International Journal of Advance Research in Science and Engineering
Volume No.07, Issue No.02, February 2018
www.ijarse.com
IJARSE
ISSN: 2319-8354

ANALYSIS OF EFFECTIVENESS FOR PLATE HEAT EXCHANGER (PHE) USING AL_2O_3 AND TIO_2 BASED NANOFLUIDS

D.Bahar[1], Jakirahemed MD[2], K. Srikanth[3]

[1]*Assistant Professor, Department of Mechanical Engineering,*
Rajiv Gandhi University of Knowledge Technologies, Basar, Nirmal-504107 (TS).
[2]*Assistant Professor, Department of Mechanical Engineering,*
Rajiv Gandhi University of Knowledge Technologies, Basar, Nirmal-504107 (TS)
[3]*Assistant Professor, Department of Chemical Engineering,*
Rajiv Gandhi University of Knowledge Technologies, Basar, Nirmal-504107 (TS)

ABSTRACT

In order to reduce the environmental impact and save energy, researchers are concerned to improve the thermal efficiency of heat exchangers. Previous work by researchers recommends that nanofluids have great potential to improve the thermal performance of heat exchanger. Nano fluids are colloidal suspensions of nano sized particles in the conventional base fluid such as water, engine oil and ethylene glycol etc. The nano particles include chemically stable metals, metal oxides and non- metallic. Addition of nano sized particles in the base fluid increases the thermal conductivity of fluid and consequently increases the heat transfer rate in heat exchangers.The present study analyses the thermal performance of nano fluids and investigated the variety of nano fluids as working fluids in plate heat exchanger (PHE). A model of PHE is designed in Solid Works and this model has been analysed with nano fluids in ANSYS software. A combination of water-Al2O3 and water-TiO2 as nano fluids with volume fraction of 0.2 is used in PHE and results of heat transfer rates are compared for three cases of flowing fluids as follows.

Case-1: cold fluid as well as hot fluid is used as water

Case-II: cold fluid as water and hot fluid as a mixture of water-TiO2 (0.2 volume fraction)

Case-III: cold fluid as water and hot fluid as a mixture of water-Al2O3 (0.2 volume fraction)

After analysis it is found that thermal performance of PHE will be comparatively better in Case-III. Therefore it is suggested to use water-Al2O3 as a nano fluid.

Key words: Plate Heat Exchanger (PHE), Nano Fluid, Nano particles, SolidWorks, ANSYS.

I INTRODUCTION

Heat exchanger is a device that promotes the transfer of heat between two fluids that are at different temperatures. Heat exchangers are commonly used in practice in a wide range of applications from households up to large plants. There are many types of heat exchangers but plate type heat exchanger is one of the best devices for the advancement and technological development in compact heat exchanger. It consists of a stack of stamped heat exchange plates which are either bolted or brazed together in a frame with gaskets due to its high thermal efficiency [1-2]. It has been addresses that the number of plates depends upon the flow rate, physical properties of the fluids, pressure drop and temperature [3]. A simple model of plate heat exchanger with directional flow of fluid is shown in Fig 1. The cold and hot fluid flows in opposite directions on either side of the plates. Water flow controlled by the placement of the plate gaskets and by changing the position of the gasket, water can be channelled over a plate or past it. Gaskets are fitted in such a way that fluids cannot mixed due a gasket failure.

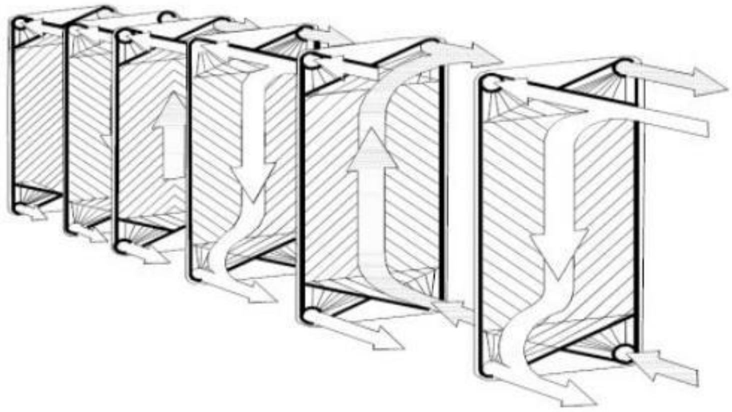

Figure 1: Plate heat exchanger

One of the ways to enhance the heat transfer by convection is to increase the thermal conductivity of the fluid. Since the publication of Maxwell's theoretical work lot of research is carried out on suspensions containing solid particles [4]. However owing to high density and large size, solid particles settle out of suspension. To resolve this problem nanotechnology pave the way to produce materials with average crystallite sizes below 50nm. Nano fluids suspend nanoparticles, a term coined by Choi in the Argonne National Laboratory, U.S.A. in 1995 [5]. Nano fluids can alter the fluid flow and heat transfer characteristics of the base fluids. Keblinski et al. [9] reviewed in a simple way to discuss the properties of nanofluids.Tiwari et al.[6] concluded experimentally that the optimum volume concentration of Al2O3, CeO2, SiO2and TiO2 nano particles in water should be 1.25, 1.0, 0.75 and 0.75 vol.%, for effectiveness, overall heat transfer coefficient, convective heat transfer coefficient and maximum heat transfer rate respectively. Javadi et al. [7] used SiO2, TiO2 and Al2O3 nanofluids in a plate heat exchanger and concluded that if nano particles volume concentration increases, Prandtl number decreases. Tiwari et al. [8] performed an experiment on a plate heat exchanger by using different nanofluids (CeO2, Al2O3, TiO2 and SiO2) and concluded that lower volume concentrations TiO2, CeO2 and the higher volume concentrations Al2O3, SiO2 nano particles shows better heat transfer characteristics. In the present work, plate type heat exchanger is simulated on the basis of computational fluid dynamics (CFD) method. Water and a mixture of water with nano fluids (TiO2, Al2O3) is taken flowing fluids and effectiveness is compared in

International Journal of Advance Research in Science and Engineering
Volume No.07, Issue No.02, February 2018
www.ijarse.com
IJARSE
ISSN: 2319-8354

different cases as afore mentioned. Figs.2 and 3 shows Transmission electron microscopy (TEM) images of dispersed Al2O3 and TiO2 respectively. Table 1 shows the specific properties of Al2O3 and TiO2.

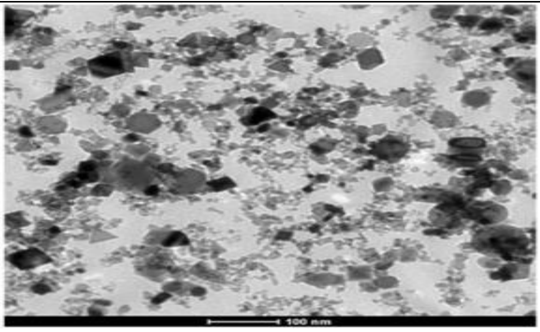

Figure 2: TEM photograph of dispersed Nano Al2O3 particles in water.Tiwari et al [6]

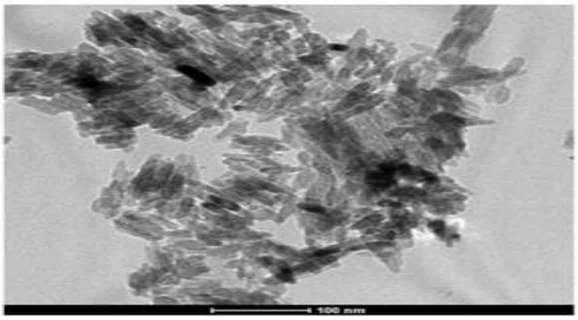

Figure 3: TEM photograph of dispersed TiO2 Nano particles in water. Tiwari et al [6]

Table 1: Properties of Nano fluids

Nano fluid	**Volume fraction, (Φ)**	**Density(ρ), kg/m3**	**Specific Heat(Cp), J/kg.K**	**Thermal conductivity (K), W/mK**	**Dynamic Viscosity(μ), kg/m.sec**
TiO2	0.2	1650	2379.678	0.97341	1.503E-3
Al2O3	0.2	1590	2539.874214	1.041835	1.503E-3

II PROCEDURE AND ANALYSIS

A PHE model with description given in Table 2 is designed and modelled in solid works as shown in Figure 4. And the same model is imported in to ANSYS in which fine meshing is created as shown in Figure 5.

Table 2: Details of plate heat exchanger (PHE) Assembly

Number of plates	10
PHE length	0.853 m
Plate width	0.365 m
Plate thickness	2 mm
Spacing between two plates	5 mm
Plate material	AISI-316
Thickness of Gasket	6 mm
Gasket Material	NITRILE BUTADIENE RUBBER (NBR)

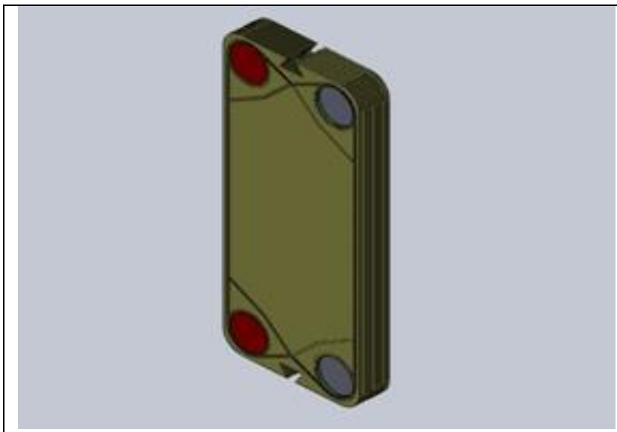

Figure 4: Plate heat exchanger assembly

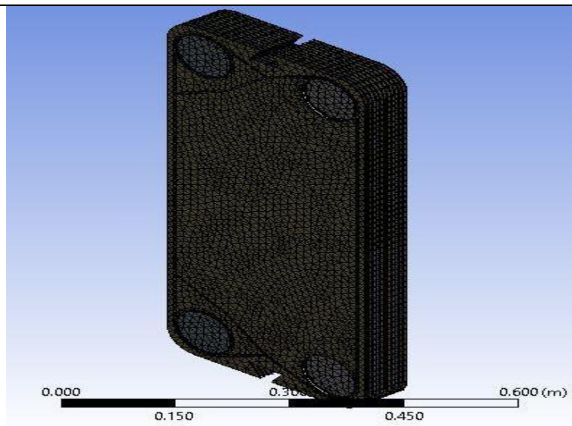

Figure 5: Meshed Model of PHE assembly

Boundary condition:

Flow parameters of hot and cold fluid are tabulated in Table 3. In flow boundary conditions, direction of flow was defined normal to boundary. The initial absolute pressure is taken as 1 MPa, the turbulent intensity was kept 5% and turbulent viscosity ratio was 10% at inlet. Outlets of cold and hot fluids were kept as out flow. All the walls were assumed to be smooth with zero roughness. The no slip condition was applied at all the walls and walls were considered as stationary wall.

Table 3: Flow parameters

Cold fluid mass flow rate($\dot{m}_c$)	7.85 kg/s
Hot fluid mass flow rate ($\dot{m}_h$)	7.85 kg/s
Cold fluid inlet Temperature (T_{ci})	300 K
Hot Fluid inlet Temperature ($T_{\square i}$)	360 K

III RESULTS AND DISCUSSIONS

With aforementioned boundary conditions, PHE model is analysed for three cases-I,II and III as mentioned in the following sections and the contours of temperature in cold fluid and hot fluid are shown in Figures 6,7 and 8 for respective cases.

Case-I: cold fluid as well as hot fluid is water

Case-II: Cold fluid as water and hot fluid as a mixture of water-TiO2 (volume fraction 0.2)

Case-III: cold fluid as water and hot fluid as a mixture of water-Al2O3 (Volume fraction 0.2)

 IJARSE
ISSN: 2319-8354

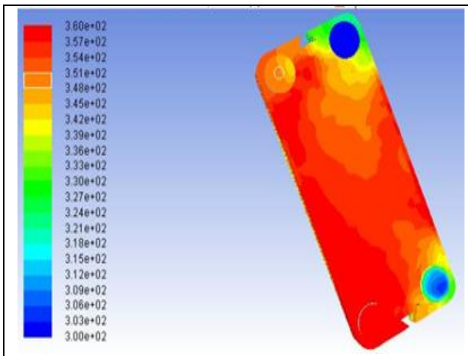

Figure 6: shows temperature contours in water (cold fluid) and water (hot fluid) for Case-I

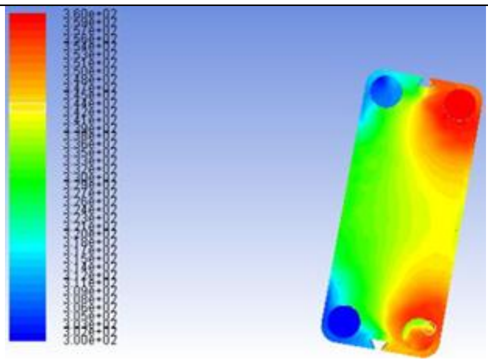

Figure 7: shows temperature contours in water (cold fluid) and water-tio$_2$ nano fluid (hot fluid) for Case-II

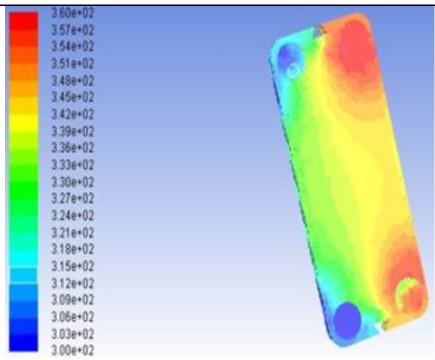

Figure 8: shows temperature contours in water (cold fluid) and water.Al2O3 nano fluid (hot fluid) for Case-III

From the analysis, outlet temperatures of cold fluid and hot fluid are also found which are presented in Table 4.

Table 4: Outlet temperatures of cold and hot fluid

Case	**Outlet temperature of cold fluid (T_{co}), K**	**Outlet temperature of hot fluid (T_{ho}), k**
I	309.0	351.0
II	310.8	341.2
III	312.2	340.5

After finding out the outlet temperatures, following equations (1,2 &3) are used to calculate the effectiveness of PHE in different cases and the results are tabulated in Table 5.

Equations used:

Heat transfer rate in cold fluid $(Q_c) = \dot{m}_c C_{pc} \Delta T_c$ …..............(1)

Heat transfer rate in cold fluid $(Q_{\square}) = \dot{m}_{\square} C_{p\square} \Delta T_{\square}$ …............(2)

Effectiveness (ϵ) = $\frac{ActualHeatTransfer}{MaximumHeatTransfer}$

$$= \frac{Q_{actual}}{\left((\dot{m}c_p)_{min}(T_{\square i} - T_{ci})\right)}$$ ……(3)

Where;

C_{pc} and $C_{p\square}$ are the specific heats of cold fluid and hot fluid respectively. Whose value is 4.182 kJ/Kg.K

ΔT_c and $\Delta T_{\square}$ are the temperature difference at inlet and outlet for cold fluid and hot fluid respectively.

Table 5: Effectiveness of PHE in different cases

Case	Cold fluid	Hot fluid	Effectiveness
I	Water	Water	0.150
II	Water	Water-TiO2	0.316
III	Water	Water-Al2O3	0.335

From Table 5, it is evident that effectiveness of PHE will be higher with Al2O3 nano particles and will be lesser without nano particles. Further effectiveness of PHE is higher by using Al2O3 nano particles as compared to TiO2 nanoparticles.

IV CONCLUSIONS

From this work it is concluded that the performance of Plate Heat Exchanger increases if we use nano fluid as one of the working fluids of Heat Exchanger and it changes with nanofluids. Present work also suggests that out of considered flowing fluids in the analysis Al2O3 nanofluid should be preferred.

REFERENCES

[1]R. K. Shah, A. S. Wanniarachchi, Plate heat exchanger design theory, in: J.M. Buchlin (Ed.), Industrial Heat Exchangers, von Karman Institute Lecture Series, (1991).

[2]W. M. Kays, A. L. London, Compact heat exchangers, 3rd ed., Krieger Publ. Co., Florida, USA, (1998)

[3]R. K. Shah, D. P. Sekuli´ c, Fundamentals of heat exchanger design, John Wiley and Sons, Inc., Hoboken, NJ, (2003).

[4] J.C. Maxwell, A Treatise on Electricity and Magnetism, second ed.,Clarendon Press, Oxford, UK, 1881.

[5] S.U.S. Choi, Enhancing thermal conductivity of fluids with nanoparticles,Developments and Applications of Non-Newtonian Flows, FED-vol.231/MD-vol. 66, 1995, pp. 99–105.

[6]A. K.Tiwari , P. Ghosh , Jahar Sarkar, Particle concentration levels of various nanofluids in plate heat exchanger for best performance" International Journal of Heat and Mass Transfer 89,2015, 1110–1118

[7] F.S. Javadi , S. Sadeghipour , R. Saidur , G. BoroumandJazi , B. Rahmati , M.M. Elias , M.R. Sohel, The effects of nanofluid on thermophysical properties and heat transfer characteristics of a plate heat exchanger, International Communications in Heat and Mass Transfer, 44,2013, 58–63

[8] A.K. Tiwari , P.Ghosh, J. Sarkar , Performance comparison of the plate heat exchanger using different nanofluids,Experimental Thermal and Fluid Science,49,2013, 141–151

[9] P. Keblinski, J.A. Eastman, D.G. Cahill, Nanofluids for thermal transport, Materials Today 8 (6) (2005) 36–44.