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SCIENTIFIC PAPER

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EXPERIMENTAL STUDIES IN PLATE HEAT EXCHANGER USING THERMINOL-55/Al_2O_3 AND GLYCEROL/Al_2O_3 NANOFLUIDS

Article Highlights

- Al_2O_3/Therminol-55/ Water and Al_2O_3/Glycerol/Water mixed nanofluid were prepared
- The heat transfer performance of Al_2O_3 suspended base fluid was studied in a plate heat exchanger
- Individual and overall heat transfer coefficients were determined and analyzed by varying flow rates

Abstract

The experiment aimed to compare the heat transfer performance of two base fluids, Therminol-55 and glycerol, both mixed with aluminum oxide nanoparticles. The investigation focused on assessing how the addition of aluminum oxide nanoparticles (at concentrations of 0.1%, 0.2%, and 0.25% by volume) affected heat transfer in a plate heat exchanger using a mixture of Therminol-55/water and Glycerol/water. Results demonstrated a significant enhancement in heat transfer efficiency for both the hot and cold sides of the exchanger when using these nanoparticle-infused base fluid mixtures. Specifically, the study observed notably improved heat transfer coefficients for the Therminol-55/water mixture with a 0.25% nanoparticle concentration, achieving 3859 W/m²K (23% higher) for the hot fluid coefficient, 4195 W/m²K (31% higher) for the cold fluid coefficient, and an overall coefficient of 2310 W/m²K (23% higher). Similarly, the Glycerol/water mixture with a 0.25% nanoparticle concentration exhibited superior performance, reaching 4491 W/m²K (30% higher) for the hot fluid coefficient, 4395 W/m²K (36% higher)for the cold fluid coefficient, and an overall coefficient of 2508 W/m²K (28% higher). These findings indicate that the Glycerol/water mixture with aluminum oxide nanoparticles outperforms the Therminol-55/water counterpart, suggesting its potential to minimize temperature differentials within the heat exchanger and enhance operational effectiveness.

Keywords: Al_2O_3; heat transfer; Therminol-55; glycerol; nanofluid; plate heat exchanger.

Nanoparticles are particles less than 100 nm in size [1]. Both synthetic and naturally occurring nanoparticles can be found in the environment. Inorganic substances are called nanoparticles. Nanoparticles are invisible to the naked eye. They can be divided into several categories according to their sizes, forms, and features. The large surface area and nanoscale size of nanoparticles give them distinct physical and chemical characteristics. Their distinct composition, size, and form greatly influence their toughness, reactivity, and other qualities. These tiny particles are ideal for strong chemical reactivity, bio-mobility, and energy absorption because of their unique properties. Nanomaterials are divided into four categories: 0D, 1D, 2D, and 3D, depending on their general form [2]. At least one dimension of nanoclusters is between 1 and 10 nm in size, exhibiting a small size

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distribution. Heat exchangers are used in industrial production processes to warm and cool fluids [3,4]. Glycols/aluminum oxide nanofluid is used as a base fluid in heat transfer applications. To achieve better heat transfer, we need to focus on improving the thermal conductivity and overall heat transfer characteristics of these fluids [5–8].

Recent advancements in energy reduction through the use of nanofluids are evident in a substantial body of research within the technical community. This innovative engineering fluid, known for its specialized applications, can lower costs in heat transfer operations by modifying appropriate base fluids [9]. Researchers have developed heat transfer fluids containing suspended nanoparticles for various heat transfer equipment [10,11]. Numerous researchers employed various metal oxides, including the addition of CuO nanoparticles to water [12,13], aluminum oxide/water [14], aluminum oxide/water-methanol [15], graphene/water-glycol [16], TiO_2,ZnO in water-ethylene glycol [17], Fe_2O_3 in engine oil-water mixture, Al_2O_3 and CuO nanoparticle suspension in engine oil, vacuum pump fluid, distilled water and ethylene glycol [18] and the results showed that this addition considerably increases the thermal conductivities of fluid mixtures and heat transfer coefficient. Experimental results of Al_2O_3 nanoparticle addition show that the Nusselt number increased significantly with respect to different volume fractions [19]. This study investigates the use of nanofluids for enhanced heat transfer in the oil and gas industry. Therminol 66, a common heat transfer fluid in heat exchangers, was chosen as the base fluid. To improve its heat transfer capabilities, Iron oxide (III) nanoparticles were incorporated at a concentration of 0.3% by weight (wt%). The fundamental properties of these nanofluids, such as density, viscosity, and specific heat capacity, were then measured as the heat transfer increased up to 46%, pressure drop increased up to 37.5% and friction factor increased up to 10% [20]. The result of the heat transfer effect showed energy savings of around 32% for cooling. Methanol has recently been used for a variety of heat transfer applications and different types of heat pipes (vapor-dynamic thermosyphons, conventional and micro heat pipes).

Numerous research works have looked into the special qualities and abilities these novel fluids have shown since nanofluids were first used in a variety of industries. The economically feasible nanomaterial aluminum oxide (Al_2O_3) has good thermophysical and heat transport properties and is non-toxic [21]. Heat transfer study was performed in Armfield plate heat exchanger (HT32) with an Armfield heat exchange service unit (HT30X) by preparing suspension of multi-wall carbon nanotubes in distilled water Hassaan *et al.*, reported 32% increase in Nusselt number (with 1.53% volume fraction) and with the same nanofluids in Shell and tube heat exchanger the percentage increase of the overall heat coefficient ranges between 6% and 76.4%, compared to distilled water [22,23] was reported. Heat transfer performance of two distinct heat exchangers with the same heat transfer area was assessed by Hassaan *et al.*, with a tubular heat exchanger (THE) and a shell-and-tube heat exchanger (STHE) and obtained heat transfer coefficient of STHE is 7–43% greater than that of tubular heat exchanger [24], also proposed a relationship between Reynolds number and MWCNT volume concentration for computing the Nusselt number [25]. In plate heat exchangers (PHEs) hybrid nanofluid (multi-walled carbon nanotubes (MWCNTs)-Al_2O_3/water) was used with various concentrations and reported an increase in the overall heat coefficient from 6% to 97% compared to pure distilled water [26]. An experiment was done using MWCNTs as operating fluids in an automotive radiator with louvered fins and flat tubes (Honda Civic 2005). From the study they reported a Nusselt number increment of 13.72% in comparison to pure water, also a correlation for estimating the Nusselt number in terms of the Reynolds number and MWCNTs volume concentration is provided [27]. While most research on the topic focuses on thermal conductivity studies, there is potential to investigate this material's heat transfer capabilities in real-time heat exchangers. Although employing nanofluids has many advantages, there are some disadvantages as well, such as instability, fouling, and surface erosion [28–30]. Therminol-55 provides a method to resist fouling, decrease pressure drop, increase heat transfer in ribbed tubes, and stop nanoparticle aggregation when making a nanofluid. Since the literature also demonstrates the effectiveness of small plate heat exchangers, we decided to use them in our inquiry [31]. Prior research hasn't explored the heat transfer performance of a specific nanofluid mixture: Al_2O_3-Water-Therminol-55 (AWT) within plate heat exchangers [32]. Also, it was found that Al_2O_3 nanoparticles containing Nanofluids showed increased critical heat flux, which was due to the improved Thermal conductivity of nanoparticles [34], hence Al_2O_3 was chosen. Elaboration of significant factors that play a vital part in enhancing the heat transfer characteristics of nanofluids is also needed to explore the heat transfer performance of nanofluids [35]. To address this gap, we investigated how adding Al_2O_3 nanoparticles (0.1% to 0.25% concentration) affects heat transfer in a Therminol-55/water and glycerol/water base fluid (5:95 volume ratio). The experiments were conducted at a constant hot fluid inlet temperature (60 °C) with varying flow rates (2 to 6 liters per minute).

MATERIALS AND METHODS

Preparation and properties of nanoparticle

Nanopowders refer to agglomerates of ultrafine particles, nanoparticles, or nanoclusters. Nanoparticles consist of three layers—surface layer, shell layer, and core layer. From the literature, it was noticed that To obtain stable Al_2O_3 nanofluids, many routes exist such as surfactant addition, pH control, ultrasonic agitation, functionalization, magnetic stirring, and high-pressure homogenization [36]. Hence in this study, the conversion of nanoparticles into Nanofluids is achieved through a two-step method with the help of a high-pressure homogenizer. The conversion of nanoparticles into Nanofluids is achieved through a two-step method. In this research, a two-step (sol-gel) technique was employed to suspend 50 nm Al_2O_3 nanoparticles in a water-methanol mixture. Base fluids with specific volume fractions (5% Therminol-55 + 95% water) were formulated according to calculated amounts derived from the below fraction Eq. (1).

$$\varphi = \frac{\left(m/\rho\right)_{Al_2O_3}}{\left(m/\rho\right)_{Al_2O_3} + \left(m/\rho\right)_{W:T}} \tag{1}$$

To ensure stability in the prepared nanofluid, a high-pressure homogenizer was employed, and the resulting nanofluid served as the cold fluid in the plate heat exchanger. The utilization of a high-pressure homogenizer ensures the uniform suspension of the prepared nanofluid throughout the base fluid. When designing energy-efficient systems, the thermal conductivity of heating or cooling fluids plays a crucial role. Among the key considerations in developing and controlling the process is the fluid's ability to conduct heat. Factors such as availability, cost, heat conductance, and the propensity of particles to stay uniformly dispersed in the base fluid with minimal agglomeration are all significant. Despite their superior thermal conductivity, metal oxide nanoparticles tend to agglomerate. In our investigation, we used Aluminum oxide (Al_2O_3) nanofluid for heat transfer analysis.

SEM images of aluminum oxide nanoparticle

Widely employed for material analysis, SEM (Scanning Electron Microscopy) plays a crucial role in identifying the microstructure and chemistry of materials. By projecting and scanning a focused stream of electrons across the surface, SEM produces detailed images. The interaction of electrons in the beam with the sample generates various signals, providing valuable information about the surface's composition. Figure 1 depicts SEM images of Al_2O_3 nanoparticles.

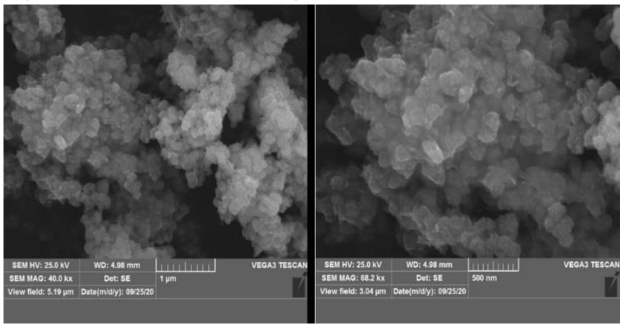

Figure 1. SEM image of Al_2O_3 nanoparticle.

Experimental setup and estimation of thermo physical properties

Experiments were conducted on a plate-type heat exchanger as described in the experimental setup (Schematic and photographic view) illustrated in Figure 2. The plate heat exchanger consists of 13 Stainless Steel corrugated plates (Alfa Laval, India) providing seven flow channels for the hot fluid and six flow channels for the cold fluid. The plate length and thickness of the plate are 0.154m and 0.25mm respectively.

Thermal conductivity was measured using a thermal conductivity analyzer (Scientico, India) and viscosity was measured with a redwood viscometer for all the concentrations of nanofluid. The density and specific heat capacity of the nanofluid were calculated from the correlations [36, 37], Eqs (2,3).

$$\rho_{nf} = (1-\varphi)\,\rho_f + \varphi\rho_p \tag{2}$$

$$Cpnf = \left((1-\varphi)\,\rho_f C_{pf} + \varphi\rho_p C_{pp}\right) / (\rho_{nf}) \tag{3}$$

The obtained results of thermophysical properties were used for calculating different dimensionless numbers (Reynolds, Prandtl, and Nusselt numbers) applied in this study.

Nanofluids based on Therminol-55 incorporating Al_2O_3 nanoparticles were prepared at different volume concentrations, including 0.1%, 0.2%, and 0.25%. The density, dynamic viscosity, heating value, and heat conductivity were subsequently calculated based on experimental findings.

Determination of Nusselt number, convective and overall heat transfer coefficient of Al_2O_3/water-methanol nanofluid

Determination of thermophysical properties of Fe_2O_3-water-engine oil nanofluid

Eq. (4), based on the Kim model, was employed

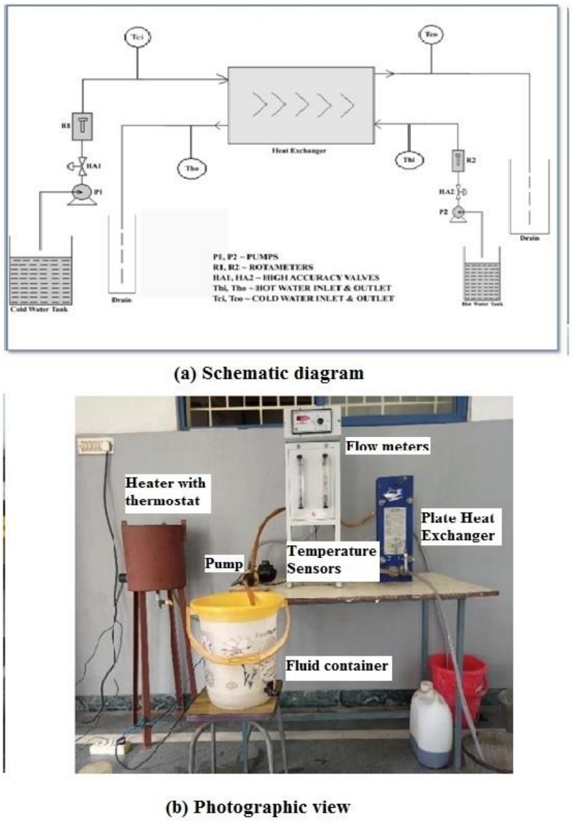

Figure 2. Schematic and photographic view of the experimental setup.

to calculate the Nusselt number of the nanofluid. Eq. (5) was utilized to determine the heat transfer coefficient of both the hot and cold fluids. Eq. (6) is employed to find the overall heat transfer coefficient.

$$Nu = 0.295(N_{\mathrm{Re}})^{0.64}(N_{\mathrm{Pr}})^{0.32}\left((\Pi/2)-\beta\right) \quad (4)$$

$$h = \left(\frac{((Nu)(D_H))}{K}\right) \quad (5)$$

$$U = \left(\frac{(Q)_{avg}}{|(A)(\Delta T_{lmtd}|}\right) \quad (6)$$

MATERIALS AND METHODS

Effect of flow rate on hot fluid heat transfer coefficient (h_h) for Therminol-55/water base fluidat 60 °C

Prior to conducting in-depth experiments with chosen nanofluids, a preliminary study was carried out using de-ionized water to ensure the experimental study's reliability. Figure 3 illustrates the impact of flow rate on the heat transfer coefficient (h_h) of the hot fluid at a hot fluid inlet temperature of 60 °C, considering various nanofluid concentrations (Therminol-55/I_2O_3) and water.

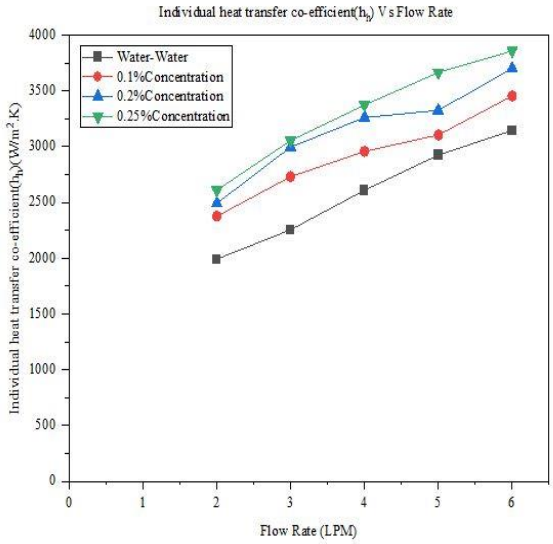

Figure 3. Effect of flow rate on hot fluid heat transfer coefficient (h_h) for Therminol-55/Water base fluid at 60 °C

According to Figure 3, The heat transfer coefficient on the hot side (hh) ranges from 1980 W/m²K for water-water, increasing to 2620 W/m²K at a flow rate of 2 Lpm for a nanofluid with a nanoparticle concentration of 0.25. With an increase in flow rate to 6 lpm, the heat transfer coefficient range also expands, starting at 3145 W/m²K for water-water and rising to 3858.77 W/m²K (for 0.25 vol.%). This underscores the significant impact of flow rate on enhancing heat transfer. This increment is because there is a significant increment in Reynolds number because of the incremental effect in density with respect to the viscosity of a nanofluid. Because of the Reynolds number increment and thermal capacity, the rate of heat transfer increases significantly.

Effect of flow rate on cold fluid heat transfer coefficient (h_c) for Therminol-55/Water base fluidat 60 °C

The effects of varying flow rates on the heat transfer coefficient on the cold side at 60°C for Therminol-55/Water base fluid were investigated and are depicted in Figure 4.

A consistent upward trend in heat transfer enhancement is evident on the cold side fluid, as depicted in Figure 4. Notably, at a low flow rate (2 Lpm) and a low nanoparticle concentration (0.25 vol.%), the heat transfer coefficient closely aligns with that of water as the base fluid. However, a gradual increase in the flow rate leads to a corresponding increase in the heat transfer rate. For example, at a flow rate of 4 lpm, the heat transfer coefficient rose to 2908.82 W/m²K (for 0.25 vol.%) from 2435.76 W/m²K (for water).

The results indicate that both the convective heat

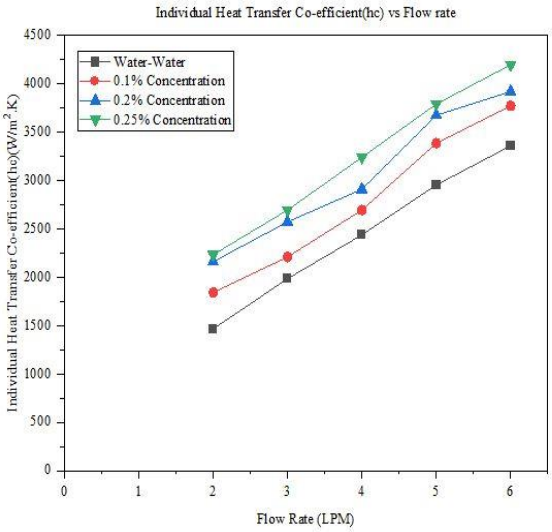

Figure 4. Effect of flow rate on cold fluid heat transfer coefficient (h_c) for Therminol-55/Water base fluid at 60 °C.

transfer coefficient and Nusselt number for Al_2O_3/Therminol-55-water nanofluid surpass those of the base fluid.

This enhancement is attributed to the improved heat transport facilitated by thermally conductive nanoparticles through the interfacial layers of fluids. The maximum enhancement was observed at 6 lpm, with a heat transfer coefficient value of 4194.54 W/m²K (for 0.25 vol.%); however, the rate of enhancement diminishes with increasing flow rate. Hence, optimizing the flow rate is essential for the efficient utilization of nanoparticles.

Effect of flow rate on hot fluid heat transfer coefficient (h_h) for Glycerol/Water base fluid at 60 °C

Given the significant impact of base fluid on heat transfer, the study was replicated with alterations in base fluid composition. This included varying the concentration and observing the effect of flow rate on the heat transfer coefficient of the hot fluid for glycerol/water-based fluid as depicted in Figure 5.

According to the data presented in Figure 5, the heat transfer coefficients for various concentrations (ranging from 0.1 vol.% to 0.25 vol.%) show notable differences. At a flow rate of 2 Lpm, the heat transfer coefficient on the hot side was recorded at 1992.23 W/m²K for water, 3845.17 W/m²K for 0.1 vol.%, and 4491.23 W/m²K for 0.25 vol.%. Similarly, at a flow rate of 6 lpm, the corresponding values were 3145.89 W/m²K for water, 3845.17 W/m²K for 0.1 vol.%, and 4101.24 W/m²K for 0.25 vol.%. These results once again underscore the effectiveness of nanoparticle suspension in enhancing heat transfer. It is also confirmed from Figure 5 that the heat transfer coefficient (h_h) enhancement is directly proportional to nanoparticle concentration and flow rate; however, the maximum enhancement was noted at 0.25 volume% of nanoparticle volume fraction.

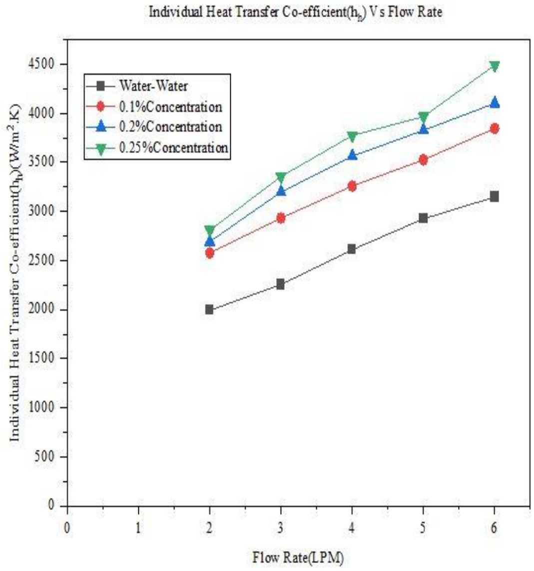

Figure 5. Effect of flow rate on hot fluid heat transfer coefficient (h_h) for Glycerol/Water base fluid at 60 °C.

Effect of flow rate on cold fluid heat transfer coefficient (h_c) for Glycerol/Water base fluid at 60 °C

The influence of flow rate on the heat transfer coefficient of the cold side at 60°C for the glycerol/water base fluid is depicted in Figure 6.

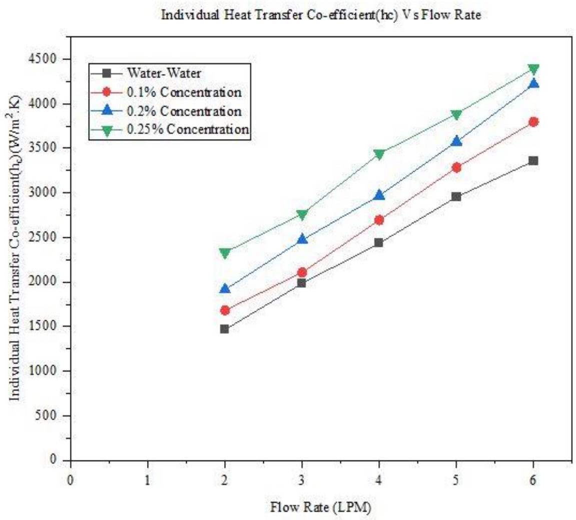

Figure 6. Effect of flow rate on cold fluid heat transfer coefficient (h_c) for Glycerol/Water base fluid at 60 °C.

The impact on the heat transfer coefficient of the cold side demonstrates an increase with a flow rate of 2 Lpm, rising from 1466.25 W/m^{2}K (for water) to 2331.96 W/m^{2}K (for 0.25 vol.% nanoparticle concentration). Similarly, at a flow rate of 6 Lpm, the cold side heat transfer coefficient increased from 3356.76 W/m^{2}K (for water) to 4394.54 W/m^{2}K (for 0.25 vol.% nanoparticle concentration). A notable enhancement in comparison to the Therminol-55/water base fluid was observed. This trend indicates a consistent rise in heat transfer rate, which correlates linearly with both nanoparticle concentration and temperature.

Effect of flow rate on overall heat transfer coefficient (U) for Therminol-55/water and glycerol/water base fluid at 60 °C

While the heat transfer coefficient was initially computed for individual fluids, calculating the overall heat transfer coefficient is crucial to harness the advantages offered by nanoparticles. Therefore, the findings regarding the overall heat transfer coefficient at 60 °C for Therminol-55/Water base fluid are illustrated in Figure 7a.

From Figure 7a, it is evident that at flow rates of 2, 4, and 6 lpm, the range of U was 673.87, 1285.65, and 1918.41 W/m²K (for 0.1 vol. % nanoparticle) and 742.57, 1600, and 2310.92 W/m²K (for 0.25 vol. %). This observation leads to the conclusion that both individual and overall heat transfer coefficients were significantly enhanced due to the presence of nano-sized solid particles.

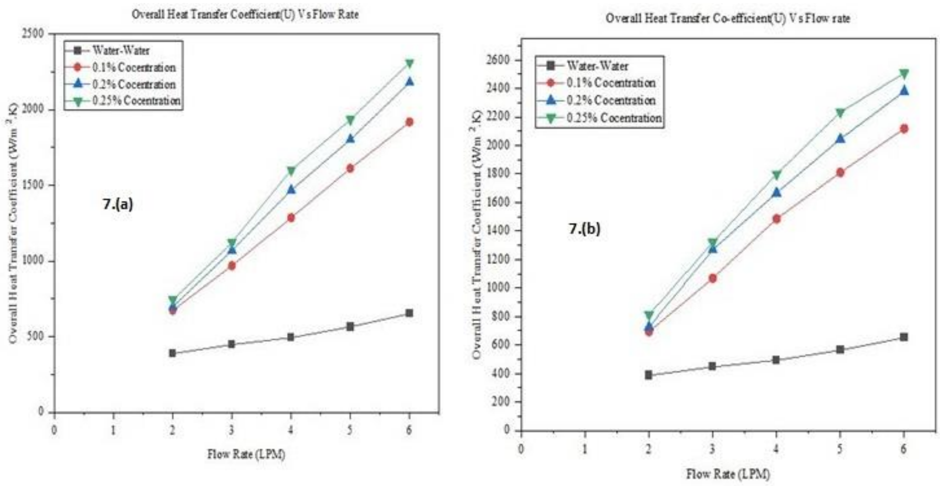

Figure 7. Effect of flow rate on overall heat transfer coefficient (U) for Therminol-55/Water and Glycerol/Water base fluid at 60 °C.

The impact of flow rate variations on the overall heat transfer coefficient at 60 °C for the glycerol/water base fluid is illustrated in Figure 7b. From Figure 7b, it was noted that Changing the base fluid favors heat transfer; Hence study was performed for both the base fluids (Therminol-55/Glycerol) Result shows that uniform enhancement in overall heat transfer rate with respect to all the concentrations (0.1, 0.2 and 0.25 vol. %) and all the flow rates. The ranges were 2118.41W/m^{2}K (for 0.1 vol. % nanoparticle to 2508.12W/m^{2}K (for 0.25 vol. % nanoparticle concentration) at a flow rate of 6 Lpm.

Due to the incremental effect on thermal conductivity of nanofluids heat transport dominates over the momentum transport and hence the Prandtl number decreases at the highest volume fractions of nanofluid. There exists a good agreement between the results calculated from these experimental values and the correlation. It was noticed that the calculated Nusselt number falls within ±8% and ±10 % deviation when compared with experimental results of (Al_2O_3/Glycerol-water) and (Al_2O_3/Therminol-55-water) nanofluids respectively, which shows the accuracy of the results of the experiment. The obtained results are consistent with the reported results that thermal conductivity, viscosity, and density of the Al_2O_3 nanofluids are increased with the addition of nanoparticles in the base fluid [22–28].

CONCLUSION

The study revealed a significant enhancement in heat transfer when nanoparticles were added to a water-water system. This improvement can be attributed to the high thermal conductivity of the solid nanoparticles, which effectively increase the rate of heat transfer within the base fluid.

Employing the (Al_2O_3/Glycerol-water) nanofluid resulted in notably decreased temperature differentials compared to the nanofluid (Al_2O_3/Therminol-55-water) within the heat exchanger, leading to improved performance of the heat exchanger.

The highest coefficients were observed at 0.25%

in Glycerol base fluid and a flow rate of 6 Lpm These peak values comprised a hot fluid coefficient of 4101.24 W/m²K, a cold fluid coefficient, and an overall coefficient of 4394.54 W/m²K and 2508.12 W/m²K respectively.

Comparing the previously mentioned heat transfer coefficient values of Glycerol base fluid nanoparticle with those of Therminol-55 base fluid nanoparticle reveals that the hot fluid coefficient increases by up to 6.28%, the cold fluid coefficient by up to 4.76%, and the overall coefficient by up to 8.5%.

Glycerol base fluid nanoparticle has a better heat transfer coefficient compared to the Therminol-55. Furthermore, the study revealed that the minimum fluid flow rate is sufficient to attain the maximum enhancement in heat transfer rate.

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NOMENCLATURE

Al_2O_3	Aluminum Oxide
TiO_2	Titanium dioxide
ZnO	Zinc Oxide
Fe_2O_3	Iron Oxide
CuO	Copper Oxide
SiO_2	Silicon dioxide
CNT	Carbon Nano Tubes
D	Dimension
D_H	Hydraulic diameter, m
ΔT_{LMTD}	Logarithmic Mean Temperature Difference
T	Therminol-55
G	Glycerol
W	Water
m	Mass, kg
U	Overall Heat transfer coefficient, W/m^2. K
N_{Nu}	Nusselt number, dimensionless
N_{Pr}	Prandtl Number, dimensionless
N_{Re}	Reynolds number, dimensionless
Q	Heat Flux, W
Cp	Specific heat capacity, J/ (kg. K)
PHE	Plate Heat Exchanger
Pr	Prandtl number, dimensionless
H	Heat transfer coefficient, W/m2. K
Hh	Hot Fluid Heat transfer coefficient, W/m2. K
Hc	Cold Fluid Heat transfer coefficient, W/m2. K
vol. %	Volume %
Greek symbols	
β	corrugation angle, °
ρ	density, kg/m3
μ	dynamic viscosity, Pa s
$\varnothing$	nanoparticle volume fraction, dimensionless
k	thermal conductivity, W/ (m.K)
Π	Corrugation angle

REFERENCES

[1] S.U.S. Choi, S. Lee, S. Li, J.A. Eastman, J. Heat Transfer 121 (1999) 280–289. https://doi.org/10.1115/1.2825978.

[2] S.K. Das, N. Putra, P. Thiesen, W. Roetzel, J. Heat Transfer 125 (2003) 567–574. https://doi.org/10.1115/1.1571080.

[3] S.S. Sonawane, R. S., Khedkar, K.L.T. Wasewar, Int. Commun. Heat Mass Transfer 49 (2013) 60–68. https://doi.org/10.1016/j.icheatmasstransfer.2013.10.001.

[4] M.A. Sabiha, R. Saidur, S. Mekhilef, O. Mahian, Renewable Sustainable Energy Rev. 51 (2015) 1038–1054. https://doi.org/10.1016/j.rser.2015.07.016.

[5] S.P. Manikandan, N. Dharmakkan, S. Nagamani, Chem. Ind. Chem. Eng. Q. 28 (2022) 95–101. https://doi.org/10.2298/CICEQ210125021M.

[6] S.P. Manikandan, N. Dharmakkan, M.D. Sri Vishnu, H. Prasath, R. Gokul, Hem. Ind. 75 (2021) 341–352. https://doi.org/10.2298/HEMIND210520031S.

[7] S.P. Manikandan, N. Dharmakkan, M.D. Sri Vishnu, H. Prasath, R. Gokul, G. Thiyagarajan, G. Sivasubramani, B. Moulidharan, Chem. Ind. Chem. Eng. Q. 29 (2023) 225–233. https://doi.org/10.2298/CICEQ220430029S.

[8] M.M. Sarafraz, A.D. Baghi, M.R. Safaei, A.S. Leon, R. Ghomashchi, M. Goodarzi, C.X. Lin, Energies 12 (2019) 1–13. https://doi.org/10.3390/en12224327.

[9] W. Xu, S. Wang, Q. Zhang, Q., Wang, H. Lu, H. Tan, Appl. Therm. Eng. 95 (2016) 165–177. https://doi.org/10.1016/j.applthermaleng.2015.10.164.

[10] E. Abu-Nada, Int. J. Heat Fluid Flow 30 (2009) 489–500. https://doi.org/110.1016/j.ijheatfluidflow.2009.02.003,

[11] M.M. Sarafraz, A.D. Baghi, M.R. Safaei, A.S. Leon, R. Ghomashchi, M. Goodarzi, C.X. Lin, Energies 12 (2019) 1–13. https://doi.org/10.3390/en12224327.

[12] S.P. Manikandan, R. Baskar, Chem. Ind. Chem. Eng. Q. 27 (2021) 15–20. https://doi.org/10.2298/CICEQ191220020P.

[13] B. Sahin, E. Manay, E.F. Akyurek, J. Nanomater. 2015 (2015) 1–10. https://doi.org/10.1155/2015/790839.

[14] S. Hoseinzadeh, P.S. Heyns, H. Kariman, Int. J. Numer. Methods Heat Fluid Flow 30 (2020) 1149–116. https://doi.org/10.1108/HFF-06-2019-0485.

[15] S.P. Manikandan, P.K. Chinnusamy, R. Thangamani, S. Palaniraj, P. Ravichandran, S. Karuppasamy, Y.R. Sanmugam, Chem. Ind. Chem. Eng. Q. 30 (2024) 257–264. https://doi.org/10.2298/CICEQ230726028M.

[16] S.P. Manikandan, R. Baskar, Chem. Ind. Chem. Eng. Q. 27 (2021) 177–187. https://doi.org/10.2298/CICEQ200504036P.

[17] S.P. Manikandan, R. Baskar, Chem. Ind. Chem. Eng. Q. 24 (2018) 309–318. https://doi.org/10.2298/CICEQ170720003M.

[18] S.P. Manikandan, R. Baskar, Period. Polytech., Chem. Eng. 62 (2018) 317–322. https://doi.org/10.3311/PPch.11676.

[19] T. Maré, S. Halelfadl, O. Sow, P. Estellé, S. Duret, F. Bazantay, Exp. Therm. Fluid Sci. 35 (2011) 1535–1543. https://doi.org/10.1016/j.expthermflusci.2011.07.004.

[20] A. Munimathan, T. Sathish, V. Mohanavel, A. Karthick, R. Madavan, R. Subbiah, S. Rajkumar, Int. J. Photoenergy 1 (2021) 6680627. https://doi.org/10.1155/2021/6680627.

[21] M. M. Sarafraz, A. Dareh Baghi, M. R. Safaei, A.S. Leon, R. Ghomashchi, M. Goodarzi, C. Lin, Energies 12 (2019) 4327. https://doi.org/10.3390/en12224327.

[22] A. M. Hassaan, Heat Trans. Res. 53 (2022) 19–34. https://doi.org/10.1615/HeatTransRes.2022042147.

[23] A. M. Hassaan, Int. J. Therm. Sci. 177 (2022) 107569. https://doi.org/10.1016/j.ijthermalsci.2022.107569.

[24] A. M. Hassaan, Heat Trans. Res. 54 (2023) 1–16. https://doi.org/10.1615/HeatTransRes.2023045768.

[25] A. M. Hassaan, Proc. Inst. Mech. Eng., Part E 236 (2022) 2139–2146. https://doi.org/10.1177/09544089221086825.

[26] A. M. Hassaan, Proc. Inst. Mech. Eng., Part E 237 (2022) 1310–1318. https://doi.org/10.1177/09544089221113977.

[27] A. M. Hassaan, Heat Mass Transfer 60 (2024) 1211–1219. https://doi.org/10.1007/s00231-024-03487-8.

[28] M. M. Sarafraz, A. Dareh Baghi, M. R. Safaei, A.S. Leon, R. Ghomashchi, M. Goodarzi, C. Lin, Energies 12 (2019) 4327. https://doi.org/10.3390/en12224327.

[29] N. S. Sahid, M.M. Rahman, K. Kadirgama, M.A. Maleque, J. Mech. Eng. Sci. 11 (2017) 3087–3094. https://doi.org/10.15282/jmes.11.4.2017.11.0277.

[30] B. Barbés, R. Páramo, E. Blanco, M.J. Pastoriza-Gallego, M.M. Pineiro, J.L. Legido, C.J. Casanova, J. Therm. Anal. Calorim. 111 (2013) 1615–1625. https://doi.org/10.1007/s10973-012-2534-9.

[31] S.Z. Heris, T.H. Nassan, S.H. Noie, H. Sardarabadi, M. Sardarabadi, Int. J. Heat Fluid Flow 44 (2013) 375–382. https://doi.org/10.1016/j.ijheatfluidflow.2013.07.006.

[32] B. Mehta, D. Subhedar, Mater. Today: Proc. (2023). https://doi.org/10.1016/j.matpr.2023.09.142.

[33] M. A. Rahman, S. M. Hasnain, S. Pandey, A., Tapalova, N., Akylbekov, R. Zairov, ACS omega 9 (2024) 32328–32349. https://doi.org/10.1021/acsomega.4c03279.

[34] M. M. Arani, Micro and Nano Technologies (2024) 45–75. https://doi.org/10.1016/B978-0-443-13625-2.00003-6.

[35] R.S. Khedkar, A. Saikiram, S.S. Sonawane, K. Wasewar, S.S. Umre, Procedia Eng. 51 (2013) 342–346. https://doi.org/10.1016/j.proeng.2013.01.047.

[36] W. Yu, H. Xie, L. Chen, Y. Li, Colloids Surf., A 355 (2010) 109–113. https://doi.org/10.1016/j.colsurfa.2009.11.044.

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NAUČNI RAD

EKSPERIMENTALNA ISTRAŽIVANJA U PLOČASTOM IZMENJIVAČU TOPLOTE KORIŠĆENJEM NANOFLUIDA Terminol-55/Al_2O_3 I GLICEROL/Al_2O_3

Cilj eksperimenata je bio da se uporede performanse prenosa toplote dve bazne tečnosti, Terminol-55 i glicerola, pomešana sa nanočesticama aluminijum-oksida. Istraživanje se fokusiralo na procenu na to kako dodatak nanočestica aluminijum-oksida (u koncentracijama od 0,1%, 0,2% i 0,25% v/v) utiče na prenos toplote u pločastom izmenjivaču toplote korišćenjem mešavine Therminol-55/voda i glicerol/voda. Rezultati su pokazali značajno poboljšanje efikasnosti prenosa toplote i za toplu i za hladnu stranu izmenjivača kada se koriste ove mešavine baznih fluida sa nanočesticama. Konkretno, studija je pokazala značajno poboljšane koeficijente prenosa toplote za mešavinu Terminol-55/voda sa koncentracijom nanočestica od 0,25%, postižući 3859 V/m²K (povećanje od 23%) za koeficijent toplog fluida, 4195 V/m²K (povećanje od 31%) za koeficijent hladnog v i ukupan koeficijent od 2310 V/m²K (povećanje od 23%). Slično tome, mešavina glicerol/voda sa koncentracijom nanočestica od 0,25% pokazala je superiorne performanse, dostižući 4491 V/m²K (povećanje od 30%) za koeficijent toplog fluida, 4395 V/m²K (povećanje od 36%) za koeficijent hladnog fluida i ukupni koeficijent od 2508 V/m²K (povećanje od 28%). Ovi rezultati ukazuju na to da mešavina glicerol/voda sa nanočesticama aluminijum-oksida nadmašuje par Terminol-55/voda, što ukazuje na njen potencijal da minimizira temperaturne razlike unutar izmenjivača toplote i poboljša operativnu efikasnost.

Ključne reči: Al_2O_3; prenos toplote; terminol-55; glicerol; nanofluid; pločasti izmenjivač toplote.