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COMPARSION AND CFD ANALYSIS OF HEATEXCHANGER WITH NANOFLUID FOR INCREASING EFFECTIVENESS WITH AND WITH OUT BAFFLES

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Abstract

The idea behind development of nanofluids is to use them as thermo fluids in heat exchangers for enhancement of heat transfer coefficient and thus to minimize the size of heat transfer equipments.. The important parameters which influence the heat transfer characteristics of nanofluids are its properties which include thermal conductivity, viscosity, specific heat and density. The thermo physical properties of nanofluids also depend on operating temperature of nanofluids. Hence, the accurate measurement of temperature dependent properties of nanofluids is essential. The aim of this project is to summarize recent developments in research on nanofluids, and to carry out cfd analysis for nano fluids.

***Key Words*:**nanofluids; thermal conductivity; heat transfer.

1 Introduction

The idea behind development of nanofluids is to use them as thermo fluids in heat exchangers for enhancement of heat transfer coefficient and thus to minimize the size of heat transfer equipments.. The important parameters which influence the heat transfer characteristics of nanofluids are its properties which include thermal conductivity, viscosity, specific heat and density. The thermo physical properties of nanofluids also depend on operating temperature of nanofluids. Hence, the accurate measurement of temperature dependent properties of nanofluids is essential. The aim of this project is to summarize recent developments in research on nanofluids, and to carry out cfd analysis for nano fluids.

2 OBJECTIVES

The main objective of this work is based on the design and thermal analysis of double pipe heat exchanger. Nanofluids have high thermal conductivity when compared to the other conventional kind of fluids used for the heat transfer in the heat exchangers. This property of the nanofluid helps in increasing the heat

transfer rate and overall performance of the equipment. The reason for using copper oxide/ water nanofluids is that it has the higher thermal conductivity and heat carrying capacity. In this work the cold fluid flows through the inner tube and the hot fluid flows through the outer shell. Due to its density the nanoparticles tends to settledown on the bottom of the inner surface of tube along the length of the heat exchanger. To avoid this kind of problems a baffle design has been made on the inner side of the tube. The main function of this baffle structure is to create a turbulence effect within the tube so as to avoid settling of the nanoparticles.

3 SOFTWARE ANALYSIS DESIGN

With the help of computational fluid dynamics the steady and unsteady flow simulation was carried out for the designed heat exchanger and based on the simulation results the thermal analysis was carried out. The double pipe heat exchanger design was done using CREO and the analysis was done using ANSYS FLUENT 15.0 software. The comparision is done for the one using water as coolant and the one using copper oxide nanofluids as the coolant.

4 DESIGN CALCULATION:

In the design of the double pipe heat exchanger we have used the counter flow method to achieve the higher heat transfer rate. The materials are selected in the manner so as to support the fluids. Steel, copper and aluminium material can be used for the pipes. The outer shell is made up of steel and the inner tube is made of copper. The inner tube is designed with the baffles to avoid sediments of the nanoparticles in the long run. Baffle material is also selected as copper. This design of the double pipe heat exchanger would help in increasing the efficiency of the heat transfer. Detailed view of the design is summarized below.

INNER TUBE: Inner diameter -0.020m Outer diameter -0.027m

ANNULUS SHELL: Inner diameter - 0.06m Outer diameter -0.062m

Length - 2.37m

INLET TEMPERATURES: Hot Fluid, $T_{hi} = 55°$C Cold Fluid, $T_{ci} = 28°$C.

FORMULAS USED:

Hot fluid heat transfer rate, $Q_h = m_h x C p_h x (Th_i - Th_o)$

Cold fluid heat transfer rate, $Q_c = m_c x C p_c x (Tc_o - Tc_i)$

Logarithmic mean temperature difference,

LMTD $(\Delta T_{lm}) = (Th_i - Tc_o) - (Th_o - Tc_i)$

$\ln(Th_i - Tc_o)/(th_o - Tc_i)$

Mass flow rate(m)= Area(A)x Velocity of flow(v) Area= 3.14xd2

Where,

m_h, m_c- mass flow rate of hot fluid & cold fluid

Cp_h, Cp_c-Specific heat of hot fluid & cold fluid

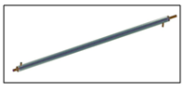
Th_i, Tc_i- Inlet temperatures of hot fluid & cold fluid

Th_o, Tc_o- Outlet temperatures of hot fluid & cold fluid

5 COMPUTATIONAL METHODOLOGY

3D- MODEL HEAT EXCHANGER:

The Heat Exchanger is modeled in Solidworks software and imported in a standard Meshing Tool. The overall length of the heat exchanger is 2360 mm. The inner and outer diameter of the shell is 62 mm and 50 mm. The inner and outer diameter of the tube is 25 mm and 19 mm. The baffle attached with the inner surface of the tube is having a pitch of 87 mm with a projecteddepthinside the tube of 5.5 mm.



1.1 Three dimensional CAD model of heat exchanger

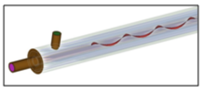


Fig 1.2 Twisted baffles inside the heat exchanger

Figure 1.2 shows the insertion of twisted baffle inside the tube in order to enhance the heat exchanger efficiency. The baffle used inside the tube increases the heat transfer area as well as convective heat transfer.

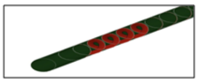


Fig 1.3 Twisted baffles inside the tube with helix

Figure 1.3 shows the detailed view of twisted baffle inside the heat exchanger. The twists are made with a pitch distance of 87 mm and the twisted baffle is made as helical shape where the maximum area is taken for convection without affecting central flow region. The twisted baffle is combined with inner tube as a single part

MESHING

The 3D model of heat exchanger is meshed with triangular elements on surfaces. The helical baffle is meshed first with minimum element size of 0.5mm and a maximum element size of 2mm.

Figure 1.4 shows the surface mesh at over the heat exchanger shell and fluid pipes. Required mesh refinements have been carried out near the area of interest.

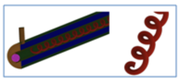


Fig 1.4 Surface mesh near the inlet of cold fluid and over the shell

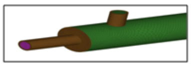


Fig 1.5 Discretized flow domain twisted baffle surface mesh

Figure1.5 shows the cut sectional view of the surface mesh and the triangular elements over the twisted baffle. It can be noted from the figure that the mesh near the baffle region is done with very refined elements in order to capture the wall effects.

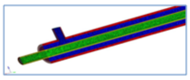


Fig 1.6 Sectional view of volume mesh

Figure 1.6 shows the cut sectional view of volume mesh inside the shell and tube heat exchanger with baffle. The overall flow domain has been depicted in the figure. The zoomed view of cut sectional volume,

6 BOUNDARY CONDITIONS AND SOLVER SETTINGS

The third process in CFD methodology is setting up the boundary conditions in the solver. The volume mesh generated in the Hyper mesh is exported as mesh file for Fluent solver using CFD input/output option. The flow domain is split into many components containing Boundary Mesh and Volume Mesh. The boundary regions are specified with appropriate boundary conditions in order to simulate the required flow and heat transfer analysis.

The boundary conditions and solver settings are consolidated in the table shown below.

TABLE.1

Sl.No.	Type	Description
1.	Flow	Steady & Incompressible
2.	Energy	Conjugate Heat Transfer (Conduction and Convection)
3.	Equations Solved	Continuity Momentum Turbulence Energy
4.	Turbulence	k- epsilon (2 Equation Model)
5.	Fluid	Water and Nano Fluids
6.	Solver	Pressure Based Navier Stokes (PBNS) along with SIMPLE solver

Boundary Conditions applied for present Investigation

TABLE 2

Sl. No	Boundary	Type	Value
1.	Cold Fluid Inlet	Mass Flow Inlet	0.217 kg/s T=301 K
2.	Hot Fluid Inlet	Mass Flow Inlet	0.134 kg/s T=328 K
3.	Baffle and Inner surface of the Tube	Standard Wall with Thermally coupled boundary condition	No Slip
4.	Outer Surface of the Shell, Inlet & Outlet Pipes	Standard Wall with Thermally Insulated Boundary Condition	No Slip and Heat Flux = 0 (W/m^2)
5.	Outlets	Pressure Outlet	Guage Pressure = 0 Pa

7 RESULTS COMPARISION OF VARIATIONS

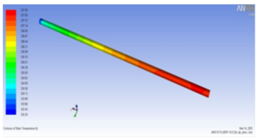


Fig2.1 Temperature variation along the outer surface of the shell

Above analysis showing the temperature variation of hot fluid which clearly explains about the amount of heat being absorbed from it.

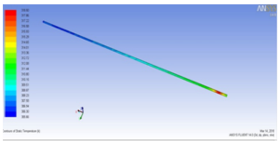


Fig2.2 Temperature variations along the inner surface of the tube

This graphical diagram shows the amount of heat absorbed by the cold fluid from the hot fluid and the temperature variation along the length of the tube.

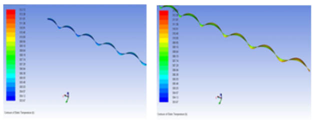


Fig2.3 Temperature variations along the baffle

The temperature variations on the baffles along the total length at the inlet and outlet side is shown in this graph.

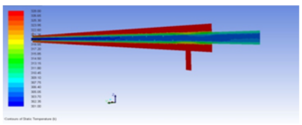


Fig2.4 Temperature variation at the exit end of cold fluid

The analysis explains about the flow of cold fluid through the inner tube and hot fluid through the outer tube

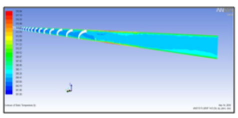


Fig2.5 Cold fluid Temperature Variations (at exit)

In the graphical diagram, Temperature variations of the cold fluid inside the inner pipe with baffles is shown from the exit.

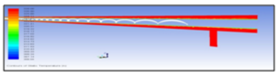


Fig2.6 Heat Transfer from shell Fluid Temperature Variations at the inlet side

Temperature variations along the inlet side of the shell fluid while entering into the heat exchanger.

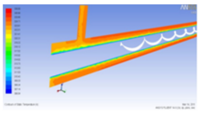


Fig2.7 Heat Transfer from shell Fluid Temperature Variations at the outlet side

Temperature variations along the outlet of the shell fluid while leaving the heat transfer equipment.

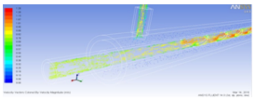


Fig2.8 Velocity Vectors showing the flow directions (counter flow)

In this graphical diagram, the velocityvectors showing the increase in the velocity of the flow of cold fluid at the baffle region, is shown.

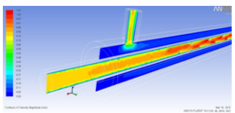


Fig2.9 Velocity contour at cold fluid inlet side (hot fluid outlet side)

The contour explains about the velocity variations at the exit of hot fluid and the inlet of cold fluid.

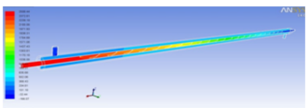


Fig2.10 Pressure Variations along the heat exchanger

It shows the Pressure variations of the inlet fluid used for cooling along the total length of the pipe.

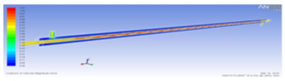


Fig2.11 Velocity Variations along the heat exchanger

It shows the variations of the velocity along the pipe length regarding the inlet fluid.

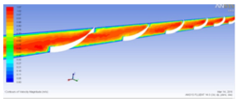


Fig2.12 Effect of baffle Velocity Contour

The detailed view of the variations in velocity (velocity contours) due to the turbulence effect of Baffles is shown in this graphical diagram.

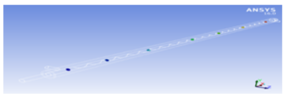


Fig 2.13 Planes for Temperature Measurement of Cold Fluid

It shows the planes that we have bisected for the accurate measurement of the heat transfer rate along the total length of the pipe.

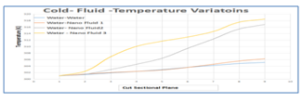


Fig 2.14 Cold fluid temperature variations

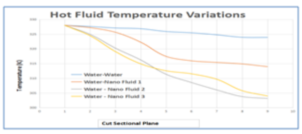


Fig2.15Hot fluid temperature variations

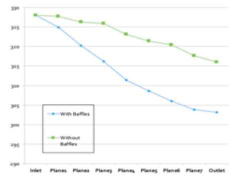


Fig2.16Comparison of Heat Exchanger with and without Baffle

8 CONCLUSION

The analysis for the double pipe heat exchanger has been done and the results are summarized. The above chart shows the variation between water and copper oxide nanofluids and is evident that as the concentrations of the nanofluids increases the thermal conductivity also increases simultaneously.In this research, we have considered the properties of CuO/Water based nanofluid in conjunction with the thermal conductivity enhancement,to improve the performance of the heat exchanger.By the analysis using C.F.D,weanalyse the improvement of heat transfer due to the use of CuONanofluid&the result shows that substantial enhancement in thermal conductivity is attainable.

It shows the temperature being absorbed by the cold fluid with and without the design of baffles.

Area-Weighted Average Static Temperature	(k)
inlet-cold-fluid	301
inlet-hot-fluid	328
outlet-cold-fluid	316.77621
outlet-hot-fluid	303.15778
Net	311.66162

Area-Weighted Average Static Temperature	(k)
inlet-cold-fluid	300.99999
inlet-hot-fluid	328
outlet-cold-fluid	312.27014
outlet-hot-fluid	312.13389
Net	312.20294

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