Heat Transfer Augmentation by using Titanium dioxide Nano fluid in a Double Tube Heat Exchanger using CFD

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Abstract- **Heat exchangers play an increasingly important role in the field of energy conservation. The need for better efficient heat exchanging system is required for new technological and industrial development. Therefore, the scientific attention is concentrating both on improving the equipment design and on enhancing the thermal potential of the working fluid. Nanofluids are considered to offer important advantages over conventional heat transfer fluids. Recent advances in nanotechnology have allowed development of a new category of fluids termed nanofluids. Such fluids are liquid suspensions containing particles that are significantly smaller than 100 nm, and have a bulk solids thermal conductivity higher than the base liquids. Nanofluids are formed by suspending metallic or nonmetallic oxide nanoparticles in traditional heat transfer fluids. These so called nanofluids display good thermal properties compared with fluids conventionally used for heat transfer and fluids containing particles on the micrometer scale. Nanofluids are the new window which was opened recently and it was confirmed by several authors that these working fluid can enhance heat transfer performance.**

An investigation of heat transfer has been carried out in a double-pipe heat exchanger equipped using TiO2 as a Nano fluid and distilled water as base fluid. The results achieved from the use of the TiO2/water Nano fluid, are compared with Al2O3/water Nanofluid. The results of CFD reveals that at similar operating conditions, heat transfer, overall heat transfer coefficient associated with the simultaneous application of TiO2 /water Nano fluid better than those associated with the Al2O3/water Nanofluid. Evidently, heat transfer rate increases with increasing TiO2 /water Nano fluid.

Index Terms- Heat Transfer, Enhancement, Active and Passive Techniques, Nanofluid, Nanoparticles, TiO2, Heat exchanger.

I. INTRODUCTION

Convective heat transfer can be enhanced passively by changing flow geometry, boundary conditions, or by enhancing thermal conductivity of the fluid [1]. Various techniques have been proposed to enhance the heat transfer performance of fluids. Researchers have also tried to increase the thermal conductivity of base fluids by suspending micro or larger sized solid particles in fluids since the thermal conductivity of solid is typically higher than that of liquids. Nanofluid is envisioned to describe a fluid in which nanometresized particles are suspended in conventional heat transfer basic fluids, including oil, water, and ethylene glycol mixture, which are alone poor heat transfer fluids [2, 3]. Since the solid nanoparticles with typical length scales of 1–100 nm with high thermal conductivity are suspended in the base fluid (low thermal conductivity), have been shown to enhance effective thermal conductivity and the convective heat transfer coefficient of the base fluid. The thermal conductivity of the particle materials, metallic or non-metallic such as Al2O3, CuO, Cu, SiO, TiO, are typically order-of-magnitude higher than the base fluids even at low concentrations, result in significant increases in the heat transfer coefficient [4,5,6]. Numerous theoretical and experimental studies of suspensions containing solid particles have been conducted since Maxwell's theoretical work was published more than 100 years ago. However, due to the large size and high density of the particles, there is no good way to prevent the solid particles from settling out of suspension.

II. LITERATURE REVIEW

A considerable amount of experimental as well as analytical and computational research has been carried out on the enhancement of heat transfer. In this chapter, a brief survey of the relevant literature is presented to indicate the extent of work already reported in open literature pertaining to the enhancement of heat transfer by introducing nano fluid.

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.

Rohit S. Khedkar et al. (2017): experimental study on concentric tube heat exchanger for water to nanofluids heat transfer with various concentrations of nanoparticles in to base fluids and application of nanofluids as working fluid. Overall heat transfer coefficient was experimentally determined for a fixed heat transfer surface area with different volume fraction of Al2O3 nanoparticles in to base fluids and results were compared with pure water. It observed that, 3 % nanofluids shown optimum performance with overall heat transfer coefficient 16% higher than water.

Akyürek et al. (2018): experimentally investigated the effects of Al2O3/Water nanofluids at various concentrations in a concentric tube heat exchanger having a turbulator inside the inner tube. Comparisons were done with and without nanofluid in the system as well as with and without turbulators in the system. Results were drawn and a number of heat transfer parameters were calculated on the basis of observed results. Various heat characteristics such as change in Nusselt number and viscosity with respect to Reynolds number, behaviour of nanofluid at various volume concentrations, changes in heat transfer coefficient, effect of the difference of pitch of turbulators on the heat transfer of nanofluid etc. were studied. They concluded that there exists a relationship between the varying pitches and the turbulence in the flow caused i.e. when the pitch is less there is more turbulence and vice versa.

III. METHODOLOGY

3.1 Geometry Setup

The geometry of double pipe heat exchanger performing the simulation study is taken form one of the research scholar's Akyürek et al. (2018) paper with exact dimension. The part of model was designed in ANSYS (Fluent) workbench 16.0 software.

Table 1: Geometric dimension of the double pipe counter flow heat exchanger.

Parameters	Values
Tube length	1.3 m
Inner tube diameter	12 mm
Tube wall thickness	2 mm
Outer tube diameter	33 mm
Pitch of turbulator	39 mm

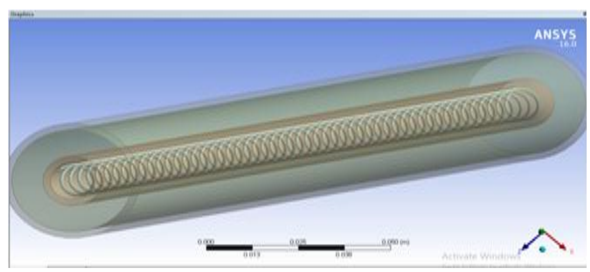

Figure 1 Geometry of double tube heat exchanger with helical turbulator.

3.2 Meshing

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 the mesh having 768043 nodes and 2116626 elements in generated.

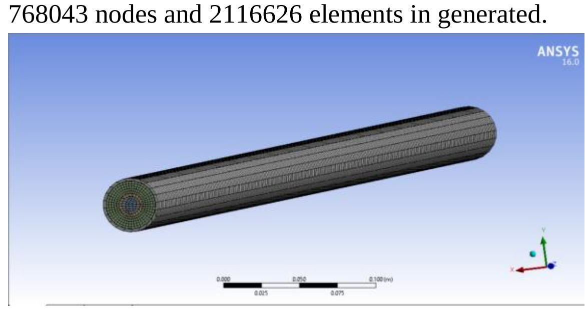

Figure 2 Meshing of double pipe heat exchanger

3.3 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.

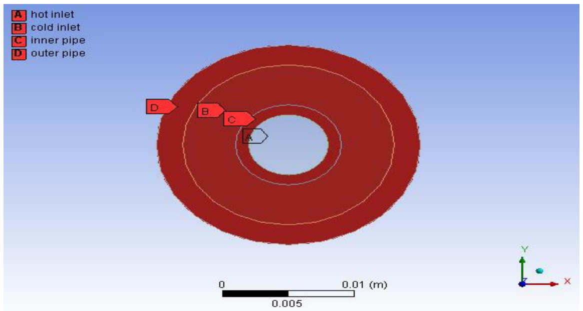

Figure 3 Name selection of double pipe heat exchanger

3.4 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 .

3.5 Model Selection

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

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

3.6 Material Selection

Table 2 Properties of Al2O3-H2O nanofluid

Concentration (% by weight)	Density (kg/m^3)	Specific heat (J/kg-K)	Thermal Conductivity (W/m-K)	Dynamic viscosity (Pa-s)
0.4	1009.888	4130.077	0.605	0.00101
0.8	1021.776	4079.363	0.613	0.00102
1.2	1033.664	4029.81	0.620	0.00103

Table 3 Properties of TiO2-H2O nanofluid

Concentration (% by weight)	Density (kg/m^3)	Specific heat (J/kg-K)	Thermal Conductivity (W/m-K)	Dynamic viscosity (Pa-s)
0.4	1010.636	4124.87	0.608	0.00101
0.8	1023.272	4069.16	0.623	0.00102
1.2	1035.908	4014.80	0.677	0.00103

*Above properties are obtained from using cho and pak corelations.

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

4.1 Aluminum oxide (Al2O3) and Water

At 0.4% volume fraction

Here we have considered aluminum oxide (Al2O3) as a nanoparticle; it is mixed with water at volume fraction of 0.4% and used as a nano fluid inside the heat exchanger. The temperature contours of alumina nano fluid at different Re number were shown in the below section

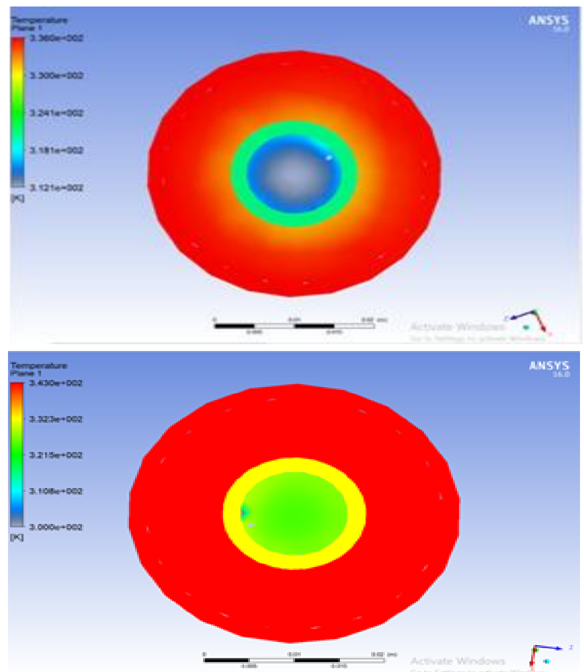

Figure 4 temperature contour at the inlet of cold fluid and outlet of cold fluid for Re = 4000.

Similarly done for 0.8 and 1.2 % concentration.

4.2 Titanium dioxide (TiO2) and Water

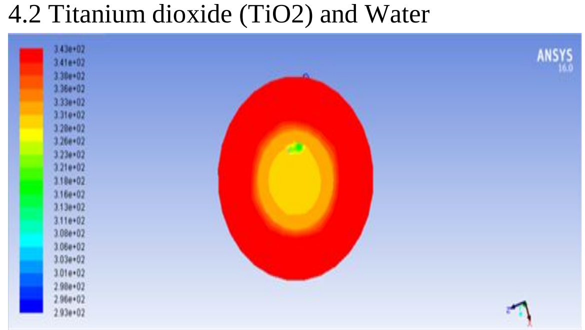

Figure 5 Temperature contour at the exit of cold fluid at Re = 4000 at 0.4% volume fraction.

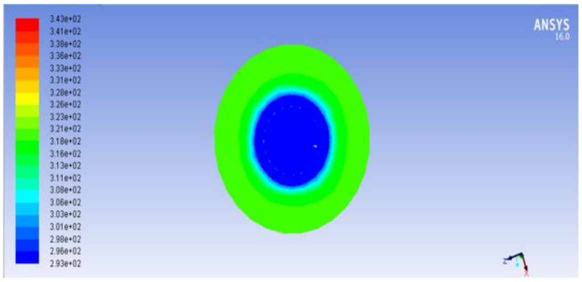

Figure 6 Temperature contour at the inlet of cold fluid at Re = 4000 at 0.4% volume fraction

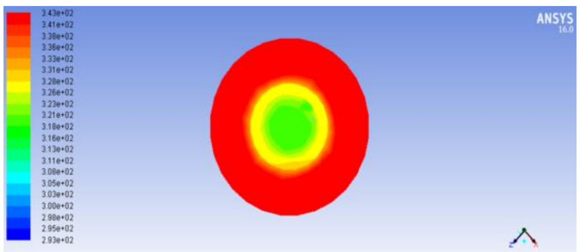

Figure 7 Temperature contour at the exit of cold fluid at Re = 4000 at 0.8% volume fraction

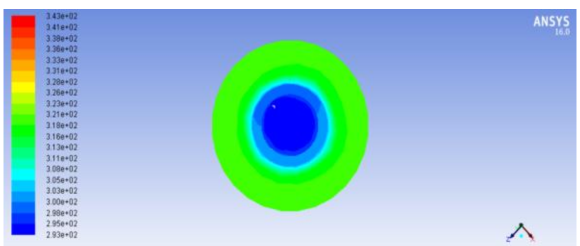

Figure 8 Temperature contour at the inlet of cold fluid at Re = 4000 at 0.8% volume fraction

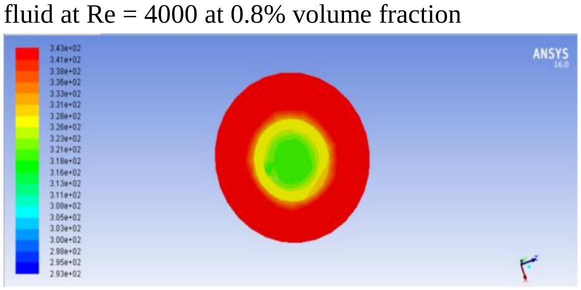

Figure 9 Temperature contour at the exit of cold fluid at Re = 4000 at 1.2 % volume fraction.

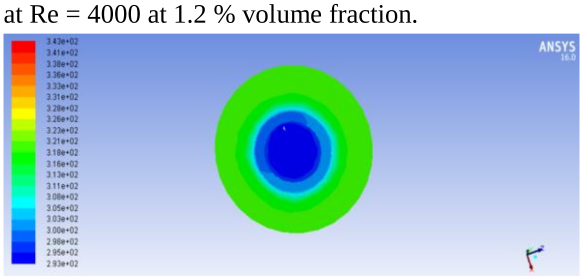

Figure 10 Temperature contour at the inlet of cold fluid at Re = 4000 at 1.2 % volume fraction

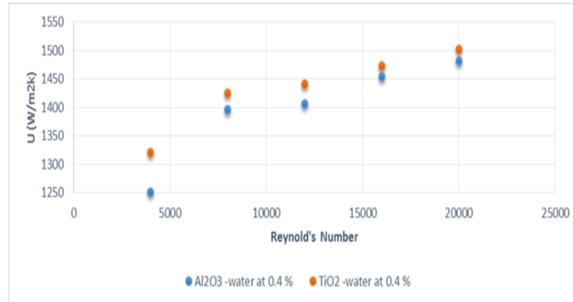

Figure 11 Comparison of overall heat transfer coefficient for different nano fluids at 0.4 % volume fraction

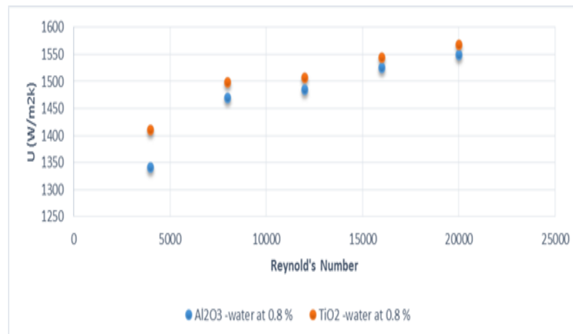

Figure 12 Comparison of overall heat transfer coefficient for different nano fluids at 0.8 % volume fraction

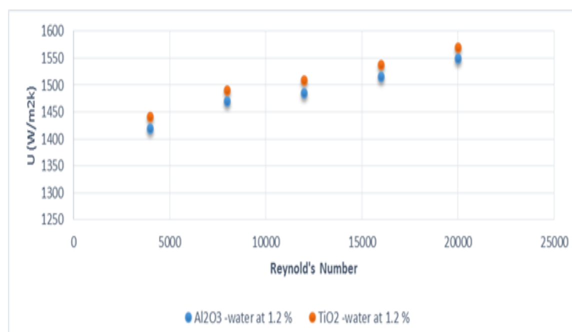

Figure 13 Comparison of overall heat transfer coefficient for different nano fluids at 1.2 % volume fraction

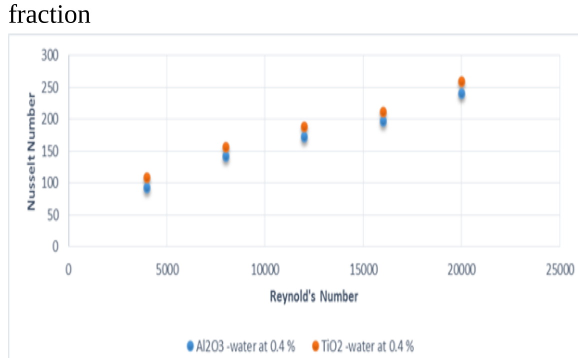

Figure 12 Comparison of Nusselt for different nano fluids at 0.4 % volume fraction

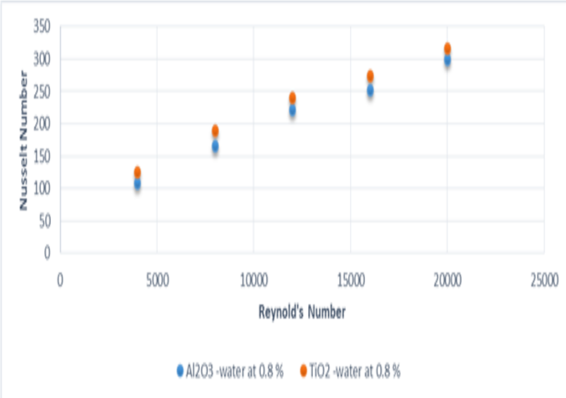

Figure 13 Comparison of Nusselt for different nano fluids at 0.8 % volume fraction.

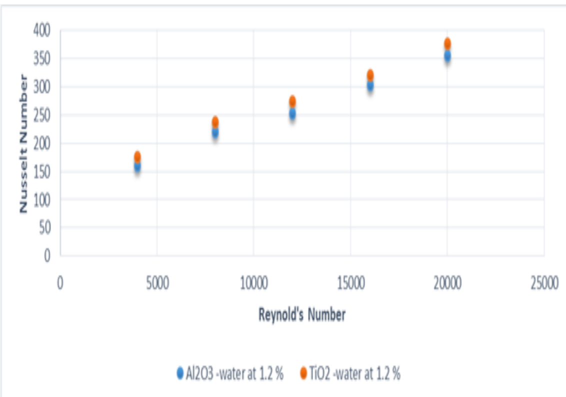

Figure 14 Comparison of Nusselt for different nano fluids at 1.2 % volume fraction.

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 analysis it is found that the value of Nu number and overall heat transfer coefficient is higher in case of Titanium oxide (TiO2) as compared to Aluminum oxide (Al2O3) by 5%.
- It is also found that as the volume fraction of nano particles increases the heat transfer rate of heat exchanger also increases.

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