CFD ANALYSIS ON DOUBLE PIPE HEAT EXCHANGER USING Fe₃O₄ NANO FLUID

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Abstract—In this project studying of double pipe heat exchange type in which the inner and annular tubes are made of GI and SS304 Materials respectively. The hot Fe3O4 nano fluid flows through inner tube at various concentrations Levels of the nano fluid are at 0.00%, 0.06% ratios. It having various flow rates of 8, 12, Liter per minute, and at a Temperatures of 20 °C & 60 °C and below atmosphere Pressures The Cold water is base fluid flows through an annulus tube. It having the Constant flow rate of 8 liters per minute and having temperature of 29°C with atmospheric pressure. The Nano fluid flows with a turbulence flow having constant Reynolds number 30,000, the solution be obtained. The model designed in CERO Software and analysis done by using the Ansys 15.0 fluid flow (CFX). Fe₃O₄ having an active heat transfer techniques (high thermal conductivity) compare to base fluid, and used in various heat Transfer applications. By giving the input parameters and boundary conditions the output pressure, velocities and temperatures are obtained, with these values friction factor, nussult number, and LMTD are to be obtained by calculations. As we know that Fe₃O₄ nano fluid have higher thermal conductivity than water. so, if increases the concentration ratio and flow rates of nano fluid to base fluid, the heat transfer rate will be increases and overall effectiveness be improved.

Keywords— Double pipe heat exchanger, Fe₃O₄ nano fluid, base fluid, Over all heat transfer coefficient, Effectiveness, nussult number, Friction factor.

I. INTRODUCTION

Heat exchanger is a device which is used to transfer heat between two fluids which may be in direct contact or may flow separately in two tubes or channels. We find numerous applications of heat exchangers in day today life. For example condensers and evaporators used in refrigerators and air conditioners. In thermal power plant heat exchangers are used in boilers, condensers, air coolers and chilling towers etc. Similarly the heat exchangers used in automobile industries are in the form of radiators and oil coolers in engines. Heat exchangers are also used in large scale in chemical and process industries for transferring the heat between two fluids which are at a single or two states.

II. DOUBLE PIPE HEAT EXCHANGER

The double-pipe heat exchanger is one of the simplest heat exchangers utilized in industry. This exchanger's name comes from how one fluid flows inside a pipe and the other fluid flows between that pipe and another pipe that surrounds the first, essentially a "tube within a tube." One way to improve heat transfer is to add fins on the outside of the inner tube. This is used to improve the heat transfer of a fluid with a low heat transfer coefficient such as a viscous liquid or a gas, which is passed on the outer side.

There are two flow configurations that can be used using a double pipe heat exchanger. These are co-current flow and counter current flow.

Co-Current Flow

In co-current flow, also known as parallel flow, the two fluids that are exchanging heat are flowing in the same direction. Co-current flow is generally employed when there is less heat transfer required, as this method has a lower heat transfer coefficient. However, this flow is used much less
than counter-current flow in industry, as this method is not as efficient given the capital costs used in purchasing the equipment.

Counter-Current Flow

The counter current flow mechanism is used for condensing, gas cooling, and liquid-liquid applications. Here, the fluids flow against each other in opposite directions. In the industry, counter current movement is used more often, as there is a higher rate of heat transfer. This method maximizes the temperature differences between the tube side and shell side fluids, resulting in more heat transfer and less surface area given a constant duty.

III. INTRODUCTION TO NANOFUIDS

Nanofluid is a mix of a base fluid and nanometer-sized particles called nanoparticles. The base fluid is commonly water, oil, and ethylene glycol, while there are different types of nanoparticles, including metals, carbides, oxides, and carbon nanotubes. There are several parameters that affect the performance of nanofluid, including the size and shape of the nanoparticle, concentration, base fluid, and if the nanoparticle type is metal or non-metal. For example, nanoparticle size has a significant impact on thermal conductivity; the small size of the nanoparticle leads to an increase in surface area, and therefore researchers have employed different types of nanofluids in different geometries to reach augmentation of heat transfer. Nanofluid can be prepared by two methods. In summary, the first method creates nanoparticles with chemical or physical processes (e.g., evaporation and inert-gas condensation processing), and then disperses them into a host fluid. The second method includes production and dispersal of the nanoparticles directly into a host fluid.

Mode Description:

- Cabling Accessed from within Assembly mode, it is used to route cables between connectors and other electrical terminators (with Creo/CABLING).
- Cast Design die assemblies and prepare castings for manufacturing (with Creo/CASTING).
- Composite Create and document parts made of composite materials (with Creo/COMPOSITE).
Legacy Import 3D data and 2D drawings into Creo Parametric from other CAD products and update these using optimized tools to work with wireframe, surface, and 2D data (with Creo /LEGACY).

MODELING PROCEDURE FOR DOUBLE PIPE HEAT EXCHANGER
PART NAME: Nano Fluid Tube

MODELING PROCEDURE:
Software used: Creo Parametric 2.0
Steps: Assembly of Double Pipe Heat Exchanger
IV. COMPUTATIONAL FLUID DYNAMICS

Computational Fluid Dynamics (CFD) is the science of predicting fluid flow, heat transfer, mass transfer, chemical reaction (e.g., combustion), and related phenomena by solving the mathematical equations that govern these processes using a numerical algorithm on a computer. The technique is very powerful and spans a wide range of industrial and non-industrial application areas.

Specifications & Dimensions

The analysis study is done in a double pipe heat exchanger having the specifications as listed below.

- Length of the pipe, \( L = 2.2 \, \text{m} \)
- Inside diameter of the inner pipe, \( D_i = 0.019 \, \text{m} \)
- Outer diameter of the inner pipe, \( D_o = 0.025 \, \text{m} \)
- Inside diameter of the annulus pipe, \( D_{ai} = 0.05 \, \text{m} \)
- Outer diameter of the inner pipe, \( D_{ao} = 0.056 \, \text{m} \)
- Radius of the U-Bent = 0.16 m
- Material of Inner pipe is Stainless Steel SS304.
- Material of the Annulus pipe is Galvanized Iron

It is necessary for any numerical tool to obey some set of governing equations of the fluid flow in order to confirm that the results obtained analytically are in accordance with existing theoretical relationships between different fluid flow parameters. When these conditions are satisfied, it is said that the simulation results obtained are correct.

Validation for 0.1 concentration:

<table>
<thead>
<tr>
<th>% of Nano Concentration</th>
<th>Thermal Conductivity (w/mK)</th>
<th>Viscosity (Centipoise)</th>
<th>Specific heat (J/gK)</th>
<th>Density (kg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
<td>0.653</td>
<td>0.3</td>
<td>4183</td>
<td>983.3</td>
</tr>
<tr>
<td>0.03</td>
<td>0.666</td>
<td>0.304</td>
<td>4182.1</td>
<td>984.5</td>
</tr>
<tr>
<td>0.06</td>
<td>0.682</td>
<td>0.308</td>
<td>4182.2</td>
<td>985.7</td>
</tr>
</tbody>
</table>

The amount of heat transfer rate or heat potential is calculated by using following energy balance equations,

For inner inner tube:

\[
Q_i = m_i \times C_{ph}(T_{hi} - T_{ho})
\]

For outer tube:

\[
Q_o = m_o \times C_{pc}(T_{co} - T_{ct})
\]

Average heat transfer:

\[
Q_{avg} = \frac{Q_i + Q_o}{2}
\]

Flow arrangement selected is counter flow type and accordingly LMTD for this stage is calculated.

\[
\Delta T_{lm} = \ln\left(\frac{T_{h1} - T_{c2}}{T_{h2} - T_{c1}}\right)
\]

The overall heat transfer coefficient is calculated as, For inner inner tube:

\[
U_i = \frac{Q_{avg}}{A_i(\Delta T_{lm})}
\]

For annulus tube:

\[
U_o = \frac{Q_{avg}}{A_o(\Delta T_{lm})}
\]

Effectiveness – NTU method

\[
\text{Effectiveness} = 1 - \exp(-NTU(1 - Z))
\]

\[
\text{Effectiveness} = \frac{1 - Z}{\exp(-NTU(1 - Z))}
\]

where, \( Z = \frac{Q}{C_{min}} \), and \( C_{min} \) is the smaller of \( C_i \) and \( C_o \).
Temperature counters for 8LPM.

Figure: 9 Contours of Temperature for 0.00% concentration of Nano fluid with 8LPM.

Figure: 10 Contours of Temperature for 0.06% concentration of Nano fluid with 8LPM

Temperature counters for 12LPM.

Figure: 11 Contours of Temperature for 0.00% concentration of Nano fluid with 12 LPM.

Figure: 12 Contours of Temperature for 0.06% concentration of Nano fluid with 12 LPM

Table: 2 The amount of heat transfer rate or heat potential is calculated by using following energy balance equations:

<table>
<thead>
<tr>
<th>Concentration (%)</th>
<th>Nusselt Number (Nu)</th>
<th>Friction Fraction</th>
<th>Heat Transfer Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00%</td>
<td>115.32</td>
<td>0.02444</td>
<td>3967.35</td>
</tr>
<tr>
<td>0.03%</td>
<td>121.82</td>
<td>0.02541</td>
<td>4270.11</td>
</tr>
<tr>
<td>0.06%</td>
<td>128.50</td>
<td>0.02639</td>
<td>4270.46</td>
</tr>
</tbody>
</table>

Table: 3 Represents the calculated values of design analysis at 0.00% concentration and 8 lpm

0.00% concentration and 8 lpm (Litres per minutes)

<table>
<thead>
<tr>
<th>Temp T_Cu= K</th>
<th>Temp T_bo= K</th>
<th>Rate of Heat Flow Q= J/S</th>
<th>LMTD</th>
<th>N.T.U</th>
<th>Effectiveness</th>
</tr>
</thead>
<tbody>
<tr>
<td>309.9</td>
<td>323.91</td>
<td>5752.87</td>
<td>23.099</td>
<td>0.43</td>
<td>0.301</td>
</tr>
</tbody>
</table>
0.00% concentration and 12 lpm

<table>
<thead>
<tr>
<th>TEMP T_{Co}= K</th>
<th>TEMP T_{ho}= K</th>
<th>RATE OF HEAT FLOW Q= J/S</th>
<th>LMTD</th>
<th>N.T.U</th>
<th>EFFECTIVENESS</th>
</tr>
</thead>
<tbody>
<tr>
<td>310.89</td>
<td>325.74</td>
<td>6073.94</td>
<td>23.879</td>
<td>0.45</td>
<td>0.32</td>
</tr>
</tbody>
</table>

0.06% concentration and 8 lpm

<table>
<thead>
<tr>
<th>TEMP T_{Co}= K</th>
<th>TEMP T_{ho}= K</th>
<th>RATE OF HEAT FLOW Q= J/S</th>
<th>LMTD</th>
<th>N.T.U</th>
<th>EFFECTIVENESS</th>
</tr>
</thead>
<tbody>
<tr>
<td>312.54</td>
<td>320.4576</td>
<td>6852.32</td>
<td>20.513</td>
<td>0.63</td>
<td>0.369</td>
</tr>
</tbody>
</table>

0.06% concentration and 12 lpm

<table>
<thead>
<tr>
<th>TEMP T_{Co}= K</th>
<th>TEMP T_{ho}= K</th>
<th>RATE OF HEAT FLOW Q= J/S</th>
<th>LMTD</th>
<th>N.T.U</th>
<th>EFFECTIVENESS</th>
</tr>
</thead>
<tbody>
<tr>
<td>313.86</td>
<td>323.789</td>
<td>7730.415</td>
<td>21.379</td>
<td>0.648</td>
<td>0.42</td>
</tr>
</tbody>
</table>

V. CONCLUSION

The present project work mainly focused on the estimation of performance of double pipe heat exchanger with return U-bend. The heat exchanger performance is analyzed in terms of effectiveness and NTU for base fluid and nanofluids.

The friction factor of nano fluid increases with increasing particle concentrations and Reynolds numbers. Maximum of 0.992-times was observed 0.06% particle loading at a Reynolds number of 30,000 compared to water.

The nusselt number also increased with increasing the nano fluid concentration at 0.06% observed 0.1142 times increases than compared to water at Reynolds number 30,000 in counter flow direction.

The use of Fe_{3}O_{4} nano particles in the base fluid gives higher heat transfer coefficient, effectiveness and NTU. The NTU is enhanced by 0.5531 -times and the effectiveness by 0.3871-times for 0.06% nanofluids at Reynolds number of 30,000.

REFERENCES


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