitch 0.07 m C is of pitch 0.09m.

The mesh that was generated within ANSYS and automatic mesh with the refinement of 2 at the inlet and outlets faces and by making sure that the mesh has captured the steepcurvature of the geometry. The type of assembly method was cut cell method and an inflation layers are of 5 is added in order to account the heat transfer in at the wall.

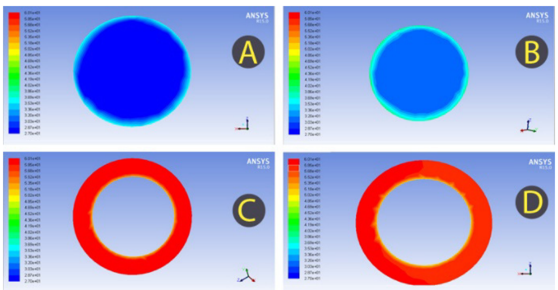
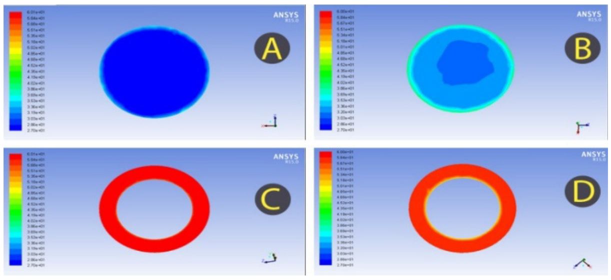
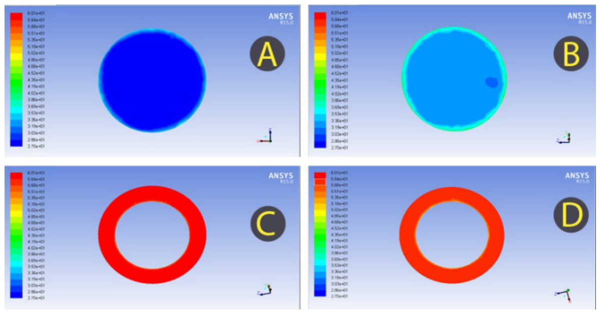


Figure 4. showing the outlet and inlet temperatures of the tube in tube helical coil heat ex-changers of pitch 0.09 A is cold water inlet B is the cold water



outlet and C is the hot waterinlet and D is the hot water outlet.

Figure 5.showing the outlet and inlet temperatures of the tube in tube helical coil heat exchangers of



pitch 0.07 A is cold water inlet B is the cold water outlet and C is the hot water inlet and D is the hot water outlet

4. Results

The Computational results that has been observed after the solution is made to converged pitch 0.09 A is cold water inlet B is the cold water outlet and C is the hot water inlet and D is the hot water outlet.

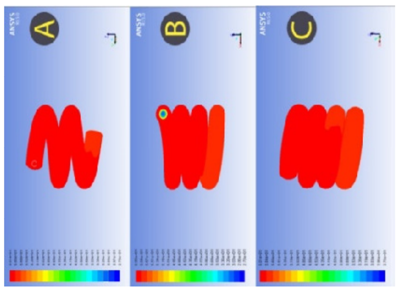


Figure 7. showing the various heat transfer Initializationand propagation in tube in tube helical coil heat exchangers

It is noted form the figures 4,5,6 of B images the inner layers of the cold outlet have shown the decrease of temperature layers and has given maximum decrease in the pitch of 0.045m tube double pipe helical coil heat exchanger.

Form the above figure7 it is observed that the decrease in the pitch has shown that heat transfer rate has started in advance for the outlet pipe than that of greater pitch. Results show that pitch of helical coil heat exchanger has a greater effect on the over- all heat transfer coefficient so the effect of Pitch on the overall heat transfer coefficients. The following are the equation taken for the calculation of the overall heat transfer coefficients.

$$Q_{cold} = \dot{m}_c \cdot c_c \cdot (T_{ci} - T_{co}) \text{ Eq. (8)}$$

$$Q_{hot} = \dot{m}_h \cdot c_h \cdot (T_{hi} - T_{ho}) \text{ Eq. (9)}$$

$$Q_{avg} = \frac{Q_{cold} + Q_{hot}}{2} \text{ Eq. (10)}$$

$$A_{annular} = \pi \cdot d_{out-in} \cdot N\sqrt{(2\pi R)^2 + p^2} \text{ Eq. (11)}$$

$$LMTD = \frac{(T_{hi} - T_{co}) - (T_{hi} - T_{ci})}{\ln\left[\frac{(T_{hi} - T_{co})}{(T_{hi} - T_{ci})}\right]} \text{ Eq. (12)}$$

$$U = \frac{Q_{avg}}{A_{annular} \cdot LMTD \cdot \Delta t_c} \text{ Eq. (13)}$$

Correction factor of the counter flow is 0.9. From the equation (11) and from equation (13) the overall heat transfer rate is given in the equation (13) so equation (7) argues best with equation (13) hence provide an proof of justification of problem statement

4. Conclusion

The graph is fitted to a cubic equation for the approximation equation in terms of terms of pitch of the helical coil heat exchanger and the overall heat transfer rate of the heat exchanger.

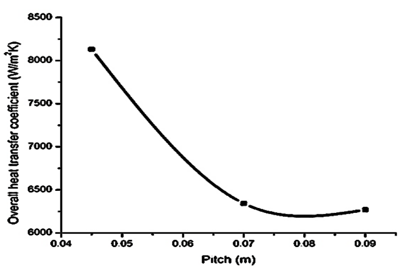


Figure 8. showing the graph of the pitch variation and over all heat transfer coefficient of tube in tube helical coil heat exchanger.

$$U = 1.5\times10^6 \cdot p^2 - 2.4\times10^5 \cdot p + 16086 \text{ Eq .(14)}$$

It is observed form the above equation if the pitch equals to the length of the helical coil there is no heat transfer and above correlation is to used only within the range of 0.045 m to 0.09 m of the pitch.

With respective to the simulation results from the figure 4 of B it is observed that the heating gradient along the face has no proper formation and from the figure 5 of B the generation of the heat gradient form the annulus face has visual change with the area showing the least default value as 27 ^{0} C and for the next 6 of B also show an higher heating gradient .This numerical results prove that the with increase in the pitch there is an noticeable change in heat exchanging pattern in the working media. With respective to the figure 8 it is observed that the cooling curl of the outer tube also shows the proportional pattern as the variation of pitch where increase in the pitch the length of the cooling curl of the hot fluid has given an conclusion the incorporating the lower pitch helps in the cooling of the hot fluid well in advance rather than the just cooling in that instant this intern helps in the reservoir mechanism of cooling and even helps in designing the compact heat exchangers.

It is proved from the numerical analysis pitch shows the parametric change in the number of turns where there is change in the dean number of the geometry, which effected the overall heat transfer coefficient. While designing the tube in tube helical coil heat exchanger the pitch of it should be in relation that have values proved from the study rather than designing with relation to the radius of the helical coil.

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