Available online at www.sciencedirect.com

ScienceDirect

Materials Today: Proceedings XX (2016) XXX–XXX

materialstoday: PROCEEDINGS

www.materialstoday.com/proceedings

PMME 2016

A CFD Investigation of Heat Transfer Enhancement of Shell and Tube Heat Exchanger Using Al_2o_3-Water Nanofluid

K.Somasekhar [a *], K.N.D.Malleswara Rao[b],V.Sankararao[c], Raffi Mohammed[d], M.Veerendra[e] and T.Venkateswararao[e]

[a,c,e]*Assistant Professors, Department of Mechanical Engineeirng, Lakireddy Bali Reddy College of Engineeirng, Mylavaram - 521230, AP, India*
[b]*Assistant Professor, Department of Mechanical Engineeirng,Andhra Loyola Institute of Engineering and Technology, Vijayawada-520008,AP,India*
[d]*Associate Professor, Department of Mechanical Engineeirng,NRI Institute of Technology, Potavarappadu-522212,AP, India*
[e]*Assistant Professor, Department of Mechanical Engineeirng,Vikas Group of Institutions, Nunna-521212, AP,India*

Abstract

A multi pass shell and tube heat exchanger with 3 tubes modelling 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.

* Corresponding Author

Selection and Peer-review under responsibility of International Conference on Processing of Materials, Minerals and Energy (July 29th – 30th) 2016, Ongole, Andhra Pradesh, India.

Keywords: Catia, multipass shell and tube exchanger, icem CFD, CFD fluent and AL2O3 water nanofluid;

1. Introduction

The importance of heat exchangers has increased immensely from the view point of energy conservation and environmental concerns. Heat exchanger plays a significant role in the operation of many systems such as power

Selection and Peer-review under responsibility of International Conference on Processing of Materials, Minerals and Energy (July 29th – 30th) 2016, Ongole, Andhra Pradesh, India.

plants, process industries and heat recovery units. Among of all type of exchangers, shell and tube exchangers are most commonly used heat exchange equipment. A Nanofluid is a fluid containing nanometre-sized particles, called nanoparticles. These fluids are engineered colloidal suspensions of nanoparticles in a base fluid. The nanoparticles used in nanofluids are typically made of metals, oxides, carbides, or carbon nanotubes. Common base fluids include water, ethylene glycol and oil. Nanofluids have novel properties that make them potentially useful in many applications in heat transfer, including microelectronics, fuel cells, pharmaceutical processes, and hybrid-powered engines, engine cooling/vehicle thermal management, domestic refrigerator, chiller, heat exchanger, in grinding, machining and in boiler flue gas temperature reduction. They exhibit enhanced thermal conductivity and the convective heat transfer coefficient compared to the base fluid. Knowledge of the rheological behaviour of nanofluids is found to be very critical in deciding their suitability for convective heat transfer applications. Heat transfer characteristics of Al_2O_3/water and TiO_2/water nanofluids were measured in a shell and tube heat exchanger under turbulent flow condition. [1] An experimental study is carried out to investigate the heat transfer characteristics of silver/water nanofluids in a shell and tube heat exchanger. [2] The heat transfer characteristics of Al2O3 – water nanofluid as a coolant used in concentric tube heat exchanger. [3]

Nomenclure	
Pe	Peclet Number
φ	Volume Fraction of nanofluid
Nu	Nusselt number
nf	Nanofluid
U_i	Overall heat transfer coefficient based on inside area
sim	simulated value
Exp	experimental value

2. Modeling of Shell and Tube Heat Exchanger:

2.1 Model Description

The shell and tube heat exchanger consists of the following components:

- Shell
- U Tubes
- Straight Baffles (25% cut segmental baffles)

2.1.1Specifications of Shell and Tube

A single shell and 2 pass tube heat exchanger is selected for analysis purpose.
The specifications of heat exchanger are given below:

Table 2.1 Specifications of shell

Material	Stainless steel
Inner Diameter	208mm
Outer Diameter	218mm
Length	500mm
25% Cut segmental Baffles	4 no's

Table 2.2 Specifications of the Tubes

Material	Stainless Steel
Outer diameter	16mm
Inner diameter	14mm
Length	500mm
No of tubes	3 no's
Arrangement	Square layout

2.2 Modelling And Mesh Generation

The geometric model was developed in CATIA v5r19 and this model is exported to ICEM CFD module in ANSYS 14.5 version inparasolid format to obtain the finite element model and to carry out the required analysis. The geometric model of the shell and tube heat exchanger is shown in Fig 2.1. Meshing has done in ICEM CFD module in ANSYS 14.5 version. The meshing element used for meshing the whole domain was hexahedral element. Hexa module is a semi-automated meshing module and presents rapid generation of multi-block structured or unstructured hexahedral volume meshes. The total number of nodes and elements obtained for shell and tube heat exchanger are 140087 and 543461 respectively. The finite element model is shown in Fig 2.2.

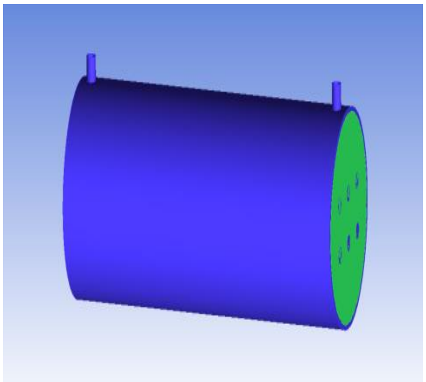


Fig 2.1 Geometric model of shell and tube heat exchanger

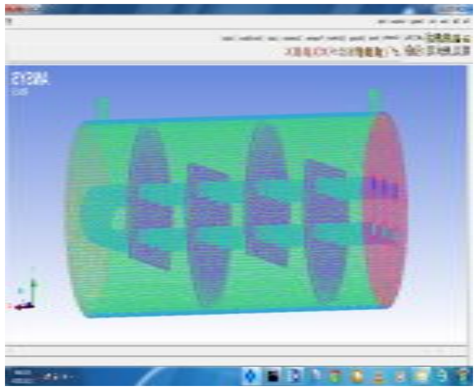


Fig 2.2 Finite element models

3. Thermo physical Properties of the Nanofluid

Thermo Physical properties of the Al_2O_3-water nanofluid are calculated by using Pak and Cho correlations. [4]

Table 3.1 Physical properties of nanoparticles

Particle	**Size(nm)**	**Density(kg/m^3)**	**Thermal Conductivity(W/mK)**	**Specific Heat (J/kgK)**
Al_2O_3	25	3970	46	750

Table 3.2 Tube Side cold fluid (Al_2O_3-H_2O nanofluid) Properties: Nanofluid properties are calculated using Pak & Cho correlations

S.NO	**Volume fraction**	**Thermal conductivity, (W/m-K)**	**Density, (kg/m$^{3)}$**	**Dynamic viscosity, (Ns/m$^{2)}$**	**Specific heat, (J/kg K)**
1	0.3%	0.622	1003.76	0.000795	4143.51
2	0.5%	0.628	1009.17	0.000799	4119.51
3	0.75%	0.633	1015.93	0.000804	4089.87
4	1%	0.641	1022.69	0.000810	4060.62
5	2%	0.664	1049.73	0.000829	3885.36

4. Results and discussion

Shell side - hot fluid (Pure water), Tube side - cold fluid: 1.Distilled water 2. Al_2O_3-water nanofluid
Shell side fluid-hot fluid inlet temperature = 363K, Tube side - cold fluid inlet temperature = 303K

Before conducting the experiments with nanofluids, initially the CFD simulation results are compared with experimental results for validating the simulation results. Initially simulation has done with hot fluid Pure water and cold fluid Distilled water. The experimental Nusselt number values are then compared with the CFD simulation Nusselt number as shown in Fig: 4.1. A good agreement with a deviation of 8 % is observed between the experimental Nusselt number and with CFD simulated Nusselt number, thus validating the CFD simulation results for its accuracy.

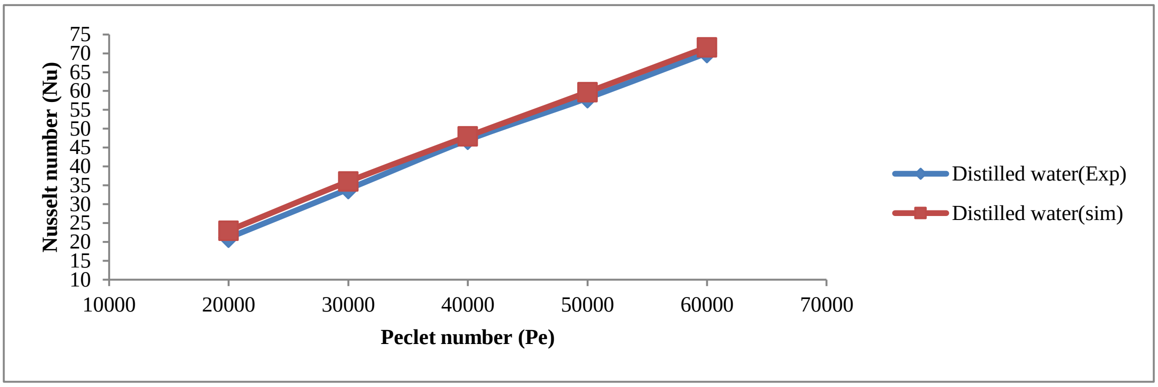
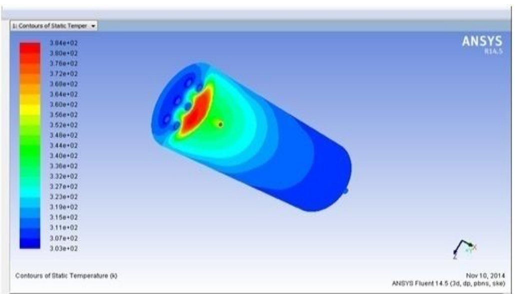


Fig4.1 Comparison of experimental Nusselt number with CFD simulated Nusselt number

4.1 Results of simulation

Thermal behaviour of a shell and tube heat exchanger is studied. Distilled water and Al_2O_3 - water nanofluid were used as the cooling mediums in the shell and tube heat exchanger. A steady state computational fluid dynamics (CFD) models was simulated by FLUENT module in ANSYS 14.5 version. The temperature variation on shell side & tube side contours of shell and tube heat exchanger are shown in Fig 4.2 & 4.3. The hot fluid on the shell side losses heat to the cold fluid as it flows along the length of the shell. The cold fluid on the tube side absorbs heat from the hot fluid as it flows along the length of the tube. It is observed that the temperature of the hot fluid stream on shell side is decreasing as it flows from inlet to outlet and simultaneously the temperature of the cold fluid stream is increasing as it flows along the length of the tube.



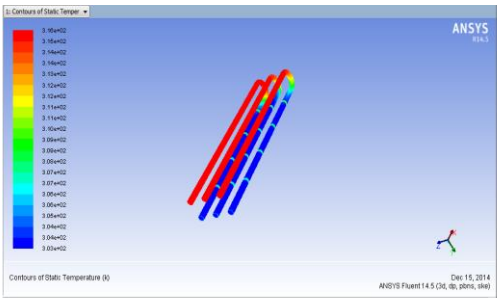


Fig:4.2 Temperature variation on shell side

Fig:4.3 Temperature variation on tube side

Tube side fluid temperature variation with respect to Peclet number is as shown in Fig: 4.4. Nanofluids exhibit higher heat exchange when compared with that of the base fluid (Distilled water). For example, at Pe=20000 the exit temperature of the cold fluid (Distilled water) from the Tube side is found to be 333K and for the Pe=20000 with 0.3% volume concentration of Al_2O_3-water nanofluid, the cold fluid outlet temperature is found to 334K. It is observed that there is an increase in Tube side fluid temperature of 1K even for a small increase in the volume concentration of Al_2O_3 nanoparticles. The increase in Tube side cold fluid temperature when compared to Distilled water for 2% volume concentration Al_2O_3-water nanofluid is observed to be 2.4 K for Pe=60000. The increase in Tube side hot fluid temperature for 0.3%, 0.5%, 0.75%, 1%, 2% volume concentrations of Al_2O_3-water nanofluid is found to be 0.5K, 1K, 1.5K, 1.9K, 2.4K respectively.

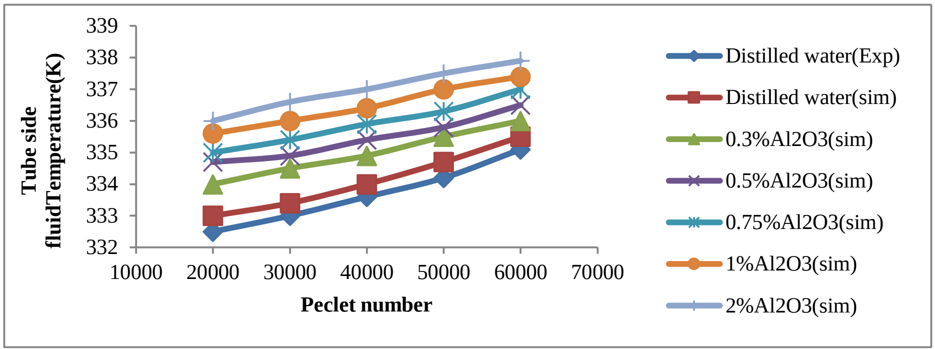


Fig:4.4 Temperature variation on tube side fluid with respect to Peclet number

Fig: 4.5 represent the overall heat transfer coefficient with respect to the Peclet number for Distilled water and Al_2O_3-water nanofluids. It is clearly observed that the overall heat transfer coefficient of nanofluids is found to be higher than that of Distilled water, due to enhanced thermo physical properties such as thermal conductivity and reduced specific heat capacity. The percentage increase in overall heat transfer coefficient when compared to Distilled water for 2% Al_2O_3-water nanofluid is observed to be 2.6% for Pe=60000. The overall heat transfer coefficient increase for 0.3%, 0.5%, 0.75%, 1%, 2% volume concentrations of Al_2O_3-water nanofluid is found to be 0.28%, 0.86%, 1.45%, 2.01%, 2.6% respectively.

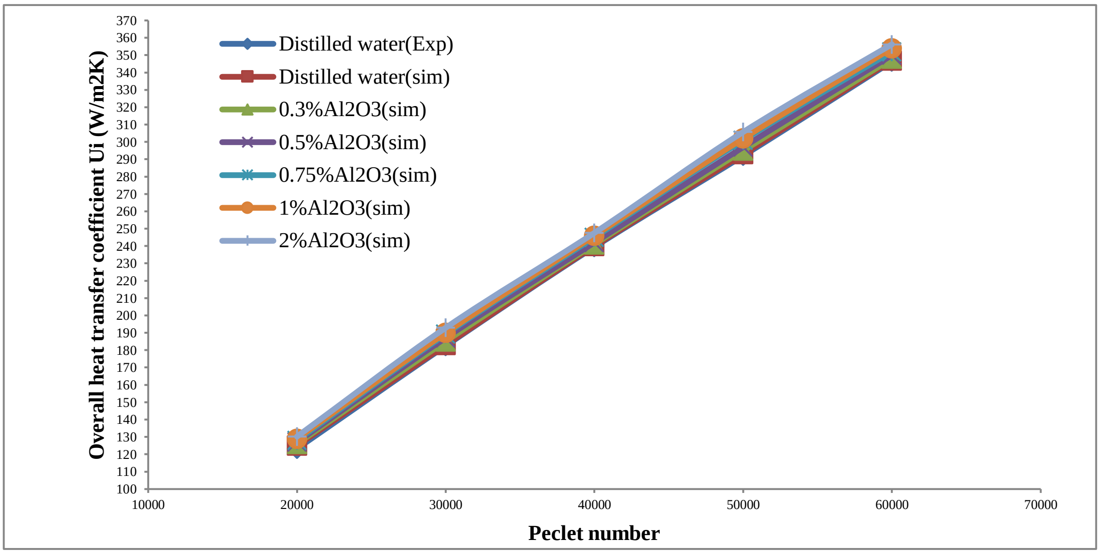


Fig: 4.5 Variation of overall heat transfer coefficient U_i (W/m^2) Vs Peclet number

The variation of Nusselt number with respect to Peclet number and particle concentration is shown in Fig:4.6.It is found that the dimensionless heat transfer coefficient increases with the increases in particle concentration and flow rates and the enhancement is profound at higher Peclet number. The percentage increase in Nusselt number when compared to Distilled water for 2% Al_2O_3-water nanofluid is observed to be 7.54% for Pe=60000. The

Nusselt number increase for 0.3%, 0.5%, 0.75%, 1%, 2% volume concentrations of Al_2O_3-water nanofluid is found to be 0.55%, 2.65%, 4.05%, 5.58%, 7.54% respectively.

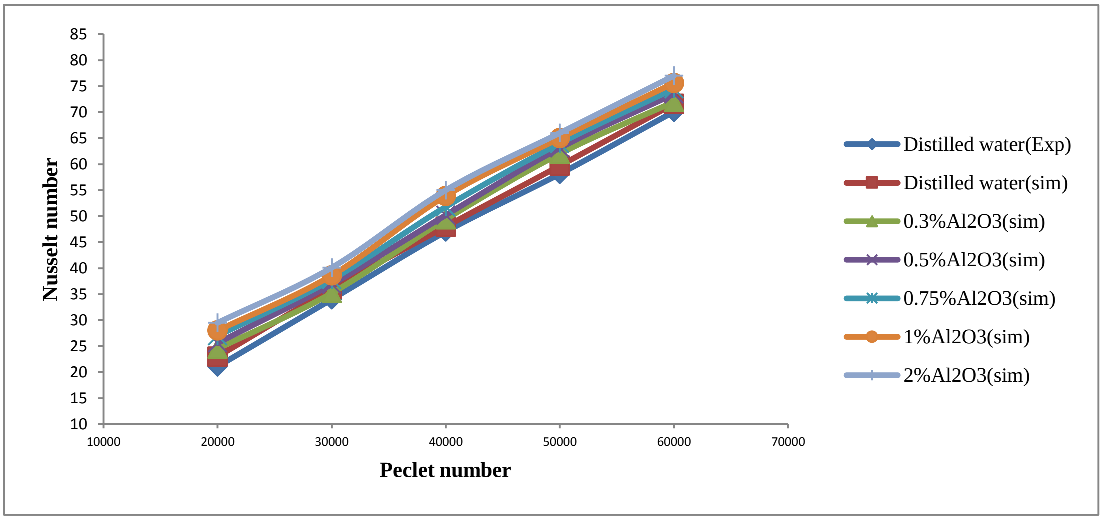


Fig:4.6 Variation of Nusselt number with respect to Peclet number.

4.2 Comparison of CFD simulated results of cooling mediums

Table4.1 Comparison of CFD simulated results of cooling mediums

Physical Properties	Distilled water as a cooling medium	Al2O3- Water nano fluid as a cooling medium at Pe=60000, 2% volume fraction	% Enhancement Or % Reduction
Over heat transfer coefficient U_i (W/m^2K)	347	356.2	2.65% enhancement
Nusselt number	71.6	77	7.54% enhancement

5.conclusion

- For effecting cooling of shell and tube heat exchanger Al_2O_3-H_2O nanofluid is the better cooling medium than the Distilled water cooling medium.
- By using of Al_2O_3-H_2O nanofluid as a cooling medium pressure drop increases on tube side than the Distilled water cooling medium.

6.References

[1] **B. Farajollahi, S.Gh. Etemad , M. Hojjat.**, Heat transfer characteristics of Al_2O_3/water and TiO_2/water nanofluids, 14(2014)489-496, 23 Aug 2013 @ Elsevier Ltd.

[2] **L. Godson, K. Deepak, C. Enoch, B. Jefferson** carried out An experimental study is carried out to investigate the heat transfer characteristics of silver/water nanofluids in a shell and tube heat exchanger, 53 (2010) 12–2 Nov 2009 @ Elsevier Ltd.

[3] **Shriram S. Sonawane, Rohit S. Khedkar, Kailas L. Wasewar**," Study on concentric tube heat exchanger heat transfer performance using Al2O3 – water based nanofluids", International Communications in Heat and Mass Transfer 49 (2013) 60–68@ 2013 Elsevier Ltd.

[4] **B.C. Pak, I.Y. Cho,** Hydrodynamic and heat transfer study of dispersed fluids with sub-micron metallic oxide particles, Experimental Heat Transfer 11 (1998) 151–170.