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Heat Transfer Augmentation in a Double Pipe Heat Exchanger Using Water-Beryllium Oxide Based Nano fluid Using CFD

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***Abstract*- Many industrial application including power plants, chemical, refrigerator and air conditioning systems use heat exchangers to remove excess generated heat out of the system. Heat exchangers have several industrial and engineering applications. The design procedure of heat exchangers is quite complicated, as it needs exact analysis of heat transfer rate and pressure drop estimations apart from issues such as long-term performance and the economic aspect of the equipment. Heat transfer augmentation techniques refer to different methods used to increase rate of heat transfer without affecting much overall performance of the system. These techniques broadly are of three types viz. passive, active and compound techniques.**

An investigation of forced convection heat transfer has been carried out in a double-pipe heat exchanger equipped using Beo/water as a nano fluid and distilled water as base fluid. The results achieved from the use of the BeO/water Nano fluid, are compared with Al_2O_3/water Nano fluid. The results of CFD reveals that at similar operating conditions, heat transfer, overall heat transfer coefficient associated with the simultaneous application of BeO/water Nano fluid better than those associated with the Al_2O_3/water Nano fluid. Evidently, heat transfer rate increases with increasing BeO /water Nano fluid volume concentration

***Index Terms*-Heat Exchanger, Heat Transfer Augmentation, Active Techniques, Passive Techniques, Compound Techniques, Beryllium Oxide, Nano Particles, CFD.**

1. INTRODUCTION

1.1HEAT EXCHANGER

Heat exchanger is defined as a device which is use to transfer energy between two fluid which are at different temperature with maximum rate and minimum cost.

1.1.1CLASSIFICATION OF HEAT EXCHANGER

There are many types of heat exchanger which are widely used in industry and application of power generation. Heat exchanger is classified based on following criteria:

- According to flow arrangements of fluids.
- According to heat transfer process.
- According to geometry of construction.

a) According to flow arrangement of fluids

A heat exchanger can have several different flow patterns. Counter flow, parallel flow, and cross flow are common heat exchanger types. A counter flow heat exchanger is the most efficient flow pattern of the three. It leads to the lowest required heat exchanger surface area because the log mean temperature drop is the highest for a counter flow heat exchanger.

i) Parallel flow heat exchanger

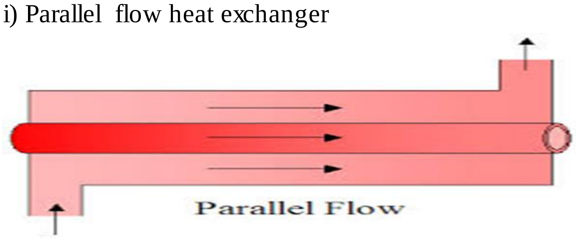


Figure 1 Parallel flow heat exchanger

ii) Counter flow heat exchanger

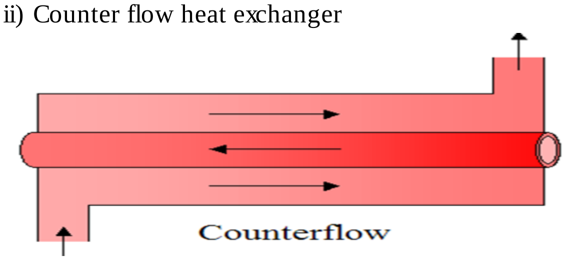


Figure 2 Counter flow heat exchanger.

iii) Cross flow heat exchanger

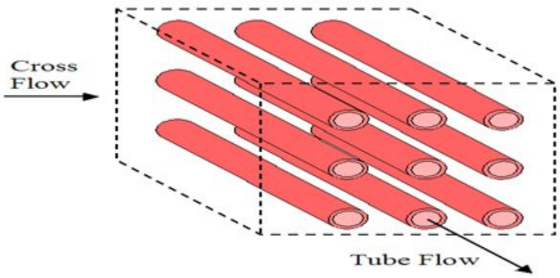
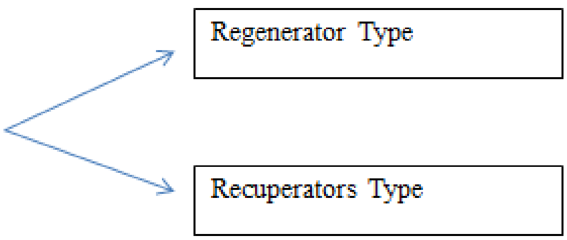


Figure 3 Cross flow heat exchanger

b) According to heat transfer process:



i) Direct contact type heat exchanger
ii) Indirect contact type heat exchanger

c) According to geometry of construction:
i) Concentric tube type heat exchanger or double pipe heat exchanger.
ii) Shell and tube type heat exchanger

1.2 HEAT TRANSFER ENHANCEMENT TECHNIQUES IN HEAT EXCHANGER

Generally, heat transfer augmentation methods are classified in three broad categories:

(a) Active method: These techniques are more complex from the use and design point of view as the method requires some external power input to cause the desired flow modification and improvement in the rate of heat transfer. It finds limited application because of the need of external power in many practical applications.

(b) Passive method: These techniques generally use surface or geometrical modifications to the flow channel by incorporating inserts or additional devices. They promote higher heat transfer coefficients by disturbing or altering the existing flow behavior (except for extended surfaces) which also leads to increase in the pressure drop. These techniques do not require any direct input of external power; rather they use it from the system itself which ultimately leads to an increase in fluid pressure drop.

(c) Compound method: 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.

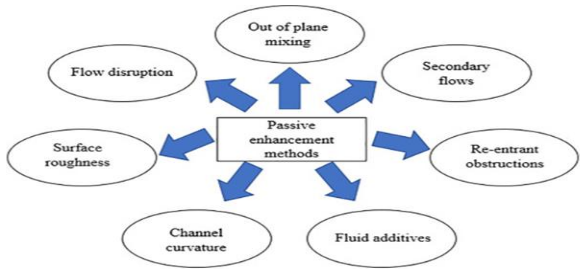


Figure 4. Passive Techniques for Heat Transfer Augmentation

1.2.1Nano 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.

The thermal conductivity of Nano fluids has drawn increasing attention since first postulated that heat transfer could be improved through the addition of metallic nanoparticles to the heat transfer fluid. He addressed the limitation in thermal conductivity of typical heat transfer fluids and suggested the addition of more conductive solid particles would enhance the fluid thermal conductivity beyond that suggested by conventional models. The advantages of using nanoparticles are that they are more easily suspended in the fluid, they may be used in micro channels, and the small size causes less wear to machinery. However, aggregation of particles must be minimized in order to benefit from these effects of small particle size.

II. LITERATURE REVIEW

As the need for more efficient heat transfer systems increases, researchers have resorted to various heat transfer enhancement techniques since the mid-1950s. The significant increase in the number of research articles dedicated to this subject thus far shows a noticeable growth and the importance of heat transfer enhancement technology.

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 protrusions mounted on the heat transfer surfaces.

Yannar et al.[2008]: Investigated the flow and heat transfer characteristic of spiral pipe heat exchanger using different type of Nano fluid with different concentration such as Al_2O_3-water, TiO_2-water, CuO-water Nano fluid with 1%, 1% and 3% concentration respectively. Test section made of copper tube had the ratio of pitch per diameter is 7, mean hydraulic diameter is 30mm, 10mm diameter and 1600mm length. Heat transfer enhanced 28% at 0.8% concentration of Nano fluid, due to high concentration shear stress of Nano fluid is increased. Heat transfer enhancement is high in spiral pipe compared with circular pipe, because the pressure drop is high in spiral pipe. Heat transfer co efficient is decreases when axial distance of Nano fluid is increasing, because formation of boundary layer.

Manag et al.[2011]: Investigated the friction factor and heat transfer rate of CuO-Water and Al_2o_3-water Nano fluid using micro channel heat sink. Dimension of test section is 100x100x20000micrometter, assumed steady state laminar flow occurred, neglected the radioactive heat transfer and adiabatic constant heat flux applied at bottom of heat sink is 5000 W/cm^2. As the result of increasing nusselt number with increasing the Reynolds number and concentration but decreased the friction factor of Nano fluid. Compared the CuO-water and Al_2O_3-water Nano fluids the CuO-water Nano fluid showed better enhancement and low friction factor.

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 Al_2O_3-water nanofluid, and Distilled water are analyzed under turbulent flow condition. Nanofluid such as Al_2O_3-H_2O 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.

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 Rohit S. Khedkar 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 Table1and 2.

Table 1: Geometric Dimension of Outer Tube

MATERIAL	STEEL
INTERNAL DIAMETER	16mm
OUTER DIAMETER	20mm
LENGTH	1000mm

Table 2: Geometric Dimension of Inner Tube

MATERIAL	STEEL
INTERNAL DIAMETER	6 mm
OUTER DIAMETER	8 mm
LENGTH	1100mm

3.1.1. GEOMETRY

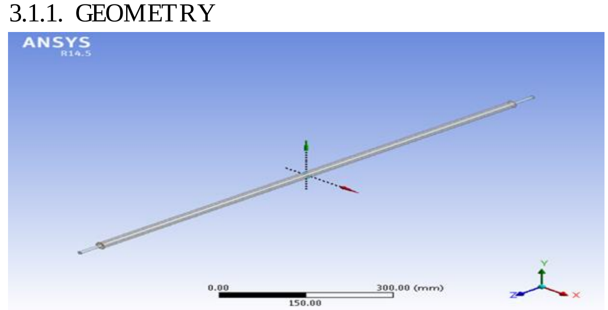


Figure 5 Isometric view of double pipe heat exchanger

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.

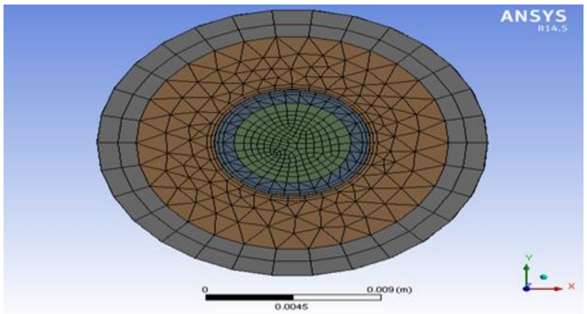


Figure 6 Meshing of double pipe heat exchanger

3.3 MATERIAL SELECTION

Physical Properties for the nanoparticles Al2O3 and BeO considered for this study are as below:

S.No	Particle	Thermal conductivity(W/m-K)	Density (Kg/m^3)	Specific Heat(J/Kg-K)
1.	Al_2O_3	46	3970	750
2.	BeO	272	3000	1030

Table 3 Properties of nanoparticles

*Above properties are obtained from using cho and pak corelations.Also mentioned in the referred base paper

Properties of working fluid Al2O3 -H2O and BeO-H2O Nano fluid are compiled in the table below:

The material property which is use in analysis is shown in Table 4

S. No	97%Water+3%Nano fluid	Thermal conductivity (W/m-K)	Density (Kg/m^3)	Dynamic Viscosity (Ns/m^2)	Specific Heat(J/Kg-K)
1.	H_2O-Al_2O_3	0.6846	1089.1	1.23*10^6	3812.78
2.	H_2O-BeO	0.6872	1060	1.23*10^6	3918.5

*Above properties are obtained from using cho and pak corelations. Also mentioned in the referred base paper.

3.4. BOUNDARY CONDITION

Here in the analysis the boundary condition is same as considered by scholar's Rohit S. Khedkar et al. (2017) during the experimental work. Some of the conditions are shown in the Table.5.

Name	Mass Flow rate (Litre/minute)	Temperature(K)
Cold Fluid	0.2,0.4.,0.6,0.8,1	303
Hot Fluid	3.5	363

Table 5: Boundary condition of different parameters

IV. RESULTS AND DISCUSSIONS

After validation of the CFD model of the heat exchanger, five different mass flow rate of Nano fluid is allowed to flow through the heat exchanger in inner tube and the results are summarized with the help of bar graph, line graph and table.

4.1 Results for Water + Aluminium Oxide Nano fluid (3%) for different mass flow rate of inner tube.

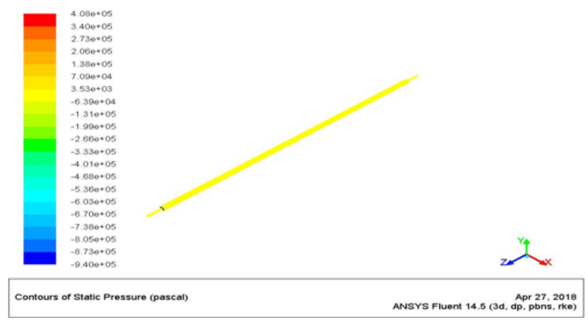


Figure 7 Contours of static Pressure at 0.2 Litre/minute for Water+3%Al2O3

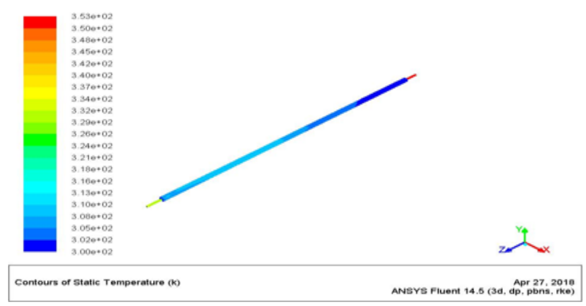


Figure 8Contours of static Temperature at 0.2 Litre/minute for Water+3%Al2O3.

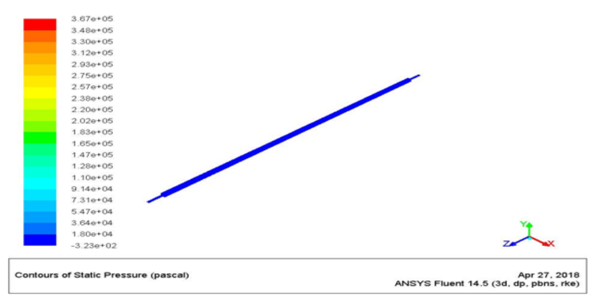


Figure 9 Contours of static Pressure at 0.4 Litre/minute for Water+3%Al2O3.

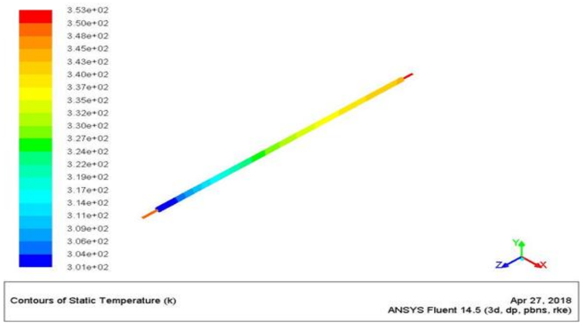


Figure 10 Contours of static Temperature at 0.4 Litre/minute for Water+3%Al2O3.

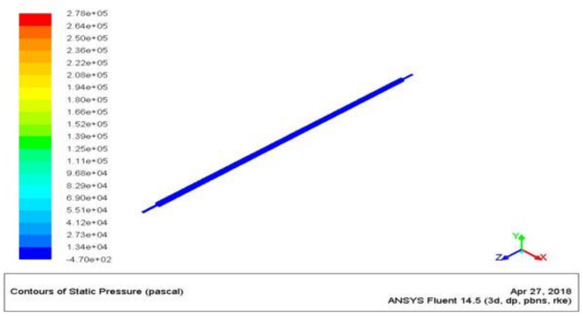


Figure 11 Contours of static Pressure at 1.0 Litre/minute for Water+3%Al2O3.

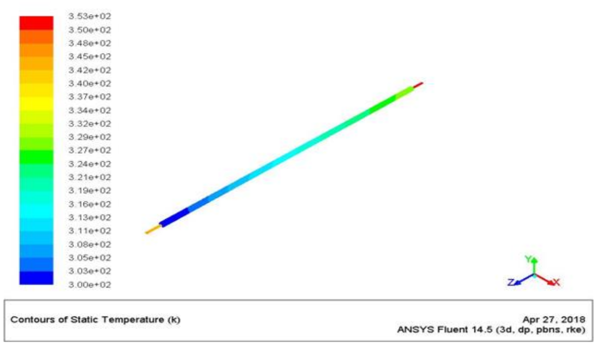


Figure 12 Contours of static Temperature at 1.0 Litre/minute for Water+3%Al2O3.

4.2 Results for Water + Beryllium Oxide Nano fluid (3%) for different mass flow rate of inner tube.

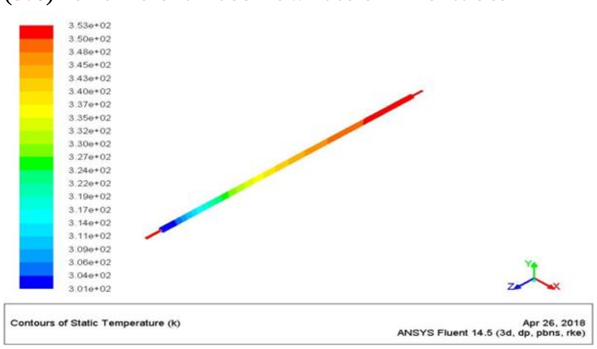


Figure 13 Contours of static Temperature at 0.2 Litre/minute for Water+3%BeO.

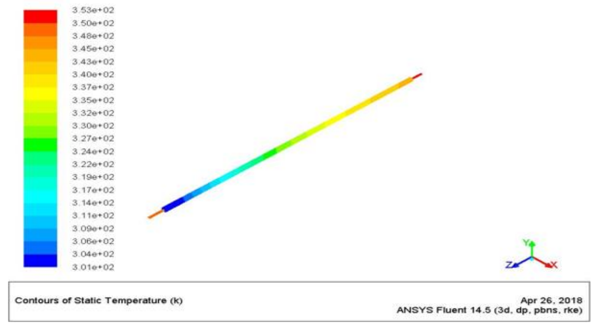


Figure 14 Contours of static Temperature at 0.4 Litre/minute for Water+3%BeO

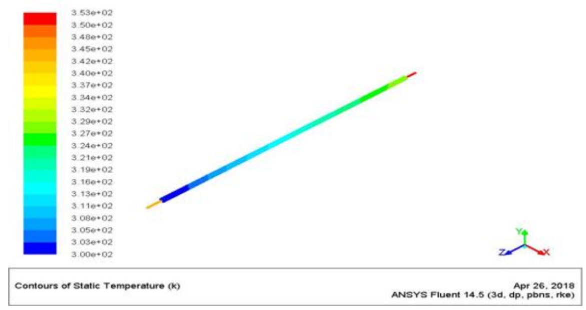


Figure 15 Contours of static Temperature at 1.0 Litre/minute for Water+3%BeO.

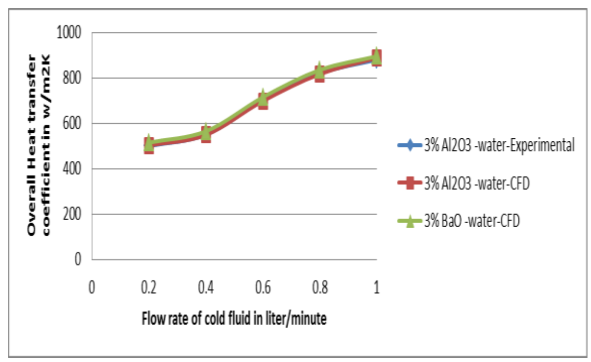


Figure 16 Comparison of Overall heat transfer coefficient against Nano fluids flow rate for 3.5 LPM of hot fluids flow rate

V. CONCLUSIONS

In this analysis, the cumulative effect on fins and Nano fluid 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;

- In order to validate the study, the dimensions of previous setup given in base paper were modeled and analysis is carried out.
- It is observed that between previous and present simulation results the variation is less than 1%.

- From the present study it has been observed that at various, 0.2, 0.4, 0.6,0.8.and 1 liter per minute mass flow rate of cold fluid and 3.5 liter per minute mass flow rate of hot fluid overall heat transfer coefficient is increased by 15% by using BeO Nano fluid .
- Fig 6.13 shows Overall heat transfer coefficient for different mass flow rate which confirms that overall heat transfer coefficient is maximum when BeO Nano fluid is used .

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