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Analysis of Heat Transfer Enhancement in a Shell and Tube Heat Exchanger Providing Fins on the Tube Using CFD

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***Abstract*- Heat transfer enhancement techniques are very important to save energy and using of optimal energy sources. It is the process of improving the performance of a heat transfer system. In the past decades, heat transfer enhancement technology has been developed and widely applied to heat exchanger applications such as automobiles, chemical industry and process industry. Much effort in the past decades has been aimed to provide economical methods for improving the performance of heat exchanger. Active, passive and compound techniques are used for the enhancement of heat transfer. Nowadays, there have been a large number of attempts to reduce size and cost of heat exchangers, in reducing size and cost of a heat exchanger are basically the heat transfer coefficient and pressure drop. The performance of heat exchangers is essential for reducing size of the system and to make the system more compact and the performance depends on the rate of heat transfer. The high rate of heat transfer is desirable because, it reduces the fuel consumption.**

In present work attempts are made to enhance the heat transfer rate in shell and tube heat exchangers by providing oval shaped fins on the tube. For this a shell and tube heat exchanger were used in which 3 tubes with fins are used. Modelling is done using ANSYS. Nanofluid such as Al2O3-H2O is used. 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 overall heat transfer coefficient which results in the enhancement of heat transfer rate of heat exchanger.

***Index Terms*- Fins, Heat exchanger, Shell and tube, Nano fluids, Heat transfer, ANSYS 14.5, Overall heat transfer coefficient.**

I. INTRODUCTION

Heat transfer devices have been used for the conversion and recovery of heat in many industrial and domestic applications. Some examples are boiling of liquid and condensation of steam in power plants, thermal processes involved in pharmaceutical and chemical industries, sensible heating and cooling of milk in dairy industries, heating of fluid in concentrated solar collector and cooling of electrical machines and electronic devices among others. Enhancing the performance of a heat transfer device is therefore of great interest since it can result in energy, material and cost saving.

A heat exchanger is a device that exchanges the heat between two or more flowing fluids. Heat exchangers may be classified on the basis of contacting techniques, construction, flow arrangement or surface compactness. A shell and tube heat exchanger is most widely used in process plants.

Enhancement of heat transfer is of vital importance in many industrial applications. Heat transfer enhancement techniques have been extensively developed to improve the thermal performance of heat exchanger systems with a view to reducing the size and cost of the systems. Swirl flow is the one of the enhancement techniques widely applied to heating or cooling systems in many engineering applications.

Heat transfer enhancement techniques are classified as the - Passive Methods, Active Methods, and Compound Methods.

A. Active Technique

The active method involves external power input for the enhancement in heat transfer; for examples it includes mechanical aids and the use of a magnetic field to disturb the light seeded particles in a flowing stream, etc.

B. Passive Technique

The Passive heat transfer methods does not need any external power input. In the convective heat transfer one of the ways to enhance heat transfer rate is to increase the effective surface area and residence time of the heat transfer fluids. By Using this technique causes the swirl in the bulk of the fluids and disturbs the actual boundary layers which increase effective surface area, residence time and simultaneously heat transfer coefficient increases in an existing system. Methods generally used are, extended surface, displaced enhancements devices, rough surfaces surface tension devices, Inserts etc.

C. Compound method

A compound method is a hybrid method in which both active and passive methods are used in combination. The compound method involves the complex designs and hence it has limited applications.

II. LITERATURE REVIEW

In the last decades, significant effort has been made to develop heat transfer enhancement techniques in order to improve the overall performance of heat exchangers. The interest in these techniques is closely tied to energy prices and, with the present increase in energy cost, it is expected that the heat transfer enhancement field will go through a new growth phase. Although there is need to develop novel technologies, experimental work on the older ones is still necessary. The knowledge of its performance shows a large degree of uncertainty which makes their industrial implementation difficult. The efficiency of heat transfer equipment is essential in energy conservation. Also, a more efficient heat exchanger can reduce the size of the heat exchanger, thus reducing the costs associated with both material and manufacturing of the heat exchanger. Improved heat transfer can make heat exchangers smaller and more energy efficient .In this work Shell and tube Heat exchanger is used to estimate the heat transfer rate. There is a lot of research going on in this area, a few of them are stated below,

Argonne National Laboratory of USA by Choi (1995) which showed that thermal performance of conventional liquid could be remarkably improved using nanoparticles. Nano fluids can be used for a wide variety of engineering applications like transportation, electronics, medical, food, defense, nuclear, space, and manufacturing of many types.

H.Niazmand et al.(2010): Studied convective heat transfer of carbon Nano tube-water Nano fluid using isothermally heated 900 curved pipe, and set an inlet temperature of fluid and wall is 293K and 363.15K. They analyzed the relation between peclet numbers and enhance heat transfer rate, inside the curve flow accelerate along the outer wall region due to centrifugal force, so maximum velocity shifted towards the outer wall of pipe and forming secondary flow. Secondary flow is formed due to curvature effect, so enhanced heat transfer by the secondary flow formation. Curvature effect is more promoted at Peclet number. Minimum intensity of flow occur at middle of the curve, due to high Reynolds number amplified the centrifugal force. Monolayer is formed at solid particle interface, so thermal conductivity of monolayer is much greater compared with bulk fluid.

Ghozatloo et al.(2014) investigated convective heat transfer of grapheme nanofluids a shell and tube heat exchanger under laminar regimes. They observed that adding 0.075 wt.% graphene to the base fluid increased the heat transfer coefficient compared to pure water.

Manna et al.(2014): Investigated the thermal conductivity enhancement of SiC-water Nano fluid using transient hot wire device. Thermal conductivity of Nano fluid is increased with increasing the concentration of nanoparticle, 26% of maximum thermal conductivity is obtained when using 0.8% concentration of Nano fluid. Mechanically milled nanoparticles having high heat transfer enhancement. Nanoparticle volume and shape is important factor to enhance the thermal conductivity of Nano fluid, at 27nm sized nanoparticle enhanced 12% of thermal conductivity Nano fluid.

Shriram S. Sonawane et al.(2015): Investigated the heat transfer characteristics of Al2O3 – water nanofluids as a coolant used in concentric tube heat exchanger .The heat exchanger is fabricated from copper concentric inner tube with a length of 1000 mm. The nanofluids are the mixture of water as base fluid and Al2O3 particles in Nano range. The results obtained from the nanofluids cooling in concentric tube heat exchanger are compared with those from base fluids. The effects of inlet flow rate of hot fluids, Reynolds's number and composition of nanofluids on concentric tube heat exchanger are considered. It is observed that average heat transfer rates for nanofluids as cooling media are higher than those for the water as cooling media, and this increases with concentration of nanofluids' composition. The results of this study have technological importance for the efficient design of concentric tube heat exchanger to enhance cooling performance at low heat flux cooling systems

K.Somasekhar et al.(2016): In this study a multi pass shell and tube heat exchanger with 3 tubes modeling is done using CATIA 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, heat transfer characteristics of Al2O3-water nanofluid, and Distilled water are analyzed under turbulent flow condition. Nanofluid such as Al2O3-H2O is used as cooling medium instead of Distilled water. Finally the CFD simulated results are compared with experimental results. The effects of Peclet number, volume concentration of suspended nanoparticles, and particle type on the heat transfer characteristics were investigated. Based on the results, adding of nanoparticles to the base fluid (Distilled water) causes the significant enhancement of heat transfer characteristics.

The above-mentioned researchers had studied various aspects of nanofluids and various methods to implemented nanofluids to enhance heat transfer rate in various heat exchangers. In some research papers, the study is focused on an increase in the effectiveness of nanofluid, (Manna et al.(2014)). However, in some paper nanofluid is utilized in tube side of shell and tube heat exchanger and their effect on , effectiveness, Nusselt number and overall heat transfer coefficient is evaluated (Khorasani et al. (2017)). There was no work found which considered cumulative effect of nanofluids and fins on shell and tube heat exchanger in terms of overall heat transfer coefficient and net heat transferred.

III.METHODOLOGY

After studying the basic steps in CFD to be followed to analysis the flow inside a duct. Now we can start the analysis of the solar air heater with actual data .following three steps are required to run the simulation-

1- Geometry modelling, 2- Meshing, 3- Name Selection, 4- Type of solver, 5- Physical model, 6- Material property, 7- Boundary condition.

Modeling of Shell and Tube Heat Exchanger

Model Description

The shell and tube heat exchanger consists of the following components:

- Shell
- U Tubes

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

Table 2 Tube Side cold fluid (Water-Al_2O_3 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

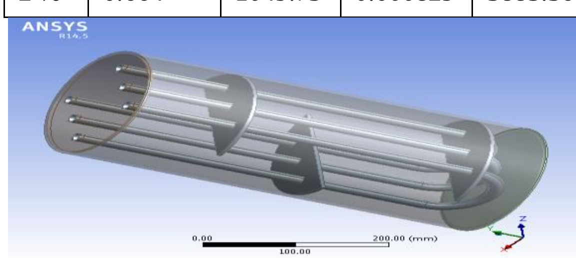


Figure 1: Geometry view of shell and tube with oval shaped fins

Meshing

The designed model of Heat Exchanger is meshed in ICEM Meshing. The meshing type have done is quardcore and tetrahedral. The numbers of nodes that are used are 473198 and the numbers of elements that are used are 2097041 in this design model. The mesh model of shell and tube heat exchanger is shown below:

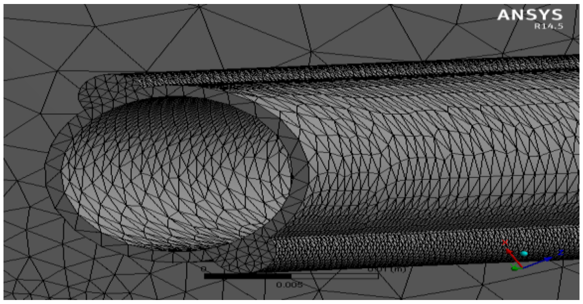


Figure 2: Mesh view

Fluent Setup

The mesh is properly checked and fine mesh is obtained. The analysis type is changed to heat transfer analysis type. The problem type is 3D and type of solver pressure-based solver. The velocity is change to absolute velocity and gravity is set y= -9.81 m/s.

Boundary Conditions

Here in the analysis the boundary condition is same as considered by scholar's K.Somashekhar et.al. (2016) 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_2O_3	303 K	0.09 kg/s
Hot fluid	Water	363 K	0.61 kg/s

IV. RESULTS AND DISCUSSIONS

Validation of the CFD model

To validate the CFD model of heat exchanger here the variation of temperature at various Peclet number obtained through CFD analysis of previous and present analysis have been compared. The comparative graph is shown in the Figure 3. Table 4 shows the percentage variation between experimental and numerical value of overall heat transfer coefficient.

Table 4: Percentage variation between previous and present CFD value of temperature

Peclet number	Temperature of fluid in previous study	Temperature of fluid in present study	Percent age Variatio n (%)
20000	336	335.4	0.17
30000	336.5	336.2	.08
40000	337	336.9	.02
50000	337.6	337.3	.08
60000	338	337.9	.02

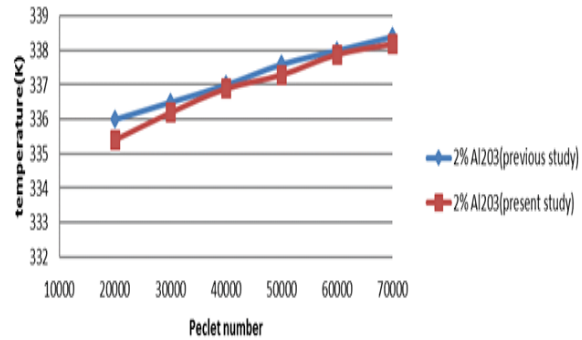


Figure 3 Comparison of inlet and outlet temperature value.

After validation of the CFD model of the heat exchanger, five different mass flow rate of nanofluid is allowed to flow through the heat exchanger with fin and without fin at its tube and the results are summarized with the help of bar graph, line graph and table. The results obtained from the formulation of this problem are discussed in this chapter and the contours of temperature and pressure difference are shown:

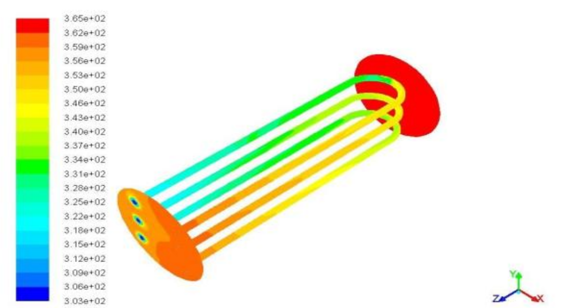


Fig4 Contours of Static Temperature

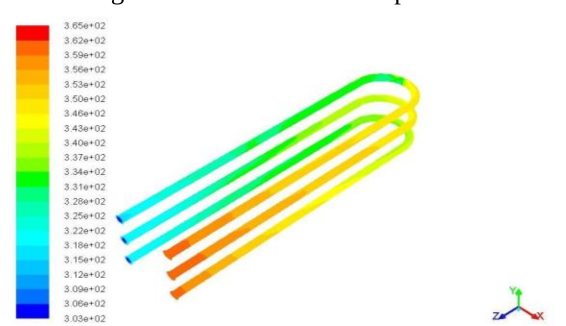
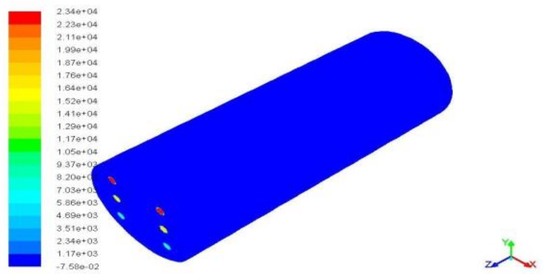
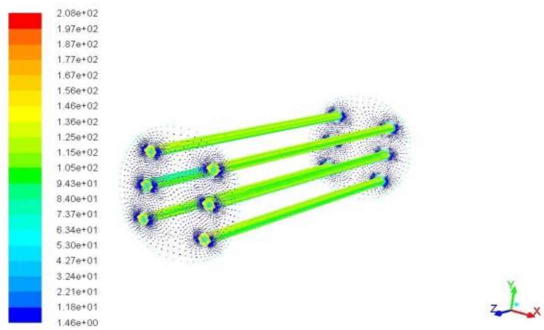


Fig.5 Contours of Static temperature on U- tube



.6. Contours of Static Pressure



7 Velocity Vectors Contours of tube for shell and tube heat exchanger with fins

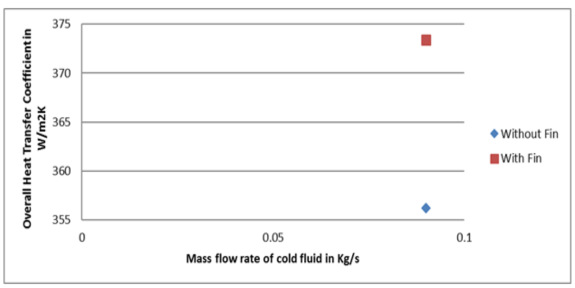


Figure 8 Mass flow rate of cold fluid V/S overall heat transfer coefficient.

The above curve shows the value of overall heat transfer coefficient increases with use of oval fin for the same mass flow rate of cold fluid. The value of overall heat transfer coefficient prominently increases use of oval fin.

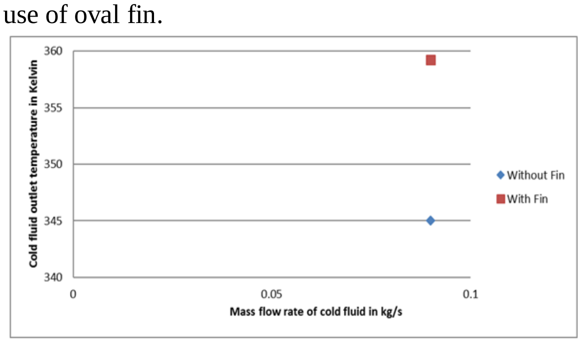


Figure 9 mass flow rate of cold fluid V/S Outlet Temperature of cold fluid.

The above curve shows the value of Outlet Temperature of cold fluid increase with use of triangular fin for the same mass flow rate of cold fluid. The value of Outlet Temperature of cold fluid prominently increases use of oval fin.

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 oval shaped 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 oval shaped 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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