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THERMAL ANALYSIS OF SHELL AND TUBE HEAT EXCHANGER

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Abstract:*Heat exchangers have been observed from the smallest electronic devices to the space shuttles. It transfers heat from one medium to another by means of direct or indirect contact. A helical coil heat exchanger with a helix angle of 30^o using CREO software was designed and fabricated. Nowadays copper is replaced by Carbon steel in industries. Presently the objective is to use ANSYS CFX 15.0 software to infer the replacability of copper with two different inner tube materials such as POCO HTC graphite and ASTM SA 179 carbon steel which also has appreciable heat transfer characteristics and good corrosion resistance than copper. A laminar hot fluid flow is the heat source medium. Also the increase in heat transfer rate with increase in mass flow rate is also observed.*

KEYWORDS: CFX, Heat transfer, helical tube, Laminar, Conduction

INTRODUCTION

The sole purpose of the heat exchangers is to enhance the heat transfer between the two fluids. This reduces the energy requirements and helps make the process more efficient. Unlike the normal straight coil heat exchangers ours is helical coil heat exchanger with helix angle of 30 degrees,it is found that the heat transfer in helical circular tubes is higher as compared to Straight tube due to their shape. Helical coils offer advantageous over straight tubes due to their compactness and increased heat transfer coefficient. The increased heat transfer coefficients are a consequence of the curvature of the coil, which induces centrifugal forces to act on the moving fluid, resulting in the development of secondary flow. Helical coils are extensively used as heat exchangers and reactors due to higher heat and mass transfer coefficients, narrow residence time distributions and compact structure

Two materials which is of totally different characteristics but with the similarity of good thermal conductivity is selected. POCO HTC Graphite and ASTM SA 179 carbon steel are compared based on the thermal heat conduction analysis.Copper is nowadays replaced by Carbon steels in industries.

Subin Michael[1]studies the changes in temperature profiles in each of the cases are taken into consideration for calculating effectiveness of heat exchanger. Better insights on optimal material selection for vital parts of a heat exchanger is obtained from comparative CFD analysis by adopting distinct industrial materials

W. Youssef, Y.T. Ge[2] observed that employing phase change materials (PCMs) for latent heat storage (LHS) application has a great potential to improve a solar thermal system performance. He also stated heat transfer enhancement is one of the essential strategies that can overcome this obstacle.

Ammar Ali Abd[3]illustratedfully the thermal and mechanical design for this heat exchanger. Here, the redesign takes place to improve the design by reselect different parameters which can enhance the heat transfer through the exchanger. The new design suggested that four tubes passes need to be used with 1.38m tube length. In addition, the tube arrangement chosen to be square type with 0.9 m shell diameter.

Finally its stated as With these parameters, the exchanger achieves high enough heat transfer coefficient and the pressure drop within specification.

Vijaya kumar reddy[4] observed from his experiments as the inner tube flow rate increased from 400 to 600lph with constant outer tube flow rate of 700LPH, the LMTD is increased by 1.33%. As the outer tube flow rate increases with constant inner tube flow rate, the LMTD decreases. As the Flow velocity or the Reynolds number increased from 4E03 to 5.62E03, the frictional factor has decreased by 0.24%.This is because of turbulence that is occurred in the coil due to semi circular baffles. As the flow velocity or the Reynolds number increases from 4,000 to 5,500 the overall heat transfer coefficient increases which can be observed as convection dominates. The addition of semicircular plates (baffles) in the annulus region has increased the turbulence in that region which enhances the heat transfer between the cold and hot sides.

M.H.Saber[5] inferred that Short baffles can be used in up and down sections of HPHE to avoid bypass flows.Entry cross area affects distribution of flow and temperature. According to the results, although increase of entry cross area helps to make better distribution, but large scale of it may increase pressure drop and operation costs. Use of baffles is a very effective role for appropriate development of flow and temperature’s profiles. The results show that using an imperfect cone with 1/5 diameter ratio, can optimizes performance of HPHE very well.

Zhan Liu[6] Full use and effective management of cold capacity are significant for improving the performance of heat exchanger in the thermodynamic vent system (TVS). To understand the operation principle of TVS easily, the thermodynamic analysis, based on the ideal gas state equation and energy conservation equation, is detailed introduced. Some key operation parameters are optimized and suggested. As the low mass flow rate and low heat fluxes are involved in flow boiling of the annular pipe fluid, the Kandlikar’s boiling heat transfer correlation is selected to predict the flow boiling process, after validated with the related experimental results. In the study conclusion is stated as with the increase of m_{cir} , the total cold capacity increases, while TVS operation time decreases. For the present study, the proper circulation mass flow range is 8–16 L/min. When m_{cir} keeps constant, the increase of g rises the total cold capacity and reduces the spraying flow temperature

Soumya Ranjan Mohanty[7] the numerical study of heat transfer characteristics of a helical coiled double pipe heat exchanger for parallel flow and the results were then compared with that of the counter-flow. The CFD results when compared with the experimental results from different studies and were well within the error limits. The study showed that there is not much difference in the heat transfer performances of the parallelflow configuration and the counter-flow configuration. Nusselt number at different points along the pipe length was determined from the numerical data. The simulation was carried out for water to water heat transfer characteristics and different inlet temperatures were studied. From the velocity vector plot it was found that the fluid particles were undergoing an oscillatory motion inside both the pipes.

Ender Ozden[8]from the CFD analysis of shell and tube heat exchanger on the shell side observed that theshellsideofasmallshell and tubeheatexchangerismodeledwithsufficientdetailtor esolvetheflowandtemperature fields.FromtheCFDsimulationresults,forfixedtubew alland shellinlettemperatures,shellsideheattransfercoefficie nt,pressuredropandheattransferratevaluesareobtaine d.Thesensitivity oftheshellsideflowandtemperaturedistributionstothe mesh density,theorderofdiscretizationandtheturbulencem odeling isobserved.Threeturbulencemodelsaretriedforthefirs tand thesecondorderdiscretizationsusingtwodifferentmes hdensities. varyingthebafflespacingbetween6and12,andthebaffl e cutvaluesof36%and25%,for0.5,1and2kg/sshellside flowrates, thesimulationresultsarecomparedwiththeresultsfro mtheKern andBell–Delawaremethods.ItisobservedthattheKernmethod alwaysunderpredictstheheattransfercoefficient.

Ashish Dewangan[9] inferred on the CFD Analysis of Heat Transfer of Helical Coil Heat Exchanger Observered that total heat transfer rate of helical tube using two different flows(Parallel and Counter Flow).In that study of heat transfer characteristics of a helical coiled double pipe heat exchanger for parallel flow and the results were then compared with that of the counter-flow.The study showed that there is not much difference in the heat transfer performances of the parallel-flow configuration and the counter-flow configurationFrom the pressure and temperature contours it was found that along the outer side of the pipes the velocity and pressure values were higher in comparison to the inner values.

Pramod Deshmukh[10]inferred that counter flow analysis of the helical coiled double pipe heat exchanger was done using the Computational Fluid Dynamics.CFD was used for the numerical study of heat transfer characteristics of a helical coiled double pipe heat exchanger of the counter-flow. The CFD results when compared with the experimental results from different studies and were well within the error limits. The simulation was carried out for water to water heat transfer characteristics and different inlet temperatures were studied. Characteristics of the fluid flow were also studied for the constant temperature and constant wall heat flux conditions.

Shiva Kumar[11]dealt with the CFD simulation of helical coiled tubular heat exchanger used for cooling water under constant wall temperature conditions.CFD results are also compared with the results obtained by the simulation of straight tubular heat exchanger of the same length under identical operating conditions. The helical coil the average temperature drop was increased by 9.5% as compared to the straight coil when the mass flow rate varied from 0.005 kg/s to 0.05 kg/s. As the mass flow rate increases the temperature drop decreases in both cases. At higher mass flow rates due to the increased velocity resident time for the fluid decreases thus reducing the temperature drop. Results indicated that helical heat exchangers showed 11% increase in the heat transfer rate over the straight tube. Simulation results also showed 10% increase in nusselt number for the helical coils whereas pressure drop in case of helical coils is higher when compared to the straight tube.

Triloki Nath Mishra[12] s shows the deviation of Nusselt Number for different curvature ratio and Reynolds Number.CFD analysis was conducted by varying inlet condition keeping the heat flux of outer wall constant. The turbulent flow model with counter flow heat exchanger is considered for analysis purpose. Copper was used as the base metal. Nusselt Number depends on curvature ratio. It increases with increase in curvature ratio. In addition, the value of Nu no. was found to increase with increase in mass flow rate (i.e. inlet velocity),With increases in D/d ratio (inverse of curvature ratio) the Nusselt number and frictional factor will decreases; for a particular value of Reynolds number. Nusselt number and frictional factor has maximum value for D/d=10 and minimum value for D/d=30.

II.MATERIALS AND DISCUSSIONS:

Ansys-CFXof the system starts with the construction of desired geometry and mesh for modeling the model. Heat exchanger is built in the ANSYS workbench design module. It is a counter-flow heat exchanger.

Two materials POCO HTC a graphite with good heat transfer coefficient and good corrosion resistance is used. Another material is ASTM SA 179 Carbon steel which is a conventional boiler tube material is also used.

III. BOUNDARY CONDITIONS:

Governing equations : Rate of increase of mass in fluid element equals the net rate of mass flow into the element

$$\frac{\partial \rho}{\partial t} + \frac{\partial(\rho u)}{\partial x} + \frac{\partial(\rho v)}{\partial y} + \frac{\partial(\rho w)}{\partial z} = 0$$

For Incompressible flow

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z} = 0$$

Inlet conditions:

Hot inlet Velocity = 0.012982456 ms^{-1}
Cold inlet Velocity= 0.053488374 ms^{-1}
Hot inlet Temperature= 323K
Cold inlet Temperature= 297K
Viscosity = 0.001003 kg/ms
Hot inlet Pressure= 67811.297 pa
Cold inlet pressure= 1335.1104 pa

Outlet Conditions:

Hot outlet Velocity = 0.99053895 ms^{-1}
Cold outlet Velocity= 0.055004768 ms^{-1}
Hot outlet Temperature= 310K
Cold outlet Temperature= 301K
Viscosity = 0.001003 kg/ms
Hot outlet Pressure= 33.900291 pa
Cold outlet pressure= 1.35228 pa

Mesh Details:

Mesh Type – Hexagonal Mesh
Smoothing- High and FINE
Size- 4.033e-005m to 8.066e-005m

MESH NODES= 223455

MESH ELEMENTS= 908502

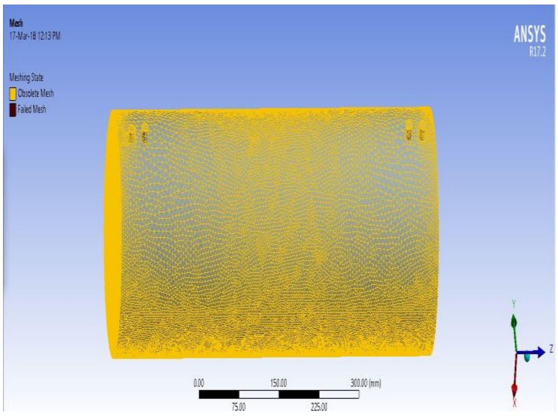


Fig1-Meshing of Shell

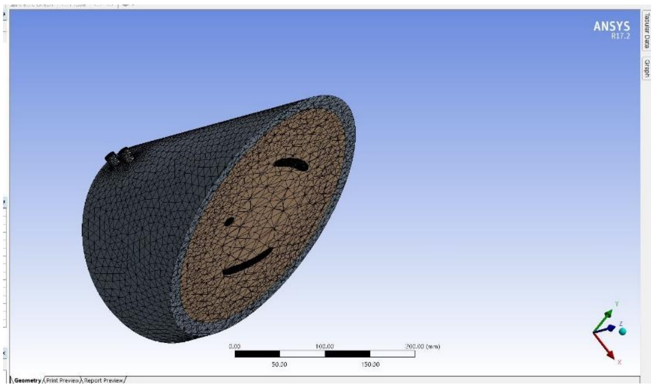


Fig.2 Cut section view of Mesh

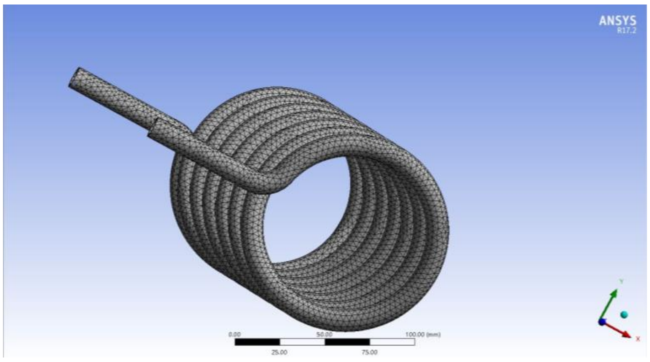


Fig 3- Meshing of Tube

Dimensions and Calculations

Design of spiral tube:

Diameter of the inner tube d_i = 10mm
Diameter of the outer tube d_o= 12.5mm
Number of turns on the tube N= 6
Pitch of the spiral tube P= 40mm
Outside diameter of the coil D= 135mm

Design of Outer shell:

Thickness of the shell t = 2mm
Diameter of the shell d = 224mm
Length of the shell L = 600mm
Area of the shell= $\pi(r)^2= \pi(112)^2$= 39.40 mm^2
Circumference of the shell
= $2\pi r = 2*\pi*112$ = 703.71mm

Flow calculations:

Entry temperature of hot fluid T1=50^oC
Entry temperature of hot fluid T2=37^oC

Entry temperature of cold fluid t1=25^{o}C
Exit temperature of cold fluid t2= 29^{o}C
Specific heat of hot fluid c1=4180J/kg K
Specific heat of cold fluid c2=4180J/kg K
Convective Heat Transfer Coefficient of Hot Water h1=3000 W/m^{2}C^0
Convective Heat Transfer Coefficient of Cold Water h2=1000 W/m^{2}C^0

SYMBOLS:

U = Overall Heat transfer coefficient (W/m^{2}K)
L_t = Length of the helical tube (meter)
N = Number of Turns of helical coil
L_1= Length of one turn (meter)
r = coil radius (meter)
λ_w= Thermal conductivity of the material
Q = Quantity of heat transfer (W/m^{2}K)

Flow Calculations:

$T_1 = 50^0$C
$T_2 = 37^0$C

FOR POCO HTC Material:

Logarithmic Mean Temperature Difference (LMTD)

LMTD = (ΔT1 - ΔT2) / ln(ΔT1/ΔT2)

= (50-29)-(37-25)/(In((50-29)/(37-25)))

(ΔTm) = 16.08˚C

Q = 971.282 J (considering the time as 2 seconds)

FOR CARBON STEEL:

Q = 972.03J

V. Analysis

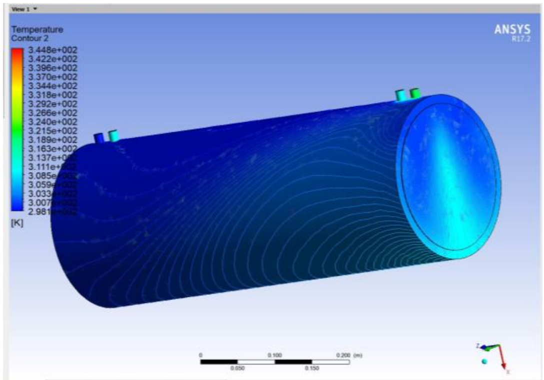


Fig-4 Carbon steel Tube side view

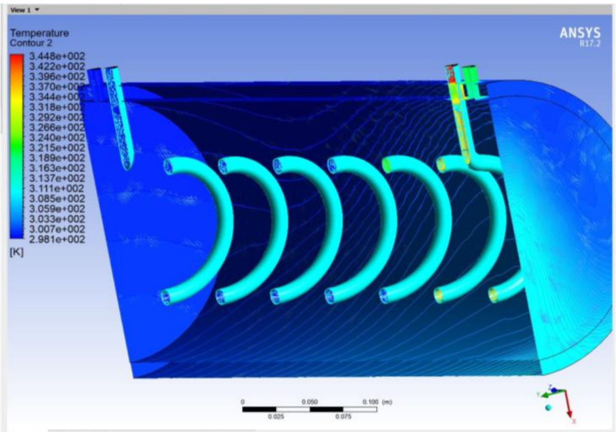


Fig.5-Carbon steel Heat transfer shell view

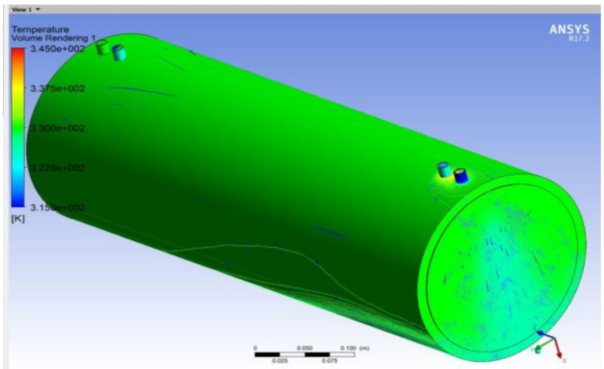


Fig 6- Poco Htc Shell side Heat Transfer

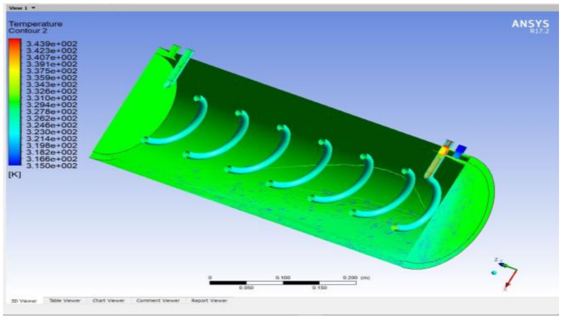


Fig.7-Poco HTC heat transfer Tube view

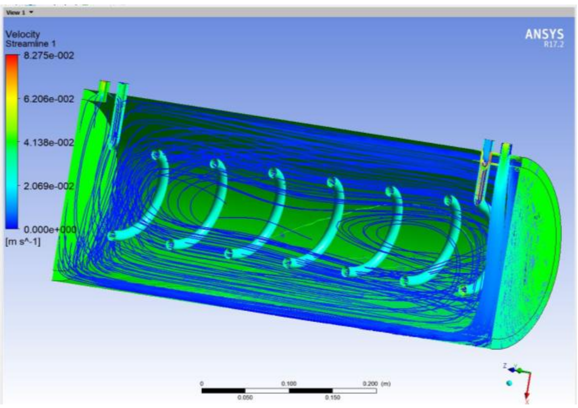
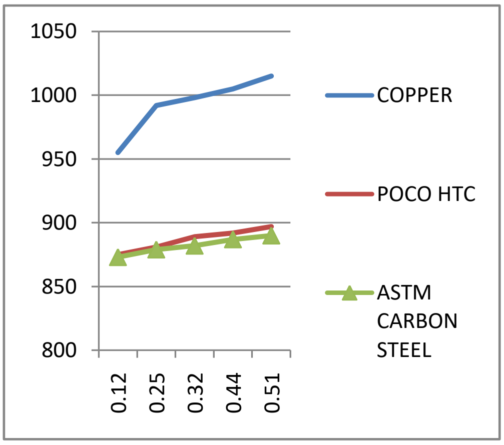
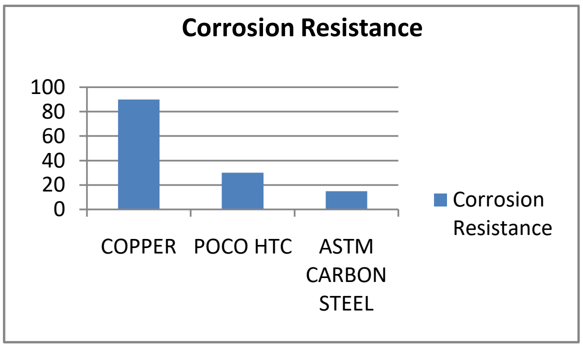


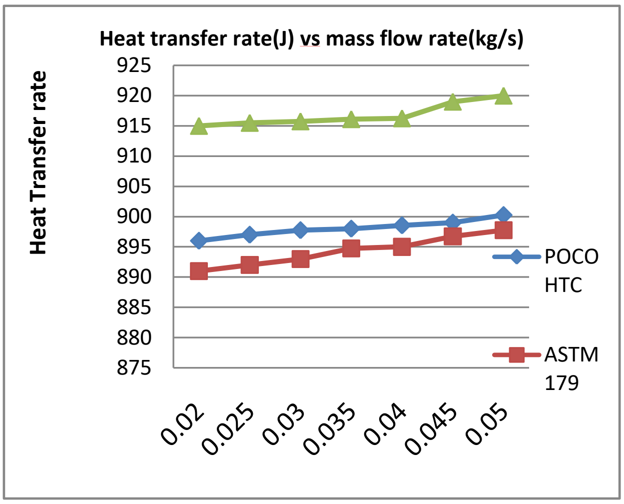
Fig.8 Velocity Profile of water inside the shell

Named selections were given namely hot inlet, cold outlet, Shell, Tube, Fluid domain (Inner of tube and inner of shell),One Interface.

The analysis was conducted with, Poco htc, Carbon steel and the results of these analysis were posted above in the figures.







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Graph 1-Heat transfer vs Mass flow rate

Graph 2- Corrosion Resistance and Graph 3- Hear transfer rate vs outlet temperature.

VI. Conclusion:

It is inferred from the ANSYS CFX that study of heat transfer characteristics of a helical coiled heat exchanger of the parallel-flow that when the CFX results when compared with the experimental results from were well within the error limits. It is proved that the POCO HTC conducts heat better than the conventional carbon steeland also other properties are quite appreciably similar so it can be replace the existing copper tubes in the industries. It posses high corrosion resistance than the copper and carbon steel. The simulation was carried out for water to water heat transfer characteristics and different inlet temperatures were studied. Characteristics of the heat transfer were also studied for the constant temperature with different mass flow rates and it stated that as the mass flow increases the heat transfer characteristics also increases. Due to high cost of poco htc matetial, we have decided to keep this as our future work.

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