Heat Transfer Performance Evaluation of Finned Tube Double Pipe Heat Exchanger Using CFD

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***Abstract*- Development of modern engineering applications demands the heat transfer enhancement. At the same time, efficient heat transfer equipment is necessary to reduce energy consumption and improve energy savings. Heat transfer enhancement is both very attractive and challenging in the research and industry fields. It has a fundamental role in improving energy efficiency, as well as in developing thermal systems with high performances. Heat transfer enhancement techniques can be found in different engineering applications, such as solar energy systems, thermal control, heat exchangers, automotive cooling, refrigeration, chemical process, etc. They are classified as passive methods and active methods. In the first method, no direct application of external power is required, whereas in the second method an external power source is necessary. The effectiveness of heat transfer enhancement techniques is strongly related to the heat transfer mechanisms.**

In present work attempts are made to enhance the heat transfer rate in double pipe heat exchangers by providing semi-circular fin on the tube. For this a double pipe heat exchanger were used in which tubes with six 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 double pipe 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. The average Nusselt number for the semi-circular fin is about 1.28 times larger as compared to that without fin heat exchanger. The overall heat transfer coefficient for the semi-circular fin is about 1.07 times larger as compared to that without fin heat exchanger.

Index Terms- Fins, Heat exchanger, double pipe, Nano fluids, Heat transfer, ANSYS 14.5, Overall heat transfer coefficient, Nusselt number.

I. INTRODUCTION

Heat exchangers are equipment being used for transfer of heat between two or more fluids at different temperatures. They are widely used in diverse energy and process applications such as power generating plant, process and chemical industry, heating, ventilation, air conditioning and refrigeration systems, and the cooling of electronic equipment. Heat exchangers may be classified in various ways, e.g., based on transfer processes, surface compactness, construction features, flow arrangements, and heat transfer mechanisms. Design and sizing of heat exchangers are generally complicated.

Heat Transfer Enhancement

Heat transfer enhancement is an important area that develops rapidly in heat transfer studies, and it has become the second generation of heat transfer technology. It is widely used in industry, agriculture, space, and biology, especially in the development, application, and saving of energy.

Heat transfer enhancement techniques refer to different methods used to increase the rate of heat transfer without affecting the overall performance of the system.

Active enhancement technology

Active enhancement utilizes the enhancements from external forces, including jet impingement, mechanical vibration, impressed electromagnetic field, and suction. These technologies require external energy and are more complex. But they have better effects, so it is worth to be applied to enhancement.

Passive enhancement technology

Passive enhancement technology is the technology on heat transfer enhancement without direct external forces, which includes treated surface, rough surface, extended surface, mechanical insert, spiral tube, and various additives in liquids or solids, etc. Each of them has different features and can be selected in accordance with specific conditions.

Compound enhancement technology

A compound augmentation technique is the one where more than one of the above mentioned techniques is used in combination with the purpose of further improving the thermo-hydraulic performance of a heat exchanger. When any two or more of these techniques are employed simultaneously to obtain enhancement in heat transfer that is greater than that produced by either of them when used individually, is termed as compound enhancement. This technique involves complex design and hence has limited applications.

There are several methods to increase the hA value:

a. Heat transfer coefficient can be increased without an appreciable increase in the surface area.
b. Surface area can be increased without appreciable changes in heat transfer coefficient.
c. Both the heat transfer coefficient and the surface area can be increased.

Extended Surfaces (Fins)

Extended surfaces have fins attached to the primary surface on one side of a two-fluid or a multifluid heat exchanger. Fins can be of a variety of geometry-plain, wavy or interrupted and can be attached to the inside, outside or to both sides of circular, flat or oval tubes, or parting sheets. Pins are primarily used to increase the surface area (when the heat transfer coefficient on that fluid side is relatively low) and consequently to increase the total rate of heat transfer.

II. LITERATURE REVIEW

Manna et al. [2014] investigated the thermal conductivity enhancement of SiC-water Nano fluid using transient hot wire device. Thermal conductivity of Nano fluid was increased with the concentration of nanoparticles, 26% of maximum thermal conductivity was obtained when using 0.8% concentration of Nano fluid. Mechanically milled nanoparticles having high heat transfer enhancement. Nanoparticles volume and shape was important factor to enhance the thermal conductivity of Nano fluid, at 27nm sized nanoparticles enhanced 12% of thermal conductivity Nano fluid.

Sivakumar et al. [2015], studied numerically and experimentally laminar flow in a circular tube fitted with twisted tape inserts under a uniform wall heat flux boundary condition. They found that the enhancement of heat transfer in a tube with twisted tape inserts was enhanced by 25–30% compared to that of the plain tube.

Sonawane et al. [2015] investigated the heat transfer characteristics of Al_2O_3– water nanofluids as a coolant used in concentric tube heat exchanger .The heat exchanger was fabricated from copper concentric inner tube with a length of 1000 mm. The nanofluids were the mixture of water as base fluid and Al_2O_3 particles in Nano range. The results obtained from the nanofluids 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 was considered. It was 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 Nanofluid' 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.

Somasekhar et al. [2016] In this study a multi pass shell and tube heat exchanger with 3 tubes modeling was done using CATIA and meshing has done using ICEM CFD software, simulations had been done by using CFD-FLUENT software. Using Fluent, computational fluid dynamics software the pressure drop, heat transfer characteristics of Al_2O_3-water Nanofluid, and Distilled water was analyzed under turbulent flow condition. Nanofluid such as Al_2O_3-H_2O was used as cooling medium instead of Distilled water. Finally the CFD simulated results were 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.

Mohammad Hussein Bahmani et al. [2017] heat transfer and turbulent flow of water/alumina nanofluid in a parallel as well as counter flow double pipe heat exchanger have been investigated. The governing equations have been solved using an in-house FORTRAN code, based on finite volume method. Single-phase and standard k- e models have been used for nanofluid and turbulent modeling, respectively. The internal fluid has been considered as hot fluid (nanofluid) and the external fluid, cold fluid (base fluid). The effects of nanoparticles volume fraction, flow direction and Reynolds number on base fluid, nanofluid and wall temperatures, thermal efficiency, Nusselt number and convection heat transfer coefficient have been studied. The results indicated that increasing the nanoparticles volume fraction or Reynolds number causes enhancement of Nusselt number and convection heat transfer coefficient. Maximum rate of average Nusselt number and thermal efficiency enhancement are 32.7% and 30%, respectively. Also, by nanoparticles volume fraction increment, the outlet temperature of fluid and wall temperature increase. Study the minimum temperature in the solid wall of heat exchangers, it can be observed that the minimum temperature in counter flow has significantly reduced, compared to parallel flow. However, by increasing Reynolds number, the slope of thermal efficiency enhancement of heat exchanger gradually tends to a constant amount. This behavior is more obvious in parallel flow heat exchangers. Therefore, using of counter flow heat exchangers is recommended in higher Reynolds numbers.

Summary of Literature Review

The above-mentioned researchers had studied various aspects of nanofluids and various methods to implement nanofluids to enhance heat transfer rate in various heat exchangers. In some research works, the study was focused on an increase in the effectiveness of nanofluid, (Manna et al. (2014)). However, in some papers 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 (Somasekhar et al. (2016)).

Many investigations, both experimental and numerical, have been conducted on different kinds of internally finned tubes using a variety of fluids (air, water, oil, ethylene, etc.). There was no work found which considered cumulative effect of nanofluids and fins on double pipe heat exchanger in terms of overall heat transfer coefficient and total heat transferred.

III. METHODOLOGY

The geometry of double pipe heat exchanger performing the simulation study is taken form one of the research scholar's Mohammad Hussein Bahmani et al. (2017) paper with exact dimension. The part of model was designed in ANSYS (Fluent) workbench14.5 software. The geometric dimension of the double pipe counter flow heat exchanger is shown in the Table 1 and 2.

Table 1: Geometric Dimension of Heat exchanger

Pipe thickness	Inner tube dia.	Outer tube dia.	Length
2mm steel	26 mm	50	2m

Table 2: Geometric Dimension of fin incorporated inner side of inner pipe

Fin Type	Fin dia.	No. of fin	Length
Semi-circular	2 mm	8	2m

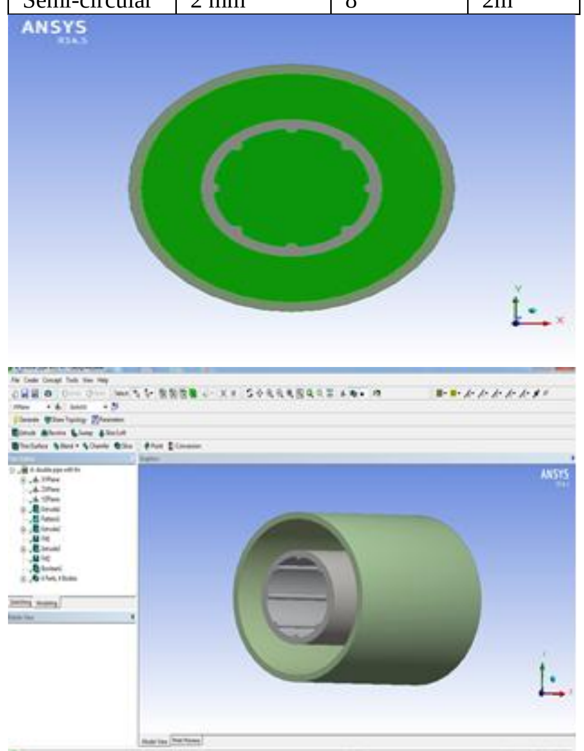

Figure 1 Geometry of double pipe heat exchanger with fin

By using ANSYS software in meshing edge sizing has been done. Inflation also makes for proper contact mesh. Mesh contains mixed cells per unit area (ICEM Tetrahedral cells) having meshing type tetrahedral and quadrilateral at the boundaries. However, for current problem:

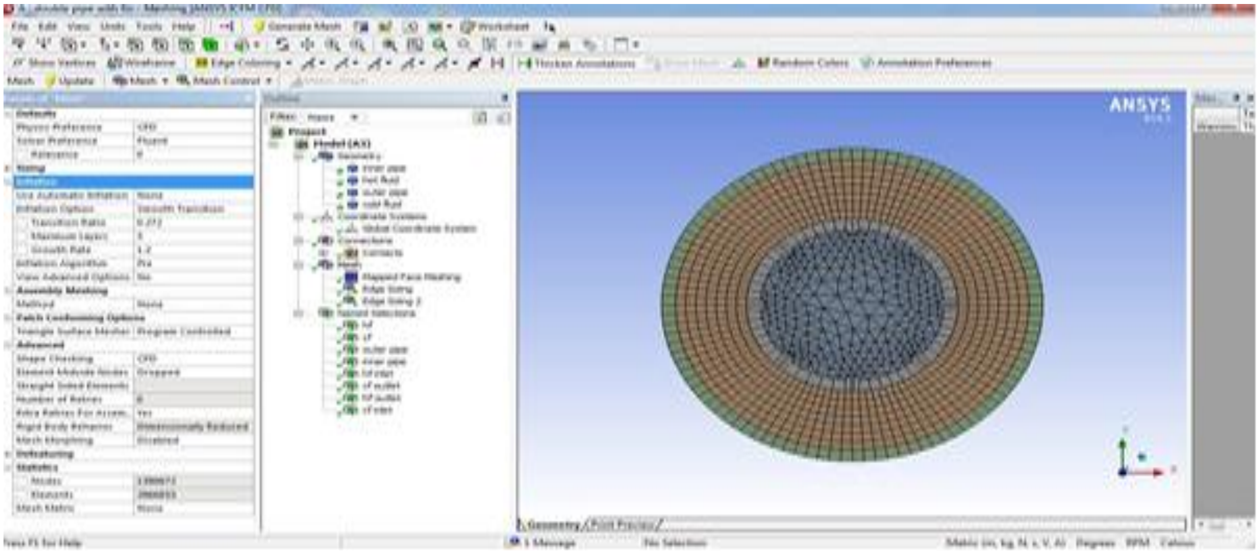

Figure 2 Meshing of double pipe heat exchanger with fin

Fluent setup and Model Selection

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

Energy – on and Viscous – Standard k-e standard wall Fn, mixture.

Material Selection

Table 3: Material Properties

Specification	Water	Al_2O_3	Steel
Density(Kg/m^3)	997.1	3970	8030
Specific Heat(J/Kg-K)	4179	765	502.48
Thermal conductivity(W/m-K)	0.613	40	16.27
Dynamic viscosity($N\text{-}s/m^2$)	0.000891	0.00012	

Boundary Condition

Here in this work hot water is flowing in the outer tube, whereas the cold fluid is flowing in inner tube. The inlet temperature of hot fluid is 350 K whereas the inlet temperature of cold fluid is 285 K. the heat transfer and hydrodynamic behavior of distilled water/Al2O3 nanofluid will be investigated in 5 % of volume fractions and at the range of Reynolds numbers between 10,000 and 30,000.The velocity of cold fluid changes as the Reynolds number of cold fluid changes. After putting the boundary conditions, the solution is initialized and then iteration is applied so that the values of all parameters can be seen in a curve line graph. After the iteration gets completed final result could be seen.

IV RESULTS AND DISCUSSIONS

Heat exchanger having semi-circular fin inside the inner tube.

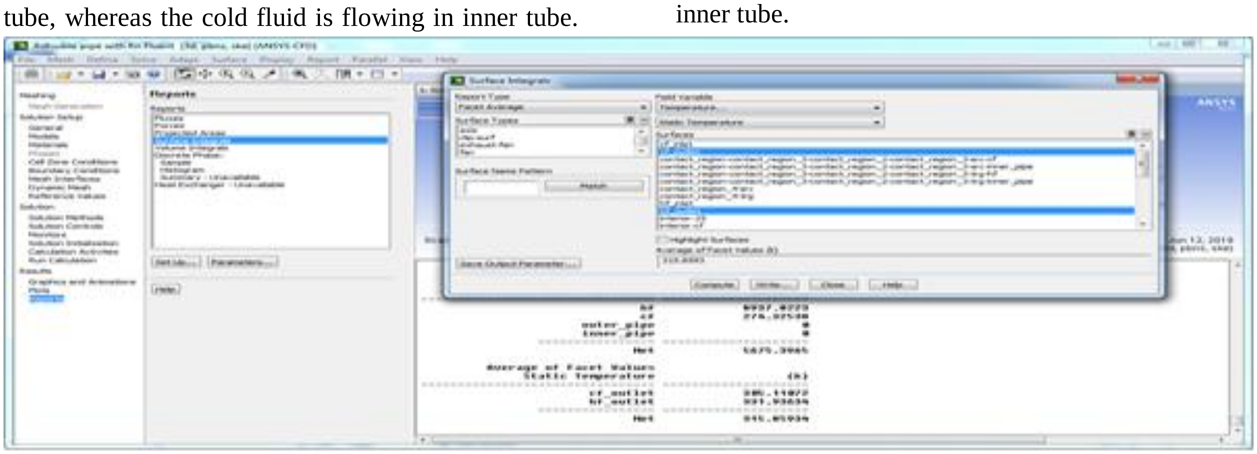

Figure 3 Outlet temperature for hot and cold fluid at Re=10,000 with fin

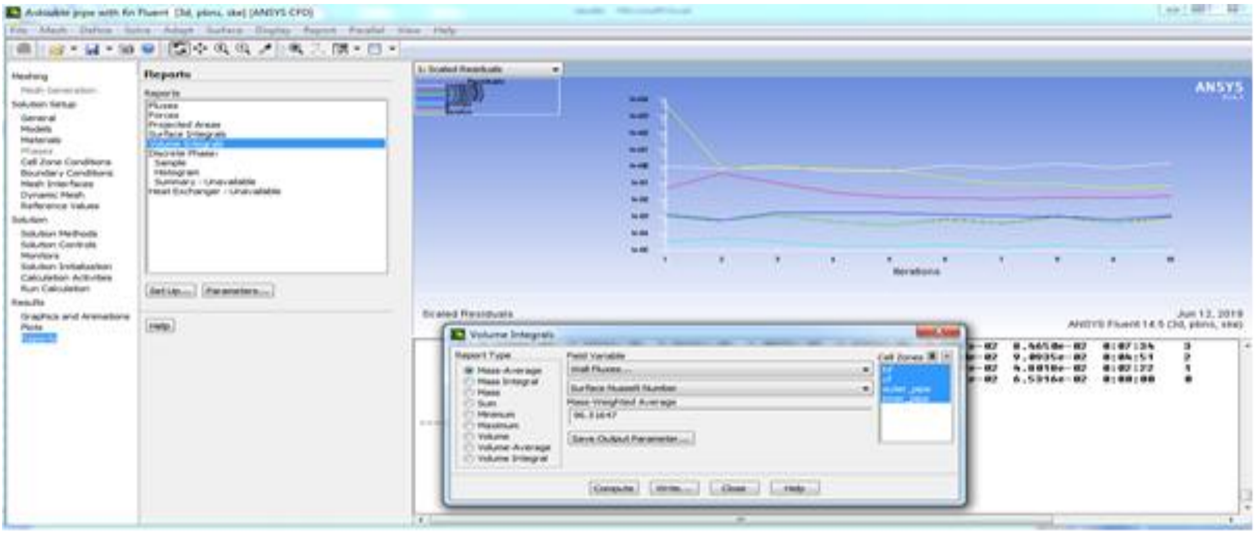

Figure 4 Nusselt number at Re=10,000 with fin

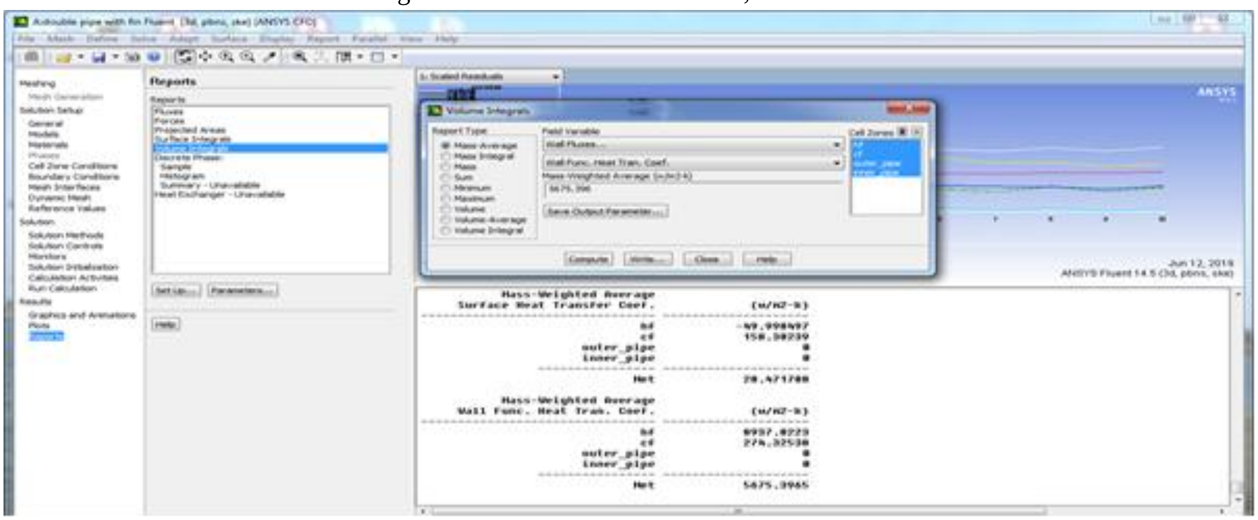

Figure 5 Heat transfer coefficient at Re=10,000 with fin

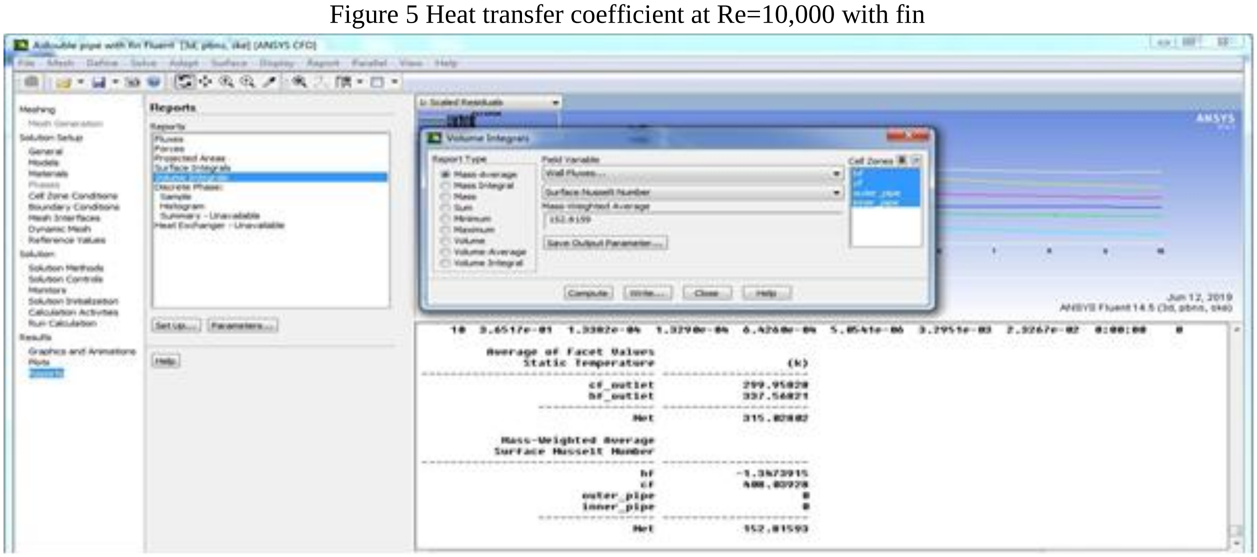

Figure 6 Nusselt number at Re=20,000 with fin

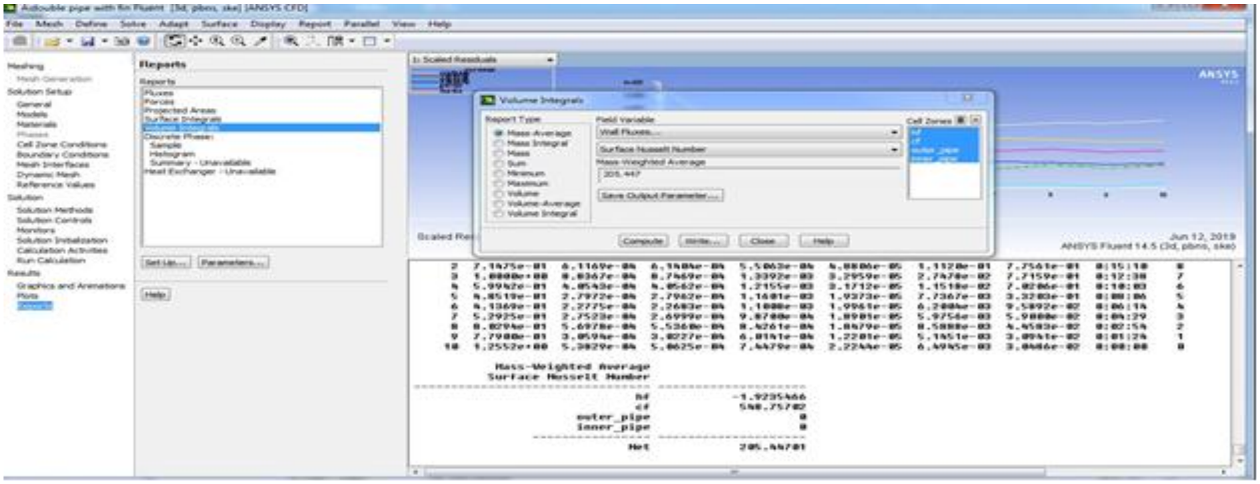

Figure 7 Nusselt number at Re=30,000 with fin.

Table 4 Results with semi-circular fin.

Reynold’s no.	Velocity (m/s)		Outlet Temp.(K)		Nusselt no.
	Inner side	Outer side	Inner side	Outer side	
10000	0.1787	0.059	331.93	305.11	96.51
20000	0.3574	0.1182	337.56	299.95	152.815
30000	0.5361	0.177291	337.48	299.96	205.44

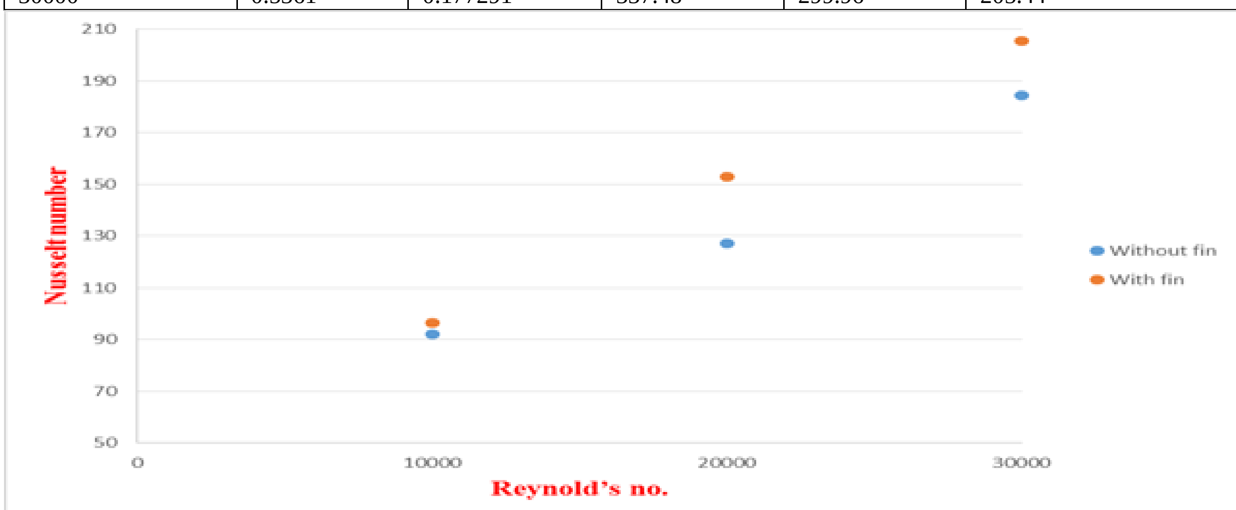

Figure 8 Comparison of Nusselt number at different Reynold’s no. with and without fin

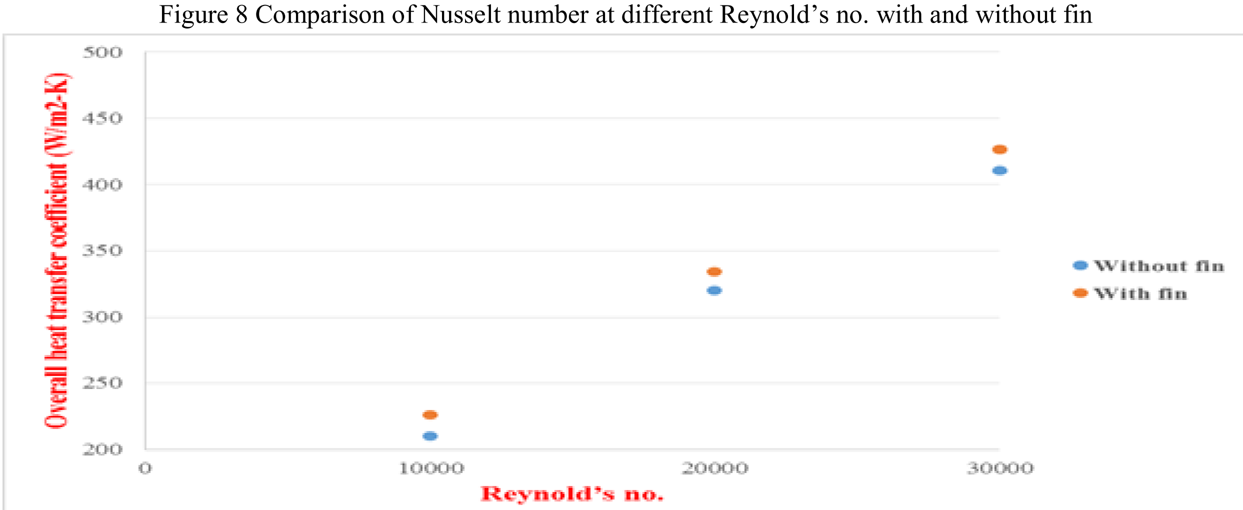

Figure 9 Comparison of Overall heat transfer coefficient at different Reynold's no. with and without fin.

V. CONCLUSIONS

A CFD heat transfer study is presented for heat exchanger with semi-circular fin. The Reynolds number spanned the range between about 10,000, 20,000 and 30,000. The main findings yielded from the results are:

- Outlet Temperature of cold fluid increase with use of semi-circular fin for the same mass flow rate of cold fluid.
- The Nusselt number and overall heat transfer coefficient observed in heat exchanger with semi-circular fin was higher as compared to the plain tube.
- The average Nusselt number for the semi-circular fin is about 1.28 times larger as compared to that without fin heat exchanger.
- The overall heat transfer coefficient for the semi-circular fin is about 1.07 times larger as compared to that without fin heat exchanger.
- For the range considered, the maximum thermal performance factor of 1.27 is found with the use of semi-circular fin as compared to the plain tube.

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