Performance Evaluation of Copper Oxide (CuO) BasedNano fluids in double pipe U - tube heat exchanger by using CFD

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Abstract

Heat exchanger is used for heat transfer from one hot fluid to cold fluid. The performance of heat exchanger is analysed by of the heat transfer rate and heat transfer coefficient. The main objective of this research work is increased the performance of the heat exchanger by using Nano fluid. CFD analysis is performed for the estimation of heat transfer rate and heat transfer coefficient of Nano-fluid flow in a double pipe U-bend heat exchanger. Theprototype of U-bend heat exchanger was developed using ANSYS 14.0 workbench. In this study Aluminium oxide (Al_2O_3,), Copper oxide (CuO), and Ethylene Glycol are used as a Nano fluids The volume fraction of Nano fluids are 0.2%, 0.3% and 0.4% were used in this analysis. The mass flow rate of hot fluid kept constant and the mass flow rate of Nano-fluids are varies from 0.154 kg/sec.The temperatures of Nano-fluids flow in a heat exchanger are kept at 343 K. The results revealed that as volume fraction are increased the heat transfer rate and heat transfer coefficientare increased, and Velocity and pressure are decreased. Based on the numerical results, the highest value of heat transfer coefficientis obtain from Al_2O_3 Nano-fluids with 0.02% volume fraction and highest heat transfer rate is CuO Nano fluid with 0.03% volume.

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

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. 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 [1]. The nanoparticle suspension in three-phase system including the solid phase (nanoparticles), 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 [2]. MWCNT/water Nano fluids improves the heat transfer about 30% as compare to plain fluids and pressure drop enhanced about 11% [3]. Al_2O_3/water-based Nano-fluid improves the thermo-hydraulic performance of serpentine tube heat exchanger (STHX) [4]. Ferrous oxide Nano fluids improved the heat transfer and friction factor characteristics of a circular tube heat exchanger [5].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 TiO_2 [12]. Al_2O_3, 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 SiO_2 [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]. Al_2O_3-water Nano fluid flowingthrough a circular pipe showing the enhancement ofheat 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 TiO_2-H_2O Nano fluid flow in a horizontal circular pipe increase the heat transfer rate [18]. Al_2O_3– 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 Al_2O_3 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]. Al_2O_3 Nano fluid improves the heat transfer coefficient and reduced the friction factor [25].

Methodology

The CFD method follows the use of commercial software ANSYS FLUENT 14.0 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 controlledand 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.

Geometry and Modelling and boundary conditions

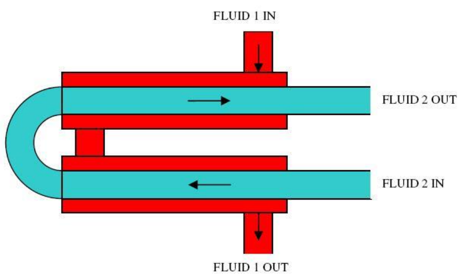

Figure: -1 Schematic representation of double pipe U-bend heat exchanger

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.

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.

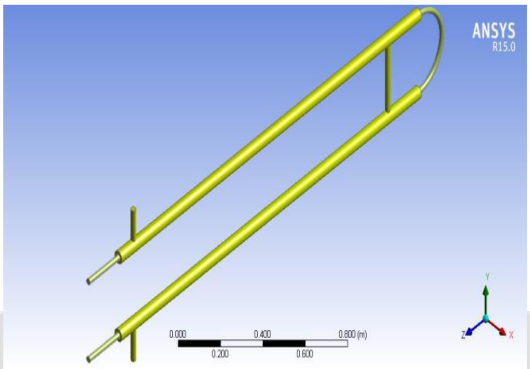

Figure:-2Geometry modelling of 2-Pass Double Pipe in ANSYS work bench

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

No. of Elements	**Cold water outlet temp (^{0}C)**	**Hot water outlet temp (^{0}C)**
876974	31.458	53.970
895612	31.625	53.625
856553	30.256	44.325

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

Thermo-Physical Properties of materials:

Pure water is used as base fluid, and Nano particles of Al_2O_3, CuO and ethylene glycol fluid used as working fluid, the properties are shown in below.

Table:-3 Thermo-Physical Properties of Nano particles

Material	Thermal conductivity (W/m-k)	Specific heat (j/kg-k)	Density (kg/m3)	Viscosity (kg/m-s)
Water	0.605	4195	997.1	0.0010 03
Al_2O_3	31.92 2	873.33 6	3950	----------
Copper Oxide	400	385	8933	----------
Ethylene Glycol	0.258 0	837	1110	----------

Results and discussion

Three types of Nanofluids Aluminium Oxide (Al_2O_3), Copper Oxide (CuO) and Ethylene Glycol were used at three volume fractions 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 Nanofluid, experiments were conducted for three volume fractions. 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 shows the velocity, pressure heat transfer rate, and heat transfer coefficients of different Nano fluids.

Compression of Pressure and different nano fluid

As can be seenthe value of pressure increased dramatically when CuO was used at volume fraction 0.3 in comparisons with other Nanofluids. The lowest pressure was recorded when Ethylene Glycol was used at volume fraction 0.4.

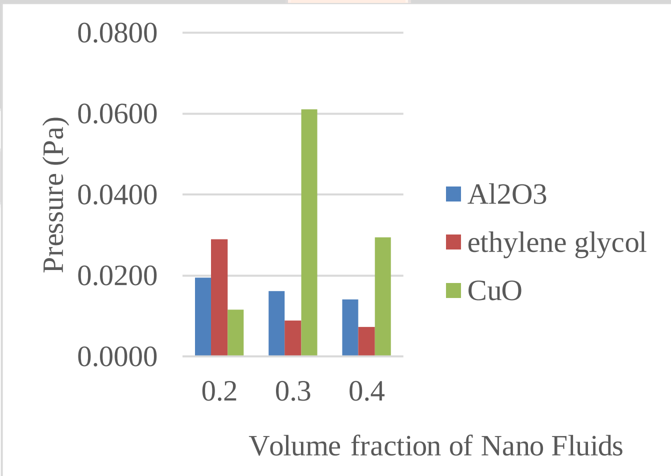

Figure: -3 Pressure vs. Nano fluids

Compression of Velocity and different Nano fluid

As can be seen, the highest value was recorded within Ethylene Glycol at volume fraction 0.2 while the smallest value was documented within CuO fluid at volume fraction 0.4.This will effect of the movements of the fluids inside the heat exchanger.

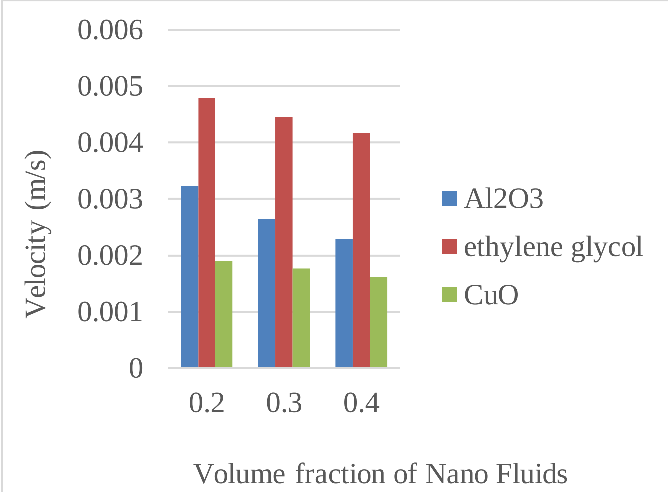

Figure:-4 Velocity vs. Nano fluids

Compression of Heat Transfer Coefficient values of different nano fluid

The highest value was recorded when Al_2O_3 was used at volume fraction 0.2 while the smallest value was documented when Ethylene Glycol was used at volume fraction 0.4.

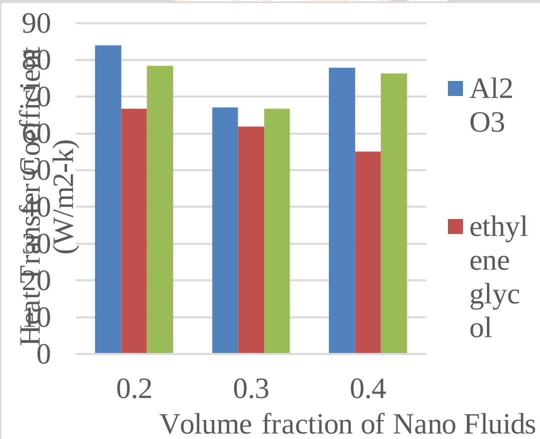

Figure: 5 Heat Transfer Coefficient vs. Nano fluids

Compression of Heat Transfer Rate and different Nano fluid

As can be seen, adding CuO nanoparticles to the base fluid increased heat transfer rate in comparison with other nanoparticles. It may be because the CuO Nanofluid has greatest thermal conductivity compared to other Nanofluid types.

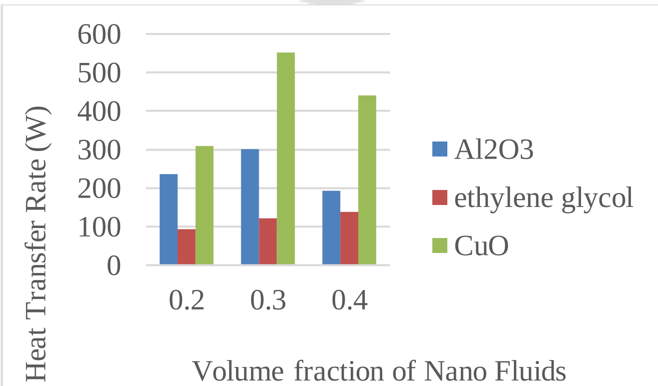

Figure:-6Heat Transfer Rate vs. Nano fluids

Conclusion

Computational Fluid Dynamics (CFD) analysis was done on the heat exchanger for three types of Nano fluids (Al_2O_3, CuO and Ethylene Glycol) at three volume fractions (0.2, 0.3 and 0.4).

It can be concluded that,

- The value of pressure is more when CuO was used at volume fraction 0.3 in comparisons with other Nano fluids.
- The highest value of the heat exchanger outlet velocity was recorded within Ethylene Glycol at volume fraction 0.2.
- The highest values of the heat transfer coefficient was recorded when Al_2O_3 and CuO were used.
- The heat transfer rate was more when CuO nanoparticles were added to the base fluid in comparison with other nanoparticles.
- The high value of heat transfer rate for any cooling system indicated to better thermal performance of the cooling system.

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 Al_2O_3 Nano fluid was the second best in comparison with other Nano fluids.

Future Scope

It is expected that knowing the above parameters & readings, we can calculate Results. For further improvement in the quality of the heat exchangers we may implement some more modifications. For better exchange of heat experimental work may be done at different Nano fluids with high volume fraction and for enhancing heat exchange we may also increase experiment work may be done at high Reynolds number using different cross sections.

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