EFFECTS OF NANOFLUIDS ON HEAT TRANSFER CHARACTERISTICS IN SHELL AND TUBE HEAT EXCHANGER

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Nowadays ensure the performance of heat exchanger is one of the toughest roles in industries. In this work focused on improve the performance of shell and tube heat exchangers by reducing the pressure drop as well as raising the overall heat transfer. This work considered as a different nanoparticles such as Aluminium oxide (Al_2O_3), Silicon dioxide (SiO_2), Titanium oxide (TiO_2) and Zirconium dioxide (ZrO_2) to form a nanofluids. This nanofluids possesses high thermal conductivity by using of this increase the heat transfer rate in shell and tube heat exchanger. The selected nanofluids are compared to base fluid based on the thermophysical properties as well as heat transfer characteristics. All the heat transfer characteristics are improved by applying of nanofluids particularly higher results are obtained with using of TiO_2 and Al_2O_3 compared to SiO_2 and ZrO_2. Mixing of nanoparticles increased in terms of volume percentage it will be increases the all Heat transfer characteristics as well as performance of the heat exchanger.

Key words*: Aluminium oxide, Thermal conductivity, Nanofluids, Heat exchanger, Prandtl number, Titanium oxide.*

1. Introduction

The main purpose of heat exchangers are used to transfers the heat inbetween two working medium such as gas or fluids [1,2]. Heat exchangers are classified based on the geometrical shape and properties of flow medium. Better adaptability nature shell and tube heat exchangers are widely used in industrial applications and also low cost in production. The baffle plates are changes the thermophysical properties of the fluid medium also changes the flow direction [3,4]. Baffles are built the rigid structure of the bundle of tubes inside the shell. In higher performance of working the failures of the tubes are prevented by the baffles and also obsreve the vibrations at the time of flow [5]. The fluid flow in the shell and tube heat exchangers are categorized by longitudional flow, transverse flow and helical flow in nature. Transverse flow with segmental baffles heat exchangers are fabricated in less cost and vastly used, it has some disadvantages huge amount of pressure loss, minimum heat transfer efficiency etc. Replacing of segmental baffles by helical baffles improve the heat transfer efficiency and offer little amount of flow restrictions [6]. Numbers of tubes are considered as bundle of tubes also termed as tube stacks, based on the usage it can be varied. The failures of the tubes are replaced in simple manner; bundle can be subdivided in two categories namely fixed tube sheet and U type sheet [7]. Normally the fixed sheets are in straight form and both ends are supported by tube plates in rigid connections. In U- tube heat exchanger the bended U shape tubes are connected by a single tube plate. The tubes are arranged in either square pattern or triangular pattern [8]. Modelling of sheel aand tube heat exchangers were also done for predicting the heat transfer rate by using methodologies such as Artifical Neural Network, Teaching Learning Optimization and Support Vector Machine [9,10].

In normal the cleaning process are made complicated in inside of the tubes to overcome this difficulties fixed tube sheet heat exchangers are used, Both ends of the heads are removed simply and cleaned well thoroughly outside of the tubes are cleaned by chemical cleaning process. In this research, it is planned for analyzing the heat transfer characteristics of all nanofluids used in the shell and tube heat exchangers effectively.

2. Experimental work

In this research study the shell and tube heat exchangers are considered to evaluate the heat transfer behavior effectively, the fluid inlet and outlet, baffle arrangements and the flow directions are illustrated in the Figure 1.

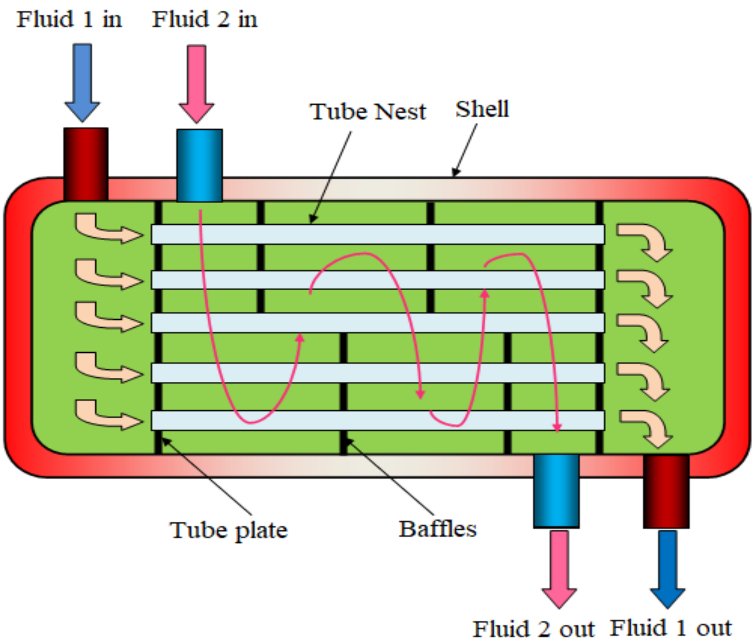

Figure 1. Parallel flow Shell and tube heat exchanger

The nanoparticles of Al_2O_3, TiO_2, SiO_2 and ZrO_2 are mixed in the base fluid such as distilled water in different volume percentage level (up to 2 %). All the nanoparticles are mixed in proper ratio with produced effective heat transfer medium. The two forms of fluid circulated into the shell and tube. it increase the heat transfer rate as well as improve the overall heat transfer coefficient.

3. Results and Discussion

Heat transfer feature of thermal conductivity, heat transfer coefficient, heat transfer rate and prandtl number of the fluid characteristics were estimated while at the time of circulated fluid in the shell and tube heat exchanger. The Table 1 presented the heat transfer coefficient results with usage of different percentage level of nanoparticles in the fluid.

3.1 Heat transfer coefficient

Table 1 Summary of Heat transfer coefficient

Nanoparticles mixing (Vol %)	Heat transfer coefficient (W/m.K)			
	Al_2O_3	SiO_2	TiO_2	ZrO_2
0.5	1365.12	1145.73	1498.77	1296.77
1	2458.61	2346.91	2555.13	2598.36
1.5	3365.57	3185.47	3465.99	3200.77
2	4025.31	3625.23	4253.22	3710.21

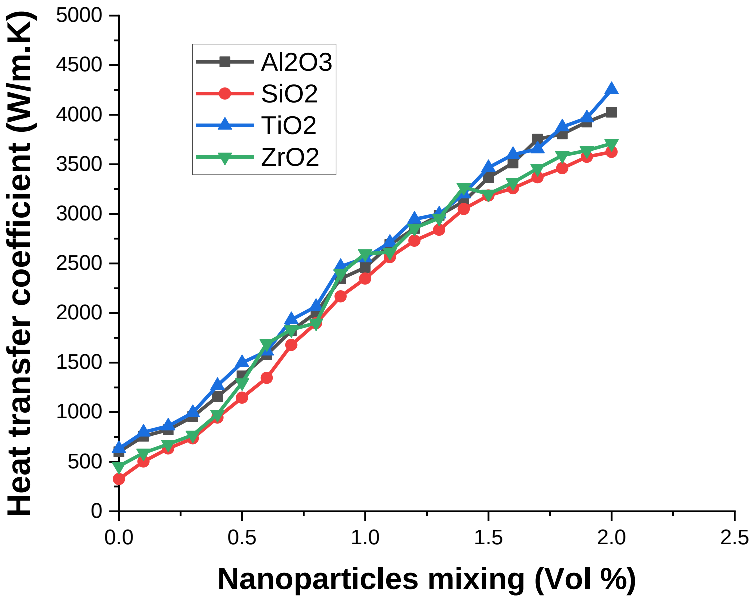

Figure 2. Graph between Nanoparticles mixing (Vol %) and Heat transfer coefficient

Increasing of nanoparticles mixing in the base fluid to increase the heat transfer coefficient it can be noticed in the Table 1. Among four nannoparticles mixing level, the 2% of Titanium oxide presented in the fluid registered a higher value of heat transfer coefficient (4253.22 W/m.K) followed by aluminium oxide (4025.31 W/m.K), zirconium oxide (3710.21W/m.K) and silicon oxide (3625.23 (W/m.K). Figure 2 shows that the interaction between Nanoparticles mixing (Vol %) and Heat transfer coefficient. The graph provided heat transfer coefficient improved by increasing of nanoparticle mixing in terms of volume fraction. Variation of heat transfer coefficient was achieved in applying of all nanofluids, finally the TiO_2 nano fluid has offered maximum heat transfer coefficient. The lower level of heat transfer coefficient was obtained by using of SiO_2 nanofluid it induced the lowest heat transfer coefficient.

3.2 Heat transfer rate

Table 2 Summary of Heat transfer rate

Nanoparticles mixing (Vol %)	Heat transfer rate (W)			
	Al_2O_3	SiO_2	TiO_2	ZrO_2
0.5	3	3	7	3
1	6.8	5.8	13.45	5
1.5	12.4	10	20.36	9.4
2	19	16.7	29.43	15.47

Higher heat transfer rate was registered by the titanium oxide nanofluid such as 29.3 W was presented in the Table 2, further aluminium oxide nano fluid offered 19 W of heat transfer rate followed by silicon oxide nano fluid of 16.7 W and the zirconium oxide of 15.47 W. Figure 3 illustrated that the relations between Nanoparticles mixing (Vol %) and Heat transfer rate. From the graph, the heat transfer rate was concluded in the aspect of increasing nanoparticles. Based on the higher density and higher specific heat, TiO_2 and Al_2O_3 offered higher heat transfer rate at the same SiO_2 and ZrO_2 offered minimum heat transfer rate.

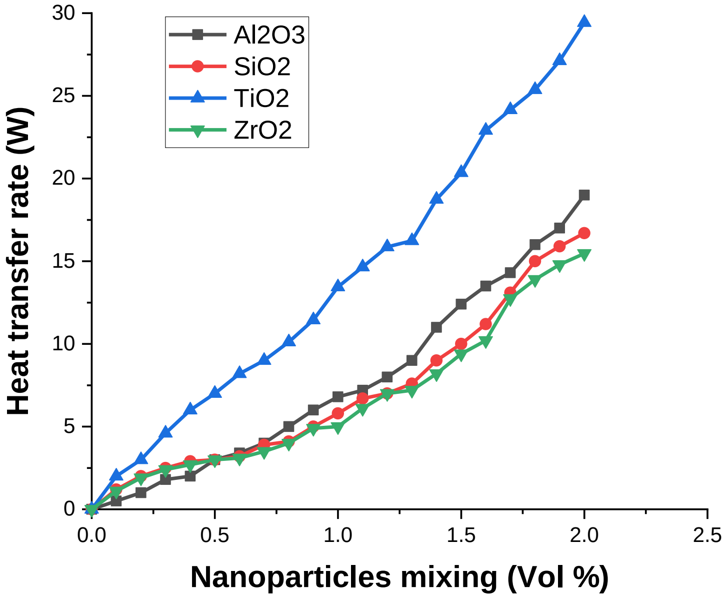

Figure 3. Graph between Nanoparticles mixing (Vol %) and Heat transfer rate

3.3 Thermal conductivity

Table 3 Summary of Thermal conductivity

Nanoparticles mixing (Vol %)	Thermal Conductivity (W/m.K)			
	Al_2O_3	SiO_2	TiO_2	ZrO_2

0.5	0.0356	0.0297	0.0356	0.0301
1	0.0363	0.0321	0.0367	0.0316
1.5	0.0369	0.0335	0.0375	0.0328
2	0.0375	0.0348	0.0383	0.0343

Table 3 presented Summary of thermal conductivity of different nanofluids, the Table 3 point out that the titanium oxide nano fluid offered higher thermal conductivity such as 0.0383 W/m.K. Minimum level of thermal conductivity was obtained through using of zirconium oxide nanofluids such as 0.0343 W/m.K. Figure 4 demonstrates that the major deviation of thermal conductivity was obtained between TiO_2 and Al_2O_3 to SiO_2 and ZrO_2,. Finally the TiO_2 offered maximum thermal conductivity with increasing of nanoparticles.

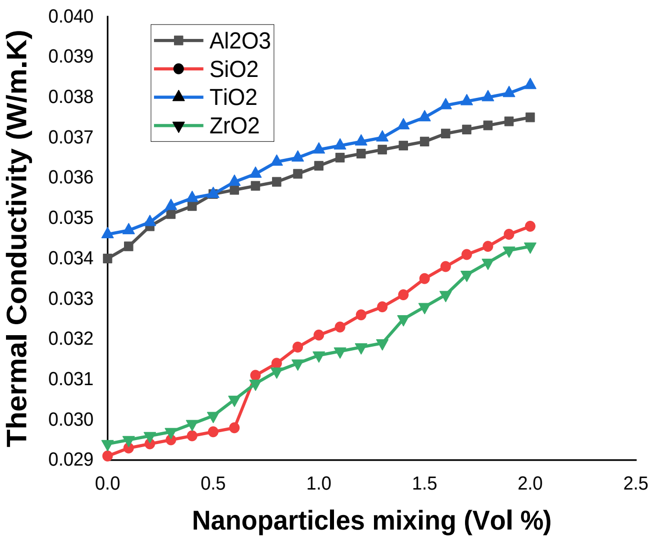

Figure 4. Graph between Nanoparticles mixing (Vol %) and Thermal conductivity

3.4 Overall Heat transfer coefficient

Table 4 illustrated the overall heat transfer coefficient of the all four nanofluids effectively; titanium oxide nanofluid offered superior overall heat transfer coefficient value such as 301.12 W/m2.K. Compared to other nanofluids, silicon oxide nanofluid offered minimum level of overall heat transfer coefficient like as 259.13 W/m2.K. From three nanofluids Al_2O_3, SiO_2 and ZrO_2 are offered minimum level of overall heat transfer coefficient compared to TiO_2 as shown in Figure 5.

Table 4 Summary of Overall heat transfer coefficient

Nanoparticles mixing (Vol %)	Overall heat transfer coefficient (W/m2.K)			
	Al_2O_3	SiO_2	TiO_2	ZrO_2
0.5	236.15	231.58	238.75	229.74
1	246.57	242.86	254.17	240.87
1.5	259.64	252.34	263.47	250.34
2	265.31	259.13	301.12	260.18

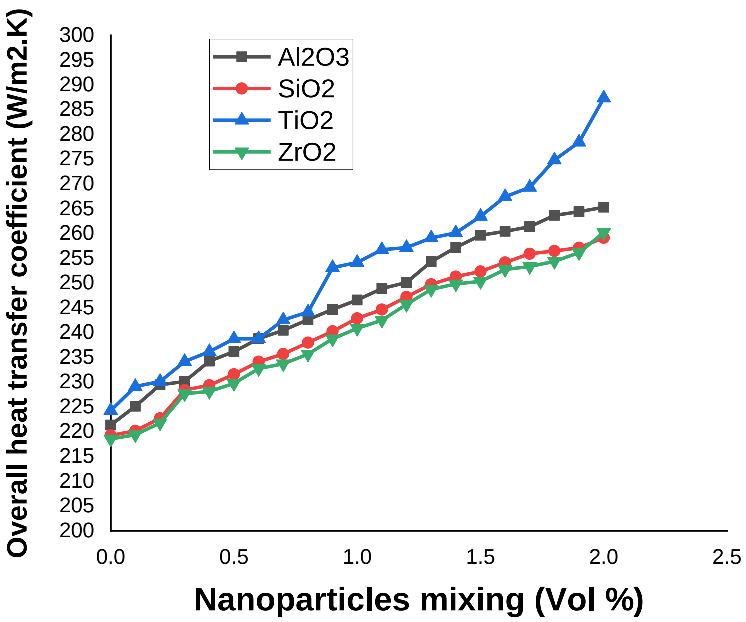

Figure 5. Graph between Nanoparticles mixing (Vol %) and Overall heat transfer coefficient

3.5 Prandtl number

The Table 5 presented the summary of Prandtl Number. The maximum prandtl numer of 0.0379 was achieved by using of Al_2O_3 nanoparticles, contrary the minimum prandtl number 0.0335 was offered by TiO_2 nano particles. Figure 6 illustrates that the increasing of nanoparticles mixing decrease the prandtl number. The titanium oxide nano fluid produced minimum prandtl number

Table 5 Summary of Prandtl Number

Nanoparticles mixing (Vol %)	Prandtl Number			
	Al_2O_3	SiO_2	TiO_2	ZrO_2
0.5	0.0459	0.0446	0.0389	0.0441
1	0.0407	0.0417	0.037	0.0414
1.5	0.0394	0.0395	0.0355	0.0393
2	0.0379	0.0375	0.0335	0.0366

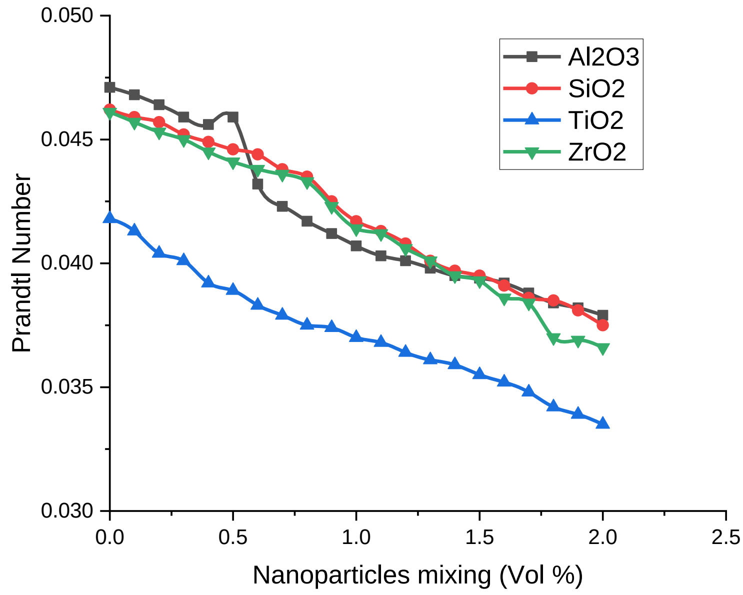

Figure 6. Graph between Nanoparticles mixing (Vol %) and Prandtl number

4. Conclusion

The heat transfer characteristics of shell and tube heat exchanger with influencing of different nano fluids are investigated in clear manner. The nanoparticles was mixed well in the base fluid at maximum 2 % of volume level. The results of this investigations were concluded as the following manner:

- From in all four nannofluids titanium oxide nanofluid registered a higher value of heat transfer coefficient as 4253.22 W/m.K, followed by aluminium oxide 4025.31 W/m.K, zirconium oxide 3710.21W/m.K and silicon oxide 3625.23 W/m.K. The TiO_2 nano fluid has offered maximum heat transfer coefficient. Lower level of heat transfer coefficient was obtained by using of SiO_2 nanofluid.
- Higher heat transfer rate was recorded by the using of titanium oxide nanofluid such as 29.3 W, followed by aluminium oxide 19 W, silicon oxide 16.7 W and the zirconium oxide of 15.47 W. Higher density and higher specific heat of TiO_2 and Al_2O_3 produced higher heat transfer rate at the same time SiO_2 and ZrO_2 offered minimum heat transfer rate.
- The titanium oxidenano fluid offered higher thermal conductivity such as 0.0383 W/m.K. Lower level of thermal conductivity was obtained through using of zirconium oxide nanofluid such as 0.0343 W/m.K. Titanium oxide nanofluid offered excellent overall heat transfer coefficient value such as 301.12 $W/m^2.K$. Silicon oxide nanofluid offered minimum level of overall heat transfer coefficient like as 259.13 $W/m^2.K$
- The maximum prandtl numer of 0.0379 was reached by using of Al_2O_3 nanoparticles, contrary the lower prandtl number 0.0335 was offered by TiO_2 nano particles.

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