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Thermal Performance and Characteristics of Double Pipe Heat Exchanger with Different Nano Fluids by Using CFD

Chakransh Chourase [1], Surjeet Singh Rajpoot [2]

[1]Research scholar, Department of Mechanical Engineering, SCOPE College of Engineering, Bhopal.
[2]Associate Professor, Department of Mechanical Engg, SCOPE College of Engineering, Bhopal.

ABSTRACT

When transferring heat from one hot fluid to a cold fluid, a heat exchanger is utilised. Heat transfer rate and heat transfer coefficient are used to evaluate heat exchanger performance. The major goal of this research project is to improve heat exchanger performance by employing nano fluid. In a twin pipe U-bend heat exchanger, CFD analysis is used to estimate the heat transfer rate and heat transfer coefficient of nanofluid flow. Utilising the ANSYS 15.0 workbench, the U-bend heat exchanger prototype was created. In this work, the nanofluids include copper oxide (CuO), aluminium oxide (Al2O3), silicon dioxide (SiO2), and ethylene glycol. In this investigation, Nano fluids with volume fractions of 0.2%, 0.3%, and 0.4% were employed. The mass flow rate of hot fluid kept constant and the mass flow rate of Nano-fluids are varies from 0.155 kg/sec. The temperatures of Nano-fluids flow in a heat exchanger are kept at 342 K. The results revealed that as volume fractions are increased the heat transfer rate and heat transfer coefficient are increased, and Velocity and pressure are decreased. Based on the numerical results, the highest value of heat transfer coefficient and heat transfer rate is obtain from CuO Nano-fluids with 0.02% volume fraction. Al2O3 Nano fluids is the second best Nano fluids and its shows the good heat transfer coefficient and heat transfer rate as compare to other Nano fluids.

Key words: Nano fluid, Numerical analysis, Volume fraction, heat exchanger, heat transfer rate, enhancement of heat transfer.

1. Introduction

Heat exchanger is used for heat transfer from hot fluid to cold fluid. The performance of heat exchanger is analysed by of the heat transfer rate and heat transfer coefficient. The addition of Nano particles in the fluids is improves the performance of the heat exchanger and overall performance of the system. Ferrous oxide Nano fluids improved the heat transfer and friction factor characteristics of a circular tube heat exchanger [1]. Al2O3/water-based Nano-fluid improves the thermo-hydraulic performance of serpentine tube heat exchanger (STHX) [2]. MWCNT/water Nano fluids improves the heat transfer about 30% as compare to plain fluids and pressure drop enhanced about 11% [3]. The nano particle suspension in three-phase system including the solid phase (nano particles), the liquid phase (fluid media), and the interfacial phase, which contributes significantly to the system properties because of its extremely high surface-to-volume ratio in Nano fluids [4]. Nano fluids used in micro channels its latter properties considerably increased the heat transfer enhancement relative to “conventional” properties and heat transfer enhancement is comparable to the enhanced skin friction rise [5]. Nano fluids improve both thermal and optical properties of current solar conversion systems. Direct solar thermal absorption collectors incorporating a Nano fluid offers the opportunity to achieve significant improvements in both optical and thermal performance. Since Nano fluids offer much greater heat absorbing and heat transfer properties compared to traditional working fluids [6]. Nano fluids increase the rate of heat transfer without affecting much the overall performance of the system, it is very useful in evaporators, air-conditioning equipment, thermal power plants, space vehicle, and automobile [7]. Nano fluid mixture with low concentration of solid particles are provided qualitative results regarding the heat transfer enhancement and provided heat transfer mechanisms [8]. Nano fluids showing the good result with Reynolds number of 20,000 and expansion ratio of 2.86, with methane [9]. Nano fluids improves the heat transfer of turbulent heat exchanger and separation flow in a symmetric expansion plane channel with the 5000 to 35,000 Reynolds number [10]. Standard k-ε model is very useful for calculated turbulent kinetic energy and velocity. This model presented the new trend for calculating the different parameter which is very useful for evaluating the performance of the turbulent flow heat exchanger [11]. Nano fluids have been used because of its higher thermal conductivity compared to traditional fluids. A new modified low- Reynolds number k-ϵ turbulence model showing the high wall heat transfer with Reynolds numbers ranging from 200 to 600 and different Nano fluids such as Cu, Ag, Al2O3, CuO, and TiO2 [12]. Al2O3, CuO, SiO2, and ZnO, with volume fraction that varied from 1% to 4% and the expansion ratio was 2, improves the heat transfer. Their results indicated that increasing Reynolds number and volume fraction augment Nusselt number; the highest Nusselt number value was associated with SiO2 [13]. Nano fluid flow and heat transfer over a backward-facing step, the results showed that the maximum heat transfer enhancement was about 26% and 36% for turbulent and laminar range, respectively, compared with pure water [14]. Al2O3-water Nano fluid flowing through a circular pipe showing the enhancement of heat transfer rate as compare to plain fluids [15]. The shap and size of Nano particles greatly affected the performance of Nano fluids. The smaller sizes of nanoparticles with spherical shape showing the higher heat transfer and enhanced the efficiency of the system [16]. The single phase dispersion model showed good performance compared to the other models [17]. Laminar TiO2-H2O Nano fluid flow in a horizontal circular pipe increase the heat transfer rate [18].

Al2O3– water Nano fluid flowing through a horizontal tube increase the heat transfer rate [19]. Cu-water Nano fluid flow in a circular tube under both the laminar and turbulent flow had increased the heat transfer coefficient [20]. The addition Al2O3 nanoparticles in the base fluids had helped to enhance the heat transfer rate. The maximum enhancement was observed to be 15% and 20% respectively at 3% under both the laminar and turbulent flow conditions [21]. Nanostructured ceramic materials have used for as promising heat transfer fluid additives owing to their outstanding heat storage capacities [22]. Nano particles based nano fluids improves the heat transfer rate in both laminar and turbulent flow condition [23]. Copper oxide nanoparticles dispersed in ethylene glycol improves the heat transfer rate as compare to water mixture [24]. Al2O3 Nano fluid improves the heat transfer coefficient and reduced the friction factor [25].

2. Methodology

The CFD method follows the use of commercial software ANSYS FLUENT 15.0 for solving the problem. The solver in ANSYS-FLUENT used is a pressure correction based SIMPLE algorithm with 2ndorder upwind scheme for discretise the convective transport terms. The heat transfer coefficients are also obtained using CFD methods and compared with analytical values. After determining the important features of the problem following procedure is followed for solving the problem in which first of all we need to specify the solution method, and initialize the solution, then run the calculation. Initially create geometry model in the ANSYS workbench, as per the experimental setup design. Meshing was done on the geometry model by program controlled and sizing was done to get the required element size, nodes and smoothening. After getting the required size of element and meshing, naming selection was done to the domain before getting the results.

3. Geometry and Modeling and boundary conditions

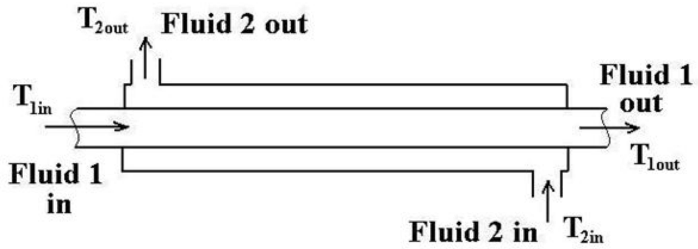

Figure 1 Schematic representation of double pipe heat exchanger

Figure represents the schematic diagram of double pipe U-bend heat exchanger. The analysis is performed on a 2-pass double pipe heat exchanger with the inner diameter of inner pipe is 0.019 m & outer diameter of inner pipe is 0.025 m, similarly for annulus pipe, the inner diameter of outer pipe is 0.05 m & outer diameter of outer pipe is 0.056 m and the total length of heat exchanger is 2.36 m (2-pass). The mass flow rate of hot water kept constant over annulus section, with different temperatures and the mass flow rate of cold water constant. There is insulation for outer wall of annulus pipe with asbestos rope to minimize the heat losses.

4. Meshing of geometry

Structured meshing method in ANSYS WORKBENCH was used for the geometry. The element for meshing considered is hexahedral shape with number of elements of 876874 to 1240000. Naming selections were also done at required places.

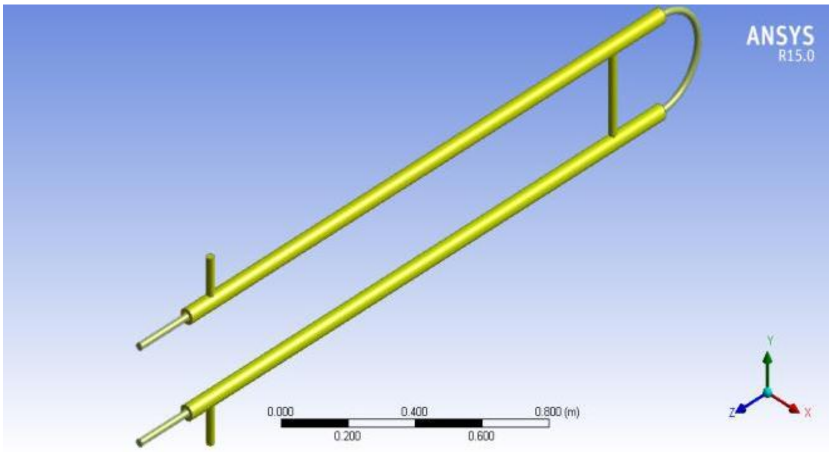

Figure 2 Geometry modelling of 2-Pass Double Pipe in ANSYS work bench

Table:- 1 Grid test results & Final mesh elements of 1124397 have been used for simulation

No. of Elements	**Cold water outlet temp (0C)**	**Hot water outlet temp (0C)**
876874	31.458	53.970
895812	31.625	53.625
856253	30.256	44.325

5. Boundary Conditions

A Velocity inlet, uniform mass flow inlets and a constant inlet temperature were assigned at the channel inlet. At the exit, pressure was specified.

Table:-2 Boundary Conditions

S.No.	Boundary Condition	Outer Pipe	Inner Pipe
1	Mass flow rate in inlet	0.155 kg/s	0.261 kg/s
2	Temperature	342 K	300 K

6. Results and discussions

As mentioned above, four types of Nano fluids (Al2O3, CuO, SiO2 and Ethylene Glycol) were used at three volume fractions as shown in Tables. In order to study the thermal performance of the heat exchanger the mass rate flow was 2Kg/s and the inlet temperature was 353K. For each Nano fluid, experiments were conducted for three volume fractions. As an example in this paper, Figures show the computational fluid dynamics (CFD) analysis of the heat exchanger by using all Nano fluids at three volume fractions (0.2, 0.3 and 0.4). Figure 8 shows the plot of the pressure against Nano fluid types at different volume fractions.

6.1 Compression of Velocity and different Nano fluid with different volume fraction:

As can be seen, the highest value was recorded within Ethylene Glycol at volume fraction 0.2 while the smallest value was documented within copper oxide Nano fluid at volume fraction 0.4. This might be because the density of the Ethylene Glycol Nano fluid has the smallest value at 0.2 volume fraction while the density of Copper oxide Nano fluid has the greatest value as per the tables.

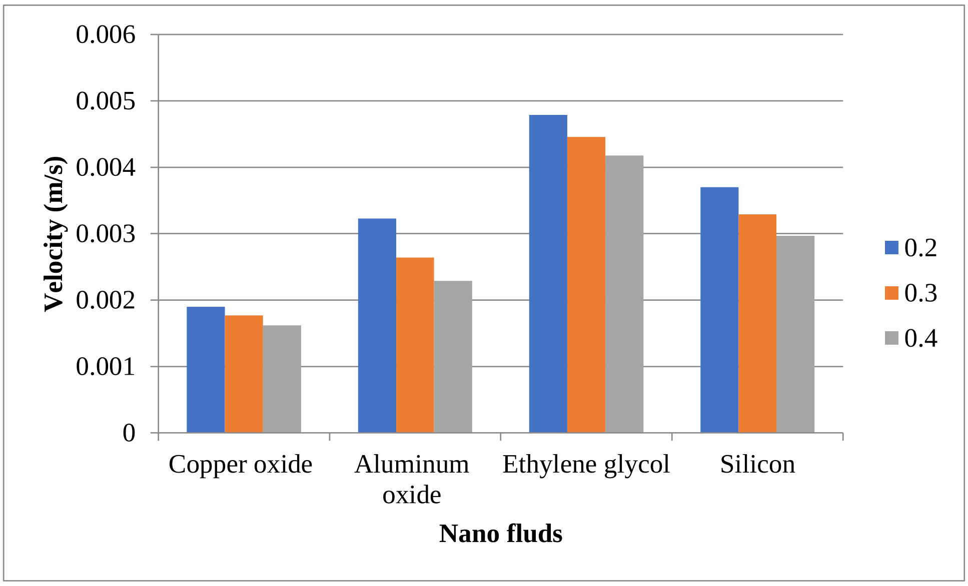

Figure 3 Velocity Vs different Nano fluids

6.2 Compression of Pressure and different Nano fluid with different volume fraction

As we can seen in the graph the value of pressure increased dramatically when copper oxide was used at volume fraction 0.4. There are very small different between silicon oxide and aluminum oxide. The lowest pressure was recorded when Ethylene Glycol was used at volume fraction 0.4.

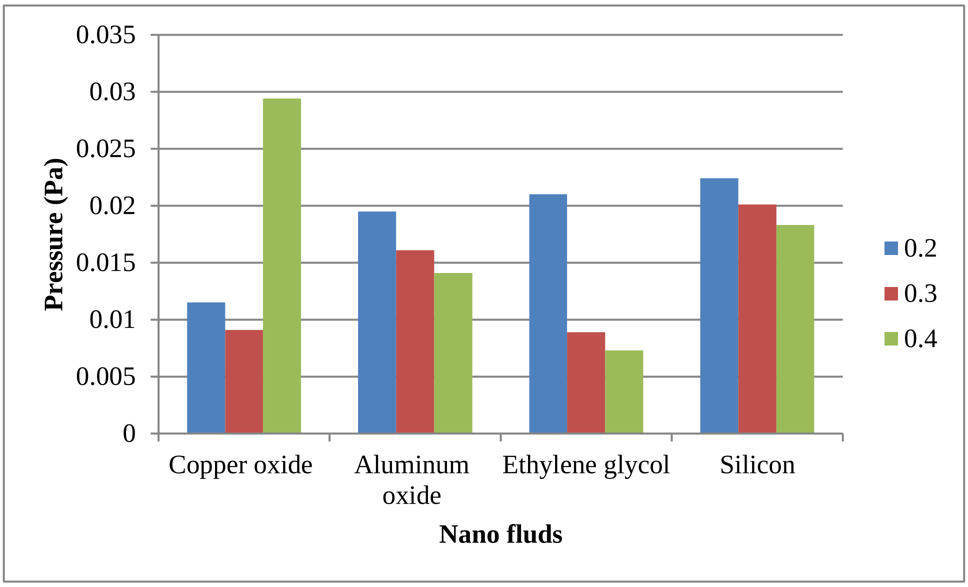

Figure 4 Pressure Vs nano fluids

6.3 Compression of Heat Transfer Coefficient values of different Nano fluid with different volume fraction

The heat transfer coefficient value of Nano fluids will effect of the movements of the fluids inside the heat exchanger. Graph presents the heat transfer coefficient as a function of Nano fluids at different volume fractions. The highest value was recorded when Al_2O_3 was used at volume fraction 0.2 while the smallest value was documented when SiO_2 was used at volume fraction 0.3. Copper oxide Nano fluids with 0.2 volume fraction show the second highest value of heat transfer coefficient.

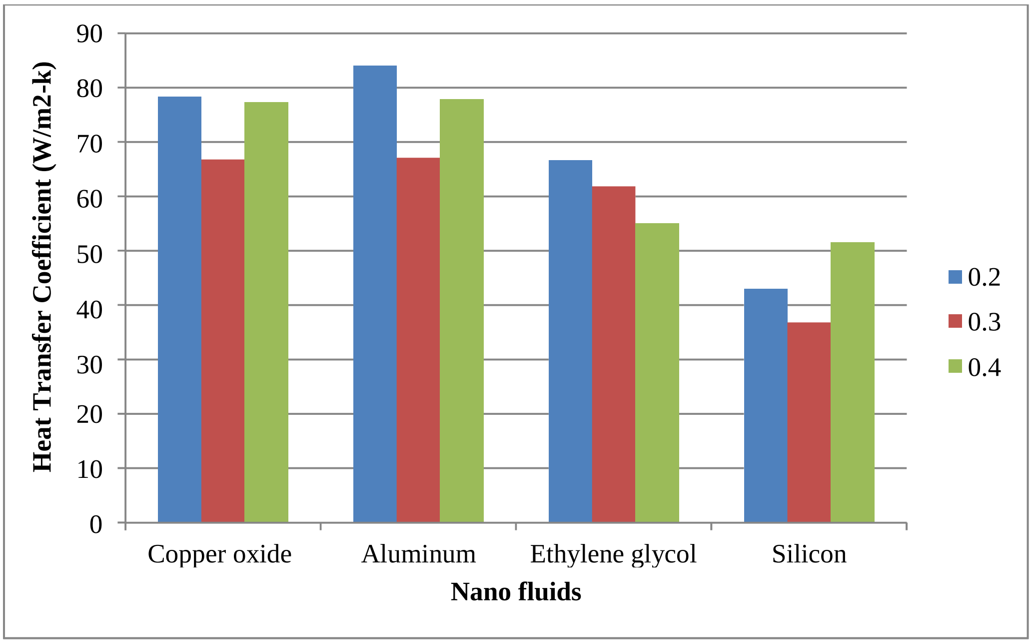

Figure 5 Heat Transfer Coefficient vs. different Nano fluids

6.4 Compression of Heat Transfer Rate and different Nano fluid with different volume fraction

The effect of Nano fluids types on the heat transfer rate of the heat exchanger was also studied as shown in Figure. As we can seen, adding CuO Nano particles to the base fluid increased heat exchanger heat transfer rate in comparison with other nano particles. It may be because the CuO Nano fluid has greatest thermal conductivity compared to other types Nano fluid as per the table. It may be also because the CuO Nano fluid had the lowest values of outlet velocity; there for, the fluid had sufficient time for contacting with air so the heat transfer rate increased.

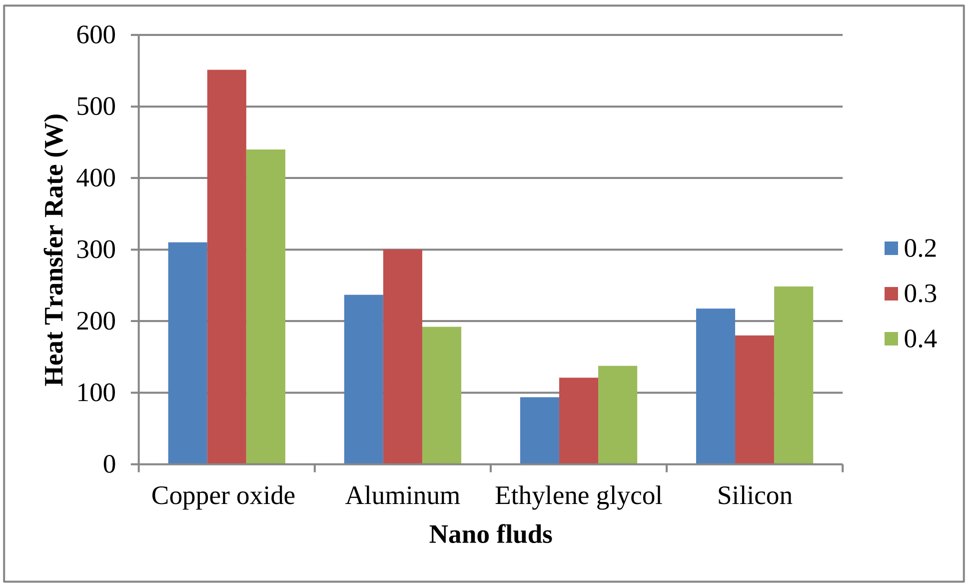

Figure 6 Heat Transfer Rate vs. different Nano fluids

7. Conclusions

Computational Fluid Dynamics (CFD) analysis was done on the Heat exchanger for four types of Nano fluids (Al2O3, CuO, SiO2, and Ethylene Glycol) at three volume fractions (0.2, 0.3 and 0.4). It should be confirmed that increasing the heat transfer rate for any cooling system will indicate to better thermal performance of the cooling system. Overall, it can be said that CuO Nano fluid showed the best performance and Al2O3 Nano fluid was the second best in comparison with other Nano fluids. It can be concluded that,

- The value of pressure is more when CuO was used at volume fraction 0.4 in comparisons with other Nano fluids. The value of pressure of SiO2 and Al2O3 at 0.2 volume fraction is almost similar.
- The highest value of the heat exchanger outlet velocity was recorded within Ethylene Glycol at volume fraction 0.2 and lowest value of velocity is CuO with 0.2 volume fraction.
- The highest values of the heat transfer coefficient was recorded when Al2O3 is used with 0.2 volume fraction. CuO Nano fluids with 0.2 volume fraction shows almost similar value of heat transfer coefficient.

The heat transfer rate was more when CuO Nano particles were added to the base fluid in comparison with other nano particles.The high value of heat transfer rate is indicated to better thermal performance of the cooling system. Overall, it can be said that CuO Nano fluid shows the best performance in comparison with other Nano fluids. An Al2O3 Nano fluid is the second best Nano fluids.

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