

Heat Transfer Augmentation of Shell and Tube Heat Exchanger by Providing FIN Using CFD

Prof. Arvind Singh¹, Bhoopendra Patel²

¹Corporate Institute of Science and Technology, Professor, RGPV Bhopal, MP, INDIA

²Corporate Institute of Science and Technology, Research Scholar, RGPV Bhopal, MP, INDIA

Abstract- The conversion, utilization, and recovery of energy in industrial, commercial, and domestic application usually involve a heat transfer process. Improved heat exchange, over and above that in the usual or standard practice, can significantly improve the thermal efficiency in such applications as well as the economics of their design and operation.

The need to increase the thermal performance of heat transfer equipment (for instance, heat exchangers), thereby effecting energy, material, and cost savings as well as a consequential mitigation of environmental degradation has led to the development and use of many heat transfer enhancement techniques. These methods are referred to as augmentation or intensification techniques. A multi pass shell and tube heat exchanger with 3 tubes with fins modelling is done using ANSYS 14.5 and meshing has done using ICEM CFD software, simulations has done by using CFD-FLUENT software. Using Fluent, computational fluid dynamics software the pressure drop, Temperature variations and heat transfer are analysed under turbulent flow condition. Nanofluid such as Al₂O₃-H₂O is used as cooling medium. The CFD simulated results achieved from the use of the creating fin in tube side in shell and tube type heat exchanger are compared with without fin. Based on the results, providing fins on tube causes the increment of surface area and Overall heat transfer coefficient which results in the enhancement of heat transfer rate of heat exchanger.

Index Terms- Shell and tube heat exchanger, CFD, Overall heat transfer coefficient, Heat transfer.

I. INTRODUCTION

Heat transfer is a science that studies the energy transfer between two bodies due to temperature difference. When material's temperature increases, the thermal agitation of its constituent molecules will increase. Then the areas which contain greater molecular kinetic energy will pass this energy to areas with less kinetic energy.

So when an object or fluid is at different temperature than its surroundings, the heat transfer will occur in such a way that the body and the surroundings reach thermal equilibrium.

A heat exchanger is a device which used to transfer thermal energy (enthalpy) between two or more fluids, between a solid surface and a fluid, or between solid particulates and a fluid, at different temperatures and in thermal contact.

Generally, there are three types of heat transfer which are conduction, convection and radiation.

- Conduction is the transfer of heat within an object or between two objects in contact.
- Convection heat transfer occurs when a fluid (liquid or gas) comes in contact with a material of a different temperature.
 1. For natural convection, it occurs when the flow of a fluid is primarily due to density differences within the fluid due to cooling or heating of that fluid.
 2. Meanwhile, forced convection occurs when the flow of fluid is primarily due to pressure differences.
- Radiation is the transfer of heat from one object to another by means of electro-magnetic waves. Radiation does not require objects to be in contact or fluid flow between those objects, it occurs in the void of space (that's how the sun warms us). Transfer of thermal energy can also occur with any combination of the three. In our study which relates to plate heat exchanger, it consists of heat transfer by conduction and convection.

Enhancement of heat transfer surfaces has developed over the years, and is the main focus in the heat exchanger industry. Enhanced surfaces yield higher heat transfer coefficient when compared to unenhanced surfaces.

Surface can be enhanced basically by two types:

- Active enhancement which requires deployment of external power which is obviously higher in operational and capital cost thus commercially unviable.
- Passive enhancement which adding extended surfaces (e.g. fins), or employing interrupted surfaces (e.g. corrugations).



Figure 1 Passive Techniques for Heat Transfer Augmentation

Shell and tube Heat Exchangers

- Shell and tube Heat Exchangers are one of the most popular types of exchanger due to the flexibility the designer has to allow for a wide range of pressure and temperature.

- A Shell and tube heat exchanger is a class of heat exchanger designs. It is the most common type of heat exchanger in oil refineries and other large chemical process, and is suited for higher
- There are two main categories of Shell and Tube Heat Exchanger, one is those which are used in petrochemical industries and the other is those which are used in power industries such as feed water heaters and power plant condensers.

Nano fluids

- Nano fluid, a suspension of nanoparticles in a continuous and saturated liquid, has been found capable to get considerably higher thermal conductivities than their respective base fluids resulting in better convective heat transfer coefficients.
- Fluids have higher specific heat compare to metals, and metals have higher thermal conductivity compare to solids. So when we added a small amount of nanoparticle to base fluid it will increase the thermal conductivity of base fluid.

II. LITERATURE REVIEW

Year / Authors	Journals	Topic	Outcomes
K Somasekhar (2017)	Science Direct	A CFD investigation of heat transfer enhancement in shell and tube heat exchanger using Al ₂ O ₃ -H ₂ O Nanofluids.	<ul style="list-style-type: none"> • For effecting cooling of shell and tube heat exchanger Al₂O₃-H₂O Nanofluids is the better cooling medium than the Distilled water cooling medium. • By using of different % Al₂O₃-H₂O Nanofluids as a cooling medium heat transfer increases on tube side than the Distilled water cooling medium.
V.Velmurugan (2017)	IJMET	Heat Transfer enhancement in Shell and tube heat exchanger using inserts	<ul style="list-style-type: none"> • The twisted tape inserts performed better than pebbles and glass sphere packing. • The effect of usage of twisted tape inserts, glass sphere packing and pebbles in enhancing the overall heat transfer rate has been studied. 4
Seid Mahdi Jafari (2017)	JAFARI	Designing and application of a shell and tube heat exchanger for Nanofluids thermal processing of liquid food products	<ul style="list-style-type: none"> • Application of Nanofluids through shell and tube heat exchangers might be carried out successfully with substantial reduction in processing time and energy,
Davood Panahi (2016)	Science Direct	Heat transfer enhancement of shell-and-coiled tube heat exchanger utilizing helical wire turbulators.	<ul style="list-style-type: none"> • Generally, this type of turbulators can be used for helical tubes and the result is higher heat transfer rate and obviously extra pressure drop.

III.METHODOLOGY

This section describes the CFD tools required for carrying out a simulation and the process one follows

in order to solve a problem using CFD. The hardware required and the three main elements of processing CFD simulations: the pre-processor, processor, and post-processor are described.

To run a simulation, three main elements are needed:

1. Pre-processor- A pre-processor is used to define the geometry for the computational domain of interest and generate the mesh of control volumes (for calculations). General, the finer the mesh in the areas of large changes, the more accurate the solution. Fineness of the grid also determines the computer hardware and calculation time needed. The open-source pre-processor used for this project is called Salomé.
2. Solver- The solver makes the calculations using a numerical solution technique, which can use finite difference, finite element, or spectral methods. Most CFD codes use finite volumes, which is a special finite difference method.
3. Post-Processor- The post-processor provides for visualization of the results, and includes the capability to display the geometry/mesh, create vector, contour, and 2D and 3D surface plots. Particles can be tracked throughout a simulation, and the model can be manipulated (i.e. changed by scaling, rotating, etc.), and all in full color animated graphics. Para View is the open-source post-processor used for this project.

Table 1 Specifications of Shell and Tube

SPECIFICATIONS OF SHELL		SPECIFICATIONS OF THE TUBES	
Material	Stainless steel	Material	Stainless steel
inner diameter	208 mm	Inner diameter	14 mm
Outer diameter	218 mm	Outer diameter	16 mm
Length	500 mm	Length	1000 mm
		No. of tube	3

The model of shell and tube type heat exchanger are modeled in design modular.

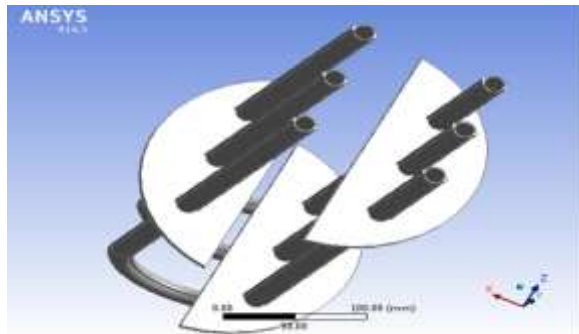


Fig. 2 Geometry model of shell and tube Heat Exchanger

MESHING

- The designed model of Heat Exchanger is meshed in ICEM Meshing.

- The meshing type have done is quardcore and tetrahedral.
- Numbers of nodes -473198.
- Numbers of elements that are used are 2097041.

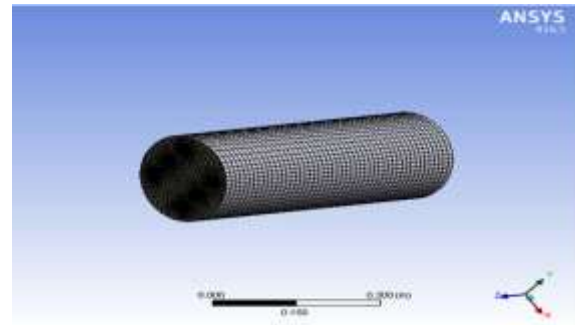


Fig. 3 Geometry model of shell and tube Heat Exchanger

NAME SELECTION

A different part of the heat exchanger and fluid flowing inside the heat exchanger is selected and the names are given to them so that boundary conditions can be applied on different boundary.

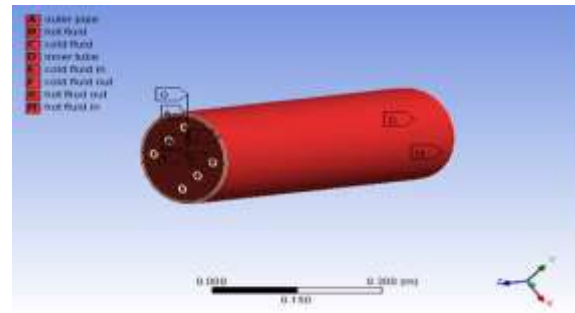


Fig. 4 Name Selection of shell and tube Heat Exchanger

MODEL SELECTION

In model selection only three parameters are selected. Remaining parameter are remained as Default. The three parameters are:-

- Multiphase – Eulerian,
- Energy – On
- Viscous – Standard k-e standard wall Fn, mixture.

MATERIAL PROPERTIES

Table 2 Tube Side cold fluid (Water-AI2O3 nanofluid) Properties Using Pak and cho Relations:

Volume Fraction	Thermal Conductivity (W/m-k)	Density (Kg/m ³)	Dynamic Viscosity (Ns/m ²)	Specific Heat (J/Kg-k)
2 %	0.664	1049.73	0.000829	3885.36

BOUNDARY CONDITIONS

Here in the analysis the boundary condition is same as considered by scholar's K.Somashekhar et.al. (2017) during the previous work. Some of the conditions are shown The boundary conditions that are applied on the model are as below:

Table 3 Bounadry conditions

Specification	Fluid	Inlet Temp	Mass Flow rate
Cold fluid	Water-Al ₂ O ₃	303 K	0.09 kg/s
Hot fluid	Water	363 K	0.61 kg/s

IV. RESULTS AND DISCUSSIONS

Heat transfer through heat exchanger depends on the mass flow rate and temperature of fluid flowing inside the heat exchanger. In current flow rate of 0.09 Kg/s of cold fluid and 0.61 Kg/s of hot fluid have been considered. Fins are provided on the tube is kept triangular to maximize the area of heat transfer. To analyze the cumulative effect of nanofluid and fins on the heat exchanger rate, the CFD model of heat exchanger has been developed. The main purpose of the present work is obtaining the maximum value of overall heat transfer rate. That can be calculated by using formula written below:

$$Q = U A \theta_m \times \text{No of tubes}$$

Where,

Q = Heat transfer in watts

A = Surface Area in square meter

θ_m = LMTD in kelvin

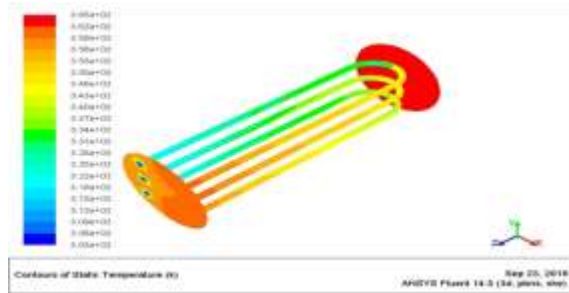


Fig.5 Contours of Static Temperature



Fig.6 Contours of Static temperature on U- tube

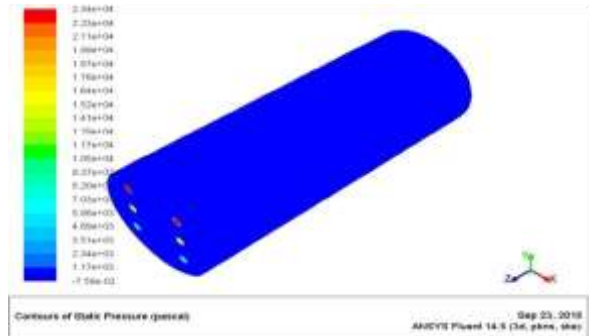


Figure 7 Contours of Static Pressure

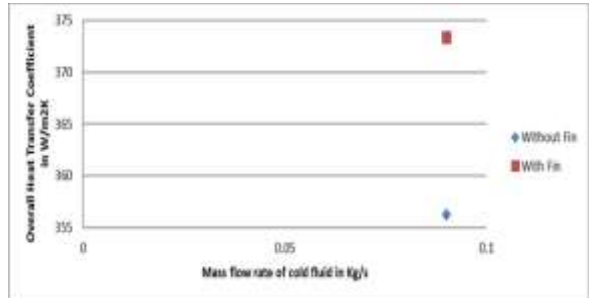


Figure 8: mass flow rate of cold fluid V/S overall heat transfer coefficient.

V. CONCLUSIONS

In this analysis, the cumulative effect on fins and nanofluid in shell and tube heat exchanger has been investigated using CFD analysis. Based on the results obtained by the CFD and mathematical calculations it is found that:

- From the CFD analysis it has been observed that at mass flow rate of cold fluid i.e. 0.09Kg/s and hot fluid i.e. 0.68 Kg/s, the overall heat transfer coefficient increased by 4.77% by using fins and nanofluid.
- From the CFD analysis it has been observed that at mass flow rate of cold fluid i.e. 0.09Kg/s and hot fluid i.e. 0.68 Kg/s, the outlet temperature of cold fluid increased by 14 Kelvin by using fins and nanofluid.
- Figures shows that overall heat transfer comparison for overall heat transfer coefficient, which confirms that net heat transfer is maximum when fins and nanofluid is used together.

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