Jurnal Tekno Insentif | Vol. 17 | No. 1 | April 2023
DOI : https://doi.org/10.36787/jti.v17i1.940 Halaman 11 - 21

Experimental Investigation of The Heat Transfer Characteristics of Hybrid Nanofluid Al_2O_3/CuO-Distilled Water with The Variation of Concentration Ratios

DEVIA GAHANA CINDI ALFIAN[1], NICHOLAS BINSAR PANDAPOTAN[2], MUHAMMAD SYAUKANI[3], DICKY J. SILITONGA[4], DEVY SETIORINI SA'ADIYAH[5], TAURISTA PERDANA SYAWITRI[6]

[1,2,3,4]Institut Teknologi Sumatera, Indonesia
[5]Institut Teknologi Kalimantan, Indonesia
[6]Universitas Muhammadiyah Surakarta, Indonesia
Email: devia.gahana@ms.itera.ac.id

ABSTRAK

Panas berlebih yang terjadi pada CPU (Central Processing Unit) komputer dapat menyebabkan penurunan kinerja komputer. Penggunaan fluida pendingin yang diaplikasikan pada perangkat waterblock dapat membantu penurunan temperatur panas berlebih. Salah satu fluida pendingin yang dapat digunakan pada waterblok adalah fluida pendingin jenis nanofluida. Nanofluida merupakan fluida kerja yang mengandung nanopartikel dan fluida dasar untuk dialirkan pada perangkat pengujian. Penelitian ini dilakukan untuk mengetahui karakteristik perpindahan panas dari perangkat uji waterblock dengan menggunakan variasi perbandingan konsentrasi 25% Al_2O_3: 75% CuO, 50% Al_2O_3: 50% CuO, 75% Al_2O_3: 25% CuO dan fraksi volume 0,3% dengan komposisi yang terdiri dari nanofluida Al_2O_3-CuO/Air Distilasi. Metode pembuatan nanofluida dilakukan dengan proses sonikasi selama 4 jam. Berdasarkan hasil penelitian menunjukkan penurunan temperatur heater paling signifikan ditunjukkan pada hybrida nanofluida dengan perbandingan 75% Al_2O_3 : 25% CuO sebesar 24,1^oC dengan debit 1 liter/menit, sedangkan pada air distilasi penurunan temperatur heater tertinggi ditunjukkan oleh flowrate 1,9 liter/menit 3,4^oC. Besarnya nilai koefisien perpindahan panas tertinggi ditunjukkan pada variasi 75% Al_2O_3 : 25% CuO pada rentang Bilangan Reynolds 41,9-113,7 dengan nilai tertinggi sebesar 345.798 W/m2^oC. Hasil pengujian menunjukkan bahwa penggunaan hibrida nanofluida dapat mengurangi temperatur lebih baik daripada air distilasi.

Kata kunci: nanofluida, *waterblock*, fraksi volume, koefisien konveksi

ABSTRACT

Excessive heat that occurs in the computer's CPU (Central Processing Unit) can cause a decrease in computer performance. Cooling fluid applied to the waterblock device can help reduce overheating temperatures. One of the cooling fluids used in waterblocks is the cooling fluid of the nanofluid type. Nanofluid is a working fluid that contains nanoparticles and base fluid to flow on the testing device. This *research was conducted to determine the heat transfer characteristics of the waterblock test device using variations in the concentration ratio of 25% Al_2O_3 : 75% CuO, 50% Al_2O_3 : 50% CuO, 75% Al_2O_3 : 25% CuO and a volume fraction of 0.3% with the same composition. consists of nanofluid Al_2O_3-CuO/Distilled Water. The method of making nanofluids is done by sonication process for 4 hours. Based on the study's results, the most significant decrease in heater temperature was shown in nanofluid hybrids with a ratio of 75% Al_2O_3 : 25% CuO of 24.1^oC with a discharge of 1 liter/minute. In contrast, the highest decrease in heater temperature in distilled water was shown by a flow rate of 1.9 liters/minute 3.4^oC. The highest value of the heat transfer coefficient is shown in the variation of 75% Al_2O_3 : 25% CuO in the Reynolds number range of 41.9-113.7 with the highest value of 345,798 W/m2^oC. The test results show that nanofluid hybrids can reduce temperature better than distilled water.*

Keywords: *nanofluid, waterblock, volume fraction, convection coefficient*

1. INTRODUCTION

CPU is an essential part of a computer device that functions as the main component of computer equipment. To maintain the state of temperature to remain stable, the CPU usually uses cooling media so that the temperature is maintained and does not run into overheating, which can damage the components. Cooling devices such as fans are less effective on laptops or computers in industries with high work performance. There are several methods to cooling the computer using a fan that is flowed by air-fluid, liquid cooling to the heatsink. Waterblock is one of the media that can use for cooling a laptop because the low price is also often found in the market. Waterblock is a heat control component of the cooling water system **(Gupta et al., 2019)**. The element of the waterblock has two parts combined into one to form the heatsink block **(Harun & Che Sidik, 2020)**. In the heatsink, there is a cavity where the liquid flows. The liquid is used to cool or maintain the stability of the temperature of the computer or laptop.

Thermal conductivity is the property of a fluid that describes the rate at which heat energy is transferred in response to a change in temperature **(Zhang & Xu, 2020)**. In order for nanofluids to be used as working fluids in heat transfer devices, a nanometer-sized particle was initially mixed with a basic fluid in the form of pure metal particles and in the form of metal oxides to form suspensions with enhanced thermal capabilities **(Ali et al., 2015; Mukherjee et al., 2020)**. In the waterblock media employed in this research **(Siricharoenpanich et al., 2020)**. Particles in the size of the nano that is dispersed in the primary fluid provide a very good brown motion effect to prevent agglomeration **(Saghir & Rahman, 2021)**. One of the advantages of nanofluid is the ability to make heat transfer where several nanomaterials are suspended in heat transfer liquids such as water **(Ahmad et al., 2021)**. Nanofluids can use many essential ingredients, such as water, ethylene glycol, and mineral oil **(Askari et al., 2021)**. As a component of nanofluids, this type of nanoparticle, such as Al_2O_3, CuO, ZnO, TiO_2, etc., has been extensively utilized **(El-Behery et al., 2022)**.

In this study, researchers utilized essential fluid distillate water due to its availability and affordability. CuO and Al_2O_3 nanoparticles are subjected to ultrasound using an ultrasonic cleaner method to create nanofluids. CuO is one of the nanoparticles with the highest conductivity among other nanoparticles. CuO in a fluid can significantly increase fluid conductivity **(Chaudhari et al., 2019)**. Al_2O_3 is a compound formed from aluminum and oxygen, so one of its properties is corrosion resistance. Nanofluid hybrids are a method of synthesizing a relatively new nanofluid **(Benkhedda et al., 2020)**. The primary purpose of synthesizing nanofluid hybrids is to obtain the properties of the essential ingredients of their constituents. A mono nanofluid does not have all the characteristics needed for a particular purpose. One example has good thermal properties **(Kazemi et al., 2020)**. Nanofluid hybrids are expected to produce better thermal conductivity compared to single nanofluids. In this study, the author carry out nanofluid hybrid synthesis with several composition ratios between nanoparticles Al_2O_3 and CuO by 25%: 75%, 50%: 50%, and 75%: 25% with a volume fraction of 0.3%.

2. MATERIALS AND METHODS

Mixing hybrid nanofluid is carried out by a two-stage method, which is carried out with nanoparticle preparation with a volume fraction of 0.3%and varying the mixture ratio between the two nanoparticles, namely Al_2O_3: CuO with a percentage ratio of 25%: 75%, 50%: 50%, 75%: 25%, and mixed into the primary fluid, namely distilled water. Before making hybrid nanofluids, first make mono nanofluids, which mix each nanoparticle with distilled water into a beaker, then each nanofluid is stirred using an ultrasonic cleaner for 3 hours. Where other ratios must separate the stirring results of each ratio, this is done so that the resulting nanofluid is more stable for each comparison of the concentration ratio. After the stirring process, the deposition process is carried out for approximately 24 hours. After the deposition process, each nanofluid is mixed according to the ratio used and stirred for 1 hour using an ultrasonic cleaner. Where other ratios must separate the stirring results of each ratio, this is done so that the resulting nanofluid is more stable for each comparison of the concentration ratio. This was done hoping that only a few nanoparticles settled in the bottle.

The number of nanoparticles and basic fluids used as constituents of hybrid nanofluids is obtained based on a set volume fraction of 0.3%. Based on the volume fraction brought, the number of nanoparticles and basic fluids can be seen in Table 1.

Table 1. Nanofluid composition

No	Composition	Al_2O_3 (gram)	CuO (gram)	Distilled Water (ml)
1	Water	-	-	600
2	Water+0.3% Al_2O_3-CuO (25% : 75%)	1.62	8.77	589.61
3	Water+0.3% Al_2O_3-CuO (50%: 50%)	3.24	5.85	590.91
4	Water+0.3% Al_2O_3-CuO (75% : 25%)	4.86	2.92	192.22

Nanofluid hybrid testing is carried out on test design tools to determine the effect of nanofluid hybrids as cooling fluids. Figure 1 depicts the design of the nanofluid hybrid testing instrument. The power supply, the heater, the measuring cup, the waterblock, the thermocouple, the hose, the thermocouple monitor, the nylon plates, and the peristaltic pumps were the components that were utilized in this research. The hybrid nanofluids that have been created will be examined using the testing apparatuses built, and the testing procedure will be carried out in accordance with the scheme shown in Figure 2.

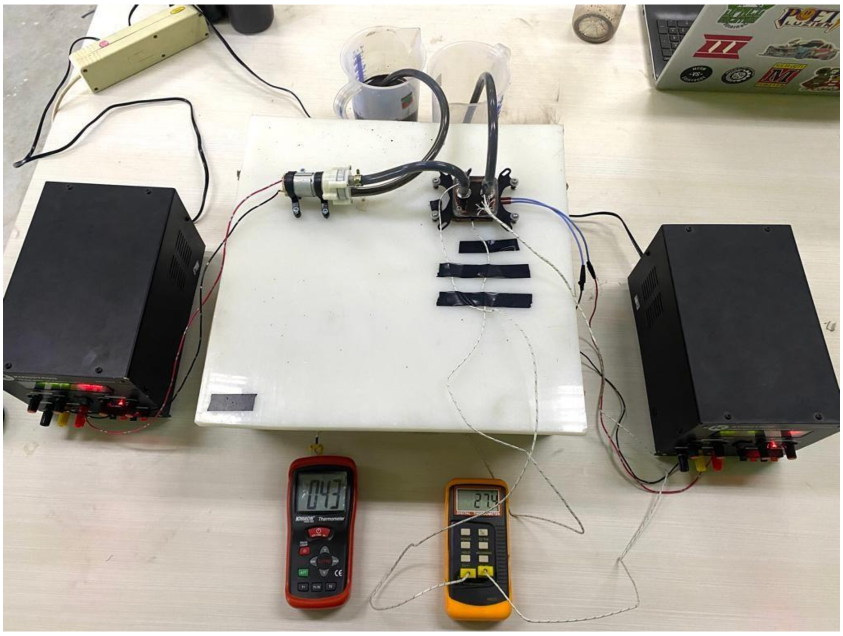

Figure 1. A series of testing tools

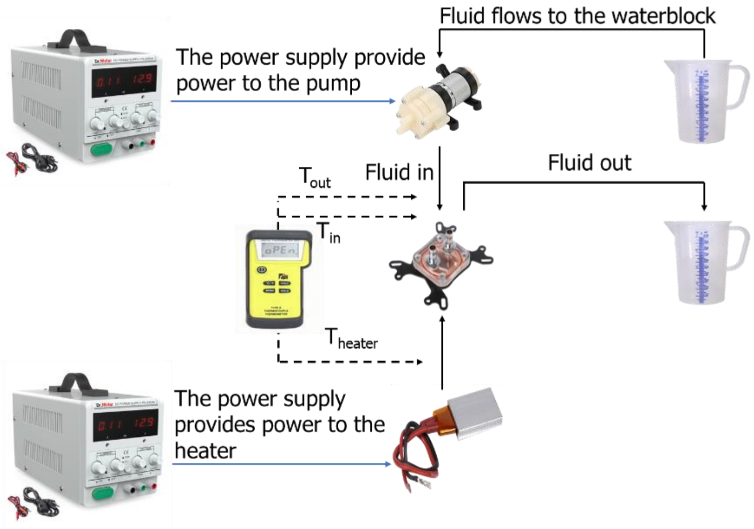

Figure 2. Scheme and Work Process of Testing Tools

3. RESULT AND DISCUSSION

The manufacture of nanofluid hybrids is carried out using the ultrasonic cleaner for 3 hours. After the stirring process, nanofluids are deposited for approximately 24 hours. The depositional process is carried out due to whether nanoparticles did not dissolve in the primary fluid. Therefore, nanoparticles that are not soluble are separated first to find out the mass of the precipitate, and from the mass of the sediment, it can be known how many nanoparticles dissolved in the basic fluid. Testing characteristics of nanofluid Al_2O_3-CuO/Distilled Water (Hybrid Nanofluids/Distilled Water) is carried out using a waterblock with a flow rate variation of 0.7-1.9 liter per minute with an interval of 0.3 liter per minute. Following are the results obtained after testing.

3.1 The Effect of Decreasing Temperature Over a Period of Time

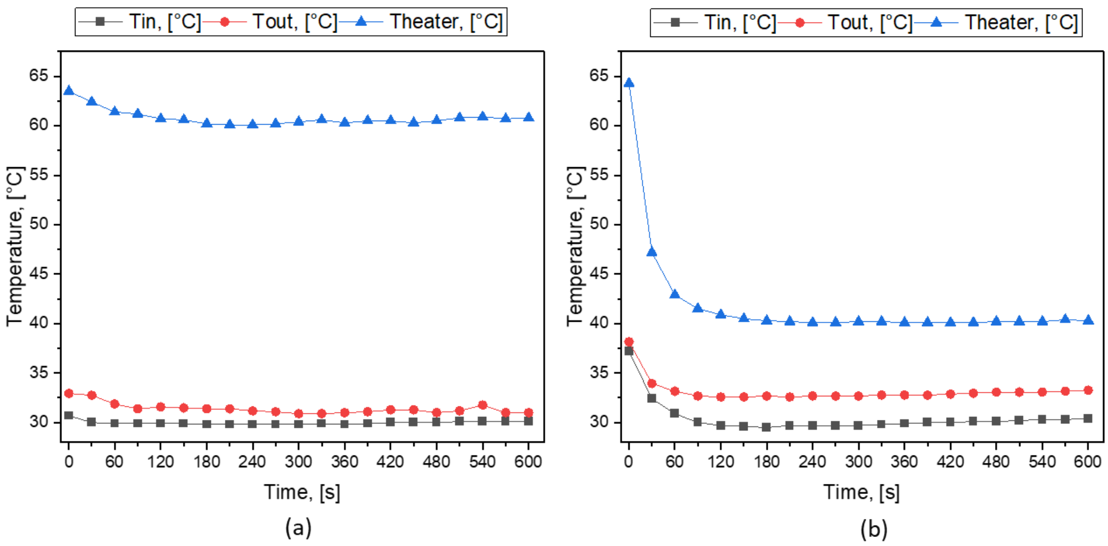

Figure 3. The Effect of Time on Temperature Reduction (a) 0.7 Liter/Minute of distilled water, (b) 0.7 Liter/Minute 75% Al_2O_3: 25%CuO

The temperature of the heater begins at 63.5ºC and falls to 60.8ºC, as shown in Figure 3(a), which depicts a temperature drop that happened in distilled water of 2.7 ºC. Figure 3.a further explains that after 270 seconds, the temperature within the heater starts to stabilize. This information can be found in the figure. Figure 3. (b) shows a decrease in the temperature in nanofluids 75% Al_2O_3: 25% CuO in 0.7 L/min of 24ºC where the heater temperature starts from 64.3ºC until it drops to 40.3ºC. Figure 3. (b) also shows a decrease in the temperature on the heater begins to stable at 240 seconds, which shows that at the second 240 data, the heater temperature decreases are ready to be taken and processed. Figure 3. (a) and Figure 3. (b) only display data T_{heater}, T_{in}, T_{out} to show the difference in temperature with the variation of the hybrid nanofluid Al_2O_3/CuO-Distilled water in the variation of the flow rate and know the effect of time on the difference in temperature entrances and electronic temperature out temperature. The data obtained is stable for calculation or analysis based on data after 600 seconds. This is similar to research conducted by **(Rafati et al., 2012)(Sharma et al., 2013)** where the more prolonged the testing is carried out, nanofluids will be more stable to reduce the temperature **(Shirzad et al., 2019)**.

3.2 Differences between Heater Temperature with Working Fluid Temperature

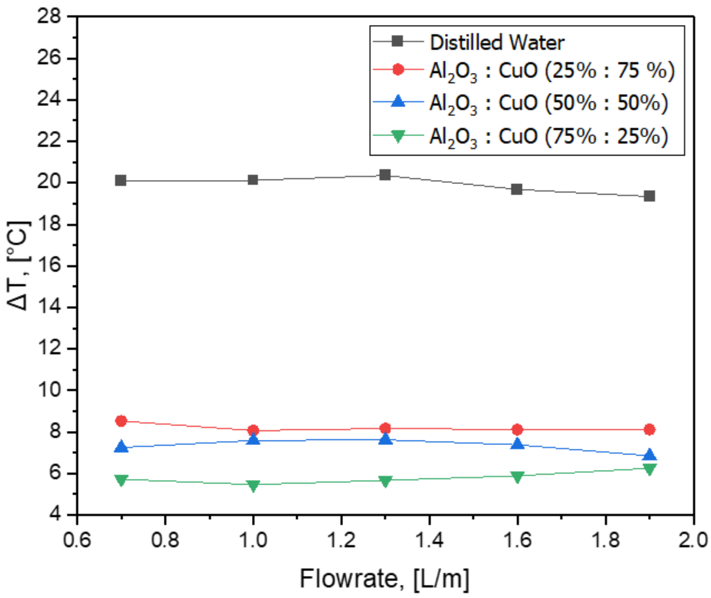

Figure 4. Flowrate comparison to temperature differences

Figure 4 shows the effect of the difference in heater temperature and working fluid. The fluid's flow rate and the ratio of nanofluid hybrid concentrations influence the temperature difference. It can be seen in Figure 4. that the lowest temperature difference is in the 75% Al_2O_3: 25% CuO ratio, with a range of 5.46ºC to 6,247ºC. The most inferior temperature difference possessed by the nanofluid hybrid ratio of 25% Al_2O_3: 75% CuO has a range of 8.1ºC to 8.5ºC. The nanofluid hybrid ratio of 50% Al_2O_3: 50% CuO has a range of 6.8ºC to 7.2ºC. In distilled water, the most inferior temperature difference is 19.34ºC to 20.35ºC. This happens due to the influence of T_{heater}, T_{in}, and T_{out}. As can be seen in the figure, the increasing number of nanoparticles Al_2O_3 mixed, the lower the difference in heater temperature. This is because CuO has a more excellent thermal conductivity between distilled water and Al_2O_3. Thermal conductivity has a function in a nanofluid where thermal conductivity can reduce the temperature of an object to a significant. This is the same as research by **(Alkasmoul et al., 2018)**, where nanofluids' thermal conductivity is a temperature function.

3.4 Comparison of Convection Coefficient Value to Reynolds Number

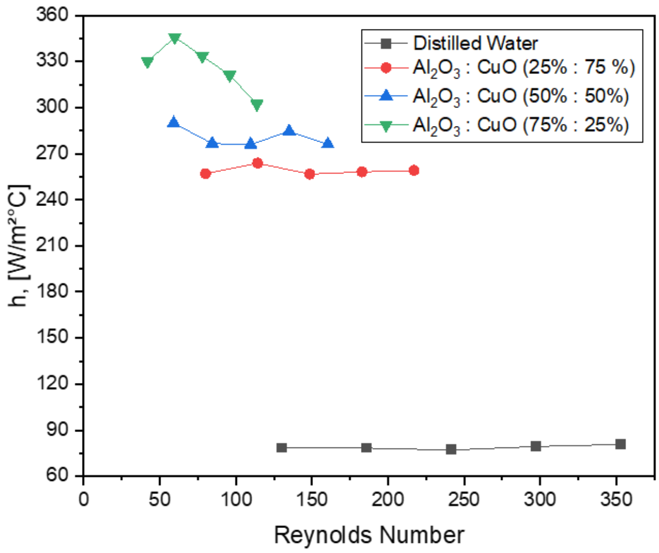

Figure 5. Comparison of Reynolds Numbers to Convection Coefficient

Figure 5 shows the ratio between the value of convection coefficient and the Reynolds number. The velocity of flow, hydraulic diameter, nanofluids density, nanofluids viscosity, heater power, and temperature difference influence the trendlines. Figure 5. shows that distilled water has a Reynolds number value with a range of 130.09 to 353.1 while nanofluid hybrids with a 25% Al_2O_3: 75% CuO Reynolds value owned in a range of 79.95 to 217.02. Nanofluid hybrids with a ratio of 50% Al_2O_3: 50% CuO Reynolds value held in a range of 59.079 to 160.36, and in nanofluid hybrids with a ratio of 75% Al_2O_3: 25% CuO Reynolds value owned in a range of 41.92 to 113.78. From Figure 5., it can be determined that the type of flow obtained is the laminar flow **(Salhi et al., 2022)**. In this study, to calculate the value of the Reynolds number is to know the length of the hydraulic diameter characteristics based on the waterblock dimension. The most significant value of the convection coefficient with the Reynolds number was found in the hybrid nanofluid 75% Al^2O_3: 25% CuO, which had a value of 345.798 W/m2°C at a flow rate of 1 L/min and a Reynolds number of 59.88, while distilled water had a value of 80.734 W/m2°C at a flow rate of 1 L/min and a Reynolds number of 353.

Figure 5. demonstrates that the more nanoparticles Al_2O_3, the higher the convection coefficient is directly proportional to the research conducted by **(Wanatasanappan et al., 2020)**, which states that the greater the concentration of Al_2O_3 given, the greater the conduction coefficient value. Moreover, 75% Al_2O_3:25%CuO nanofluid hybrids have the highest thermal convection coefficient. According to **(Hamid et al., 2017)**, the considerable increase in thermal conductivity is likely owing to the high kinetic energy of the nanoparticles, which results in the effect of Brownian motion.

3.5 Comparison of pump power with flowrate

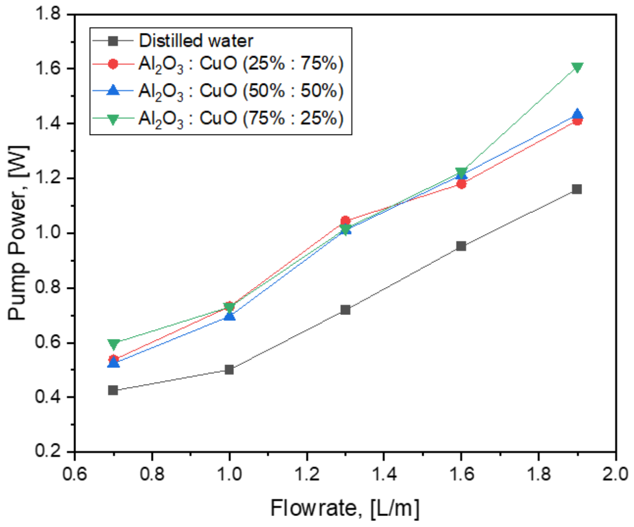

Figure 6. Flowrate comparison with pump power

Figure 2 depicts the flow rate and pump power relationship based on working fluid variations. It shows that the highest pump power value occurs in nanofluid hybrids with a ratio of 75% Al_2O_3: 25% CuO with a value of 1.61 W, where the flow rate used is 1.9 liters/minute. Figure 6 also explains that the pump power increase is directly proportional to the flowrate and hybrid nanofluid used. Viscosity causes the increase in pump power to flowrate in a worling fluid. The viscosity value of distilled water is 0.000623 Ns/m^2. In contrast, in nanofluid hybrids 25% Al_2O_3: 75% CuO viscosity value obtained is 0.000836 NS/m^2 and in nanofluid hybrids 50% Al_2O_3: 50% CuO viscosity value obtained is 0.000799 NS/m^2 and in nanofluid hybrids 75% Al_2O_3: 25% CuO viscosity value obtained is 0.000741316 NS/m^2. A higher nanoparticle composition also influences the increase in pump power. Therefore, the viscosity value of a nanofluid hybrid is increasing. According to research conducted by **(Alrashed et al., 2018)**, the higher the nanoparticles' composition, the higher the nanofluid hybrid's viscosity value will be higher and cause the power in the system to increase. In addition, research conducted by **(Mukherjee et al., 2020)**, stated that the greater the flow rate used, the more pump power is needed.

4. CONCLUSION

The results of the Nanofluid Al_2O_3-CuO/Water hybrid experiment can be concluded as follows:

1. The use of hybrid nanofluids has a very significant effect on increasing the convection coefficient compared to only base fluids.
2. Testing of hybrid nanofluids with varying ratios of Al_2O_3 and CuO (75%:25%, 50%:50%, and 25%:75%) applied to waterblocks is in the Reynolds number range of 41.9-217, while distilled water is in the Reynolds number range 130-353.
3. The most significant value of the convection coefficient with the Reynolds number was obtained in the hybrid nanofluid 75% Al_2O_3 : 25% CuO with a value of 345.798 W/m$^{2\circ}$C with a Reynolds Number of 59.88 at a flow of 1 L/minute, while distilled water was 80.734 W/m$^{2\circ}$C with a Reynolds Number of Reynold 353 at a flow of 1 L/min. The influence of

nanofluid hybrid concentration ratio and flow rate causes differences in heat transfer characteristics. In addition, the greater the concentration of Al_2O_3 nanoparticles given, the greater the value of the convection coefficient.

4. The highest pump power value occurs in hybrid nanofluids with a ratio of 75% Al_2O_3 : 25% CuO with a value of 1.61 W with a flow rate of 1.9 liters/minute. The increase in pump power is directly proportional to the rise in the flow rate of the working fluid. Hybrid nanofluid composition with the highest viscosity variations can affect the increase in pump power.

ACKNOWLEDGMENT

The authors would like to thank the Sumatra Institute of Technology for assisting the implementation of this research by providing access to laboratory facilities for the research to be conducted.

REFERENCES

Ahmad, S., Coban, H. H., Khan, M. N., Khan, U., Shi, Q. H., Muhammad, T., Chinram, R., & Kadry, S. (2021). Computational analysis of the unsteady 3D chemically reacting MHD flow with the properties of temperature dependent transpose suspended Maxwell nanofluid. *Case Studies in Thermal Engineering*, *26*. https://doi.org/10.1016/j.csite.2021.101169

Ali, H. M., Ali, H., Liaquat, H., bin Maqsood, H. T., & Nadir, M. A. (2015). Experimental investigation of convective heat transfer augmentation for car radiator using ZnO-water nanofluids. *Energy*, *84*, 317–324. https://doi.org/10.1016/j.energy.2015.02.103

Alkasmoul, F. S., Al-Asadi, M. T., Myers, T. G., Thompson, H. M., & Wilson, M. C. T. (2018). A practical evaluation of the performance of Al2O3-water, TiO2-water and CuO-water nanofluids for convective cooling. *International Journal of Heat and Mass Transfer*, *126*, 639–651. https://doi.org/10.1016/j.ijheatmasstransfer.2018.05.072

Alrashed, A. A. A. A., Akbari, O. A., Heydari, A., Toghraie, D., Zarringhalam, M., Shabani, G. A. S., Seifi, A. R., & Goodarzi, M. (2018). The numerical modeling of water/FMWCNT nanofluid flow and heat transfer in a backward-facing contracting channel. *Physica B: Condensed Matter*, *537*, 176–183. https://doi.org/10.1016/j.physb.2018.02.022

Askari, S., Ettefaghi, E., Rashidi, A., Seif, A., Rudd, J. A., Alonso, J. A., & Khodabakhshi, S. (2021). Ultra-stable nanofluid containing Functionalized-Carbon Dots for heat transfer enhancement in Water/Ethylene glycol systems: Experimental and DFT studies. *Energy Reports*, *7*, 4222–4234. https://doi.org/10.1016/j.egyr.2021.07.001

Benkhedda, M., Boufendi, T., Tayebi, T., & Chamkha, A. J. (2020). Convective heat transfer performance of hybrid nanofluid in a horizontal pipe considering nanoparticles shapes effect. *Journal of Thermal Analysis and Calorimetry*, *140*(1), 411–425. https://doi.org/10.1007/s10973-019-08836-y

Chaudhari, S. S., Chakule, R. R., & Talmale, P. S. (2019). ScienceDirect Experimental Study of Heat Transfer Characteristics of Al 2 O 3 and CuO Nanofluids for Machining Application. In *Materials Today: Proceedings* (Vol. 18). www.sciencedirect.com

El-Behery, S. M., Badawy, G. H., El-Askary, W. A., & Mahfouz, F. M. (2022). Effects of Nanofluids on the Thermal Performance of Double Pipe Heat Exchanger. *Mech. Eng*, *45*(2), 13–25.

Gupta, R., Chavan, O., Dinesh, P., & Bankar, M. (2019). Experimental Analysis on Liquid-cooled Minichannel Heatsink for Personal Computers. *International Research Journal of Engineering and Technology*, *6*(4). www.irjet.net

Hamid, K. A., Azmi, W. H., Nabil, M. F., & Mamat, R. (2017). Improved thermal conductivity of TiO2-SiO2 hybrid nanofluid in ethylene glycol and water mixture. *IOP Conference Series: Materials Science and Engineering*, *257*(1). https://doi.org/10.1088/1757-899X/257/1/012067

Harun, M. A., & Che Sidik, N. A. (2020). A Review on Development of Liquid Cooling System for Central Processing Unit (CPU). *Journal of Advanced Research in Fluid Mechanics and Thermal Sciences*, *98*(113), 98–113. https://doi.org/10.37934/ARFMTS.78.2.98113

Kazemi, I., Sefid, M., & Afrand, M. (2020). A novel comparative experimental study on rheological behavior of mono & hybrid nanofluids concerned graphene and silica nano-powders: Characterization, stability and viscosity measurements. *Powder Technology*, *366*, 216–229. https://doi.org/10.1016/j.powtec.2020.02.010

Mukherjee, S., Mishra, P. C., & Chaudhuri, P. (2020). Thermo-economic performance analysis of Al2O3-water nanofluids — An experimental investigation. *Journal of Molecular Liquids*, *299*. https://doi.org/10.1016/j.molliq.2019.112200

Rafati, M., Hamidi, A. A., & Shariati Niaser, M. (2012). Application of nanofluids in computer cooling systems (heat transfer performance of nanofluids). *Applied Thermal Engineering*, *45–46*, 9–14. https://doi.org/10.1016/j.applthermaleng.2012.03.028

Saghir, M. Z., & Rahman, M. M. (2021). Brownian motion and thermophoretic effects of flow in channels using nanofluid: A two-phase model. *International Journal of Thermofluids*, *10*. https://doi.org/10.1016/j.ijft.2021.100085

Salhi, J.-E., Zarrouk, T., Salhi, M., & Salhi, N. (2022). Analysis of the surface state's influence on the thermohydraulic behavior of an incompressible fluid in convective laminar flow through a microchannel with corrugated surfaces. In *EHEI Journal of Science and Technology* (Vol. 02). https://revues.imist.ma/index.php/ehei-jst/index.

Sharma, V. I., Buongiorno, J., McKrell, T. J., & Hu, L. W. (2013). Experimental investigation of transient critical heat flux of water-based zinc-oxide nanofluids. *International Journal of Heat and Mass Transfer*, *61*(1), 425–431. https://doi.org/10.1016/j.ijheatmasstransfer.2013.02.009

Shirzad, M., Ajarostaghi, S. S. M., Delavar, M. A., & Sedighi, K. (2019). Improve the thermal performance of the pillow plate heat exchanger by using nanofluid: Numerical simulation. *Advanced Powder Technology*, *30*(7), 1356–1365. https://doi.org/10.1016/j.apt.2019.04.011

Siricharoenpanich, A., Wiriyasart, S., Srichat, A., & Naphon, P. (2020). Thermal cooling system with Ag/Fe3O4nanofluids mixture as coolant for electronic devices cooling. *Case Studies in Thermal Engineering*, *20*. https://doi.org/10.1016/j.csite.2020.100641

Wanatasanappan, V. V., Abdullah, M. Z., & Gunnasegaran, P. (2020). Thermophysical properties of Al2O3-CuO hybrid nanofluid at different nanoparticle mixture ratio: An experimental approach. *Journal of Molecular Liquids*, *313*. https://doi.org/10.1016/j.molliq.2020.113458

Zhang, Y., & Xu, X. (2020). Predicting the thermal conductivity enhancement of nanofluids using computational intelligence. *Physics Letters, Section A: General, Atomic and Solid State Physics*, *384*(20). https://doi.org/10.1016/j.physleta.2020.126500