Heat Transfer Characteristics of Hybrid Nanofluids Al_2O_3/ZnO as Working Fluid in Electronic Cooling Systems

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Abstract

The use of nanofluid as a working fluid to improve equipment performance has been growing recently. Utilization of nanofluid hybrids is the development of mono nanofluid to improve heat transfer performance which is still not maximized when using mono nanofluid. This research was conducted to determine the performance of hybrid nanofluids with composition of Al_2O_3/ZnO-Distilled Water as working fluids in electronic devices. The process of making hybrid nanofluids was carried out using a two-step method using an ultrasonic cleaner for 3 hours. Furthermore, the test was carried out by varying the ratio of Al_2O3 and ZnO nanoparticles at 25%:75%, 50%:50%, 75%:25% at exactly 0.5% volume fraction. Based on the test results, adding nanoparticles can increase the heat transfer in the working fluid. The use of nanofluid hybrids at varying ratios of Al_2O_3:ZnO (50%:50%) with a flow rate of 0.7 L/min has the highest heat transfer coefficient value of 220.14 $W/m^2.^oC$ at Reynolds Number 178.4 and requires pumping power of 0.649 W. Moreover, distilled water with a flow rate of 0.7 L/min has the heat transfer coefficient of 77.48 $W/m^2.^oC$ at Reynolds Number 130.1 and requires a pump power of 0.425 W.

Keywords: Nanofluids, Hybrid Nanofluids, Heat Transfer Coefficient, Electronic Cooling

Abstrak

Penggunaan nanofluida sebagai fluida kerja untuk meningkatkan kinerja peralatan akhir-akhir ini semakin berkembang. Pemanfaatan hibrida nanofluida merupakan pengembangan dari mono nanofluida untuk meningkatkan kinerja perpindahan panas yang masih belum maksimal. Penelitian ini dilakukan untuk mengetahui kinerja hibrida nanofluida dengan komposisi Al_2O_3/ZnO-Air Distilasi sebagai fluida kerja pada perangkat elektronik. Proses pembuatan hibrida nanofluida dilakukan dengan metode dua langkah menggunakan ultrasonic cleaner selama 3 jam. Selanjutnya pengujian dilakukan dengan memvariasikan perbandingan nanopartikel Al_2O3 dan ZnO sebesar 25%:75%, 50%:50%, 75%:25% pada fraksi volume 0,5%. Berdasarkan hasil pengujian, penambahan nanopartikel dapat meningkatkan perpindahan panas pada fluida kerja. Penggunaan hibrida nanofluida pada variasi rasio Al_2O3 dan ZnO (50%:50%) dengan laju aliran 0,7 L/menit memiliki nilai koefisien perpindahan panas tertinggi sebesar 220,14 $W/m^2.^oC$ pada bilangan Reynolds 178,4 dan membutuhkan daya pompa sebesar 0,649 W. Selain itu, air distilasi dengan laju alir 0,7 L/menit memiliki koefisien perpindahan panas sebesar 77,48 $W/m^2.^oC$ pada bilangan Reynolds 130,1 serta membutuhkan daya pompa sebesar 0,425 W.

***Kata kunci:** Nanofluida, Nanofluida Hibrida, Koefisien Perpindahan Panas Pendingin Elektronik*

1. Introduction

Currently, computers are one of the important things in daily life. Almost all activities can be done using computer programs, such as making reports, doing calculations, reading articles, learning, even just playing games can be done by computers. Along with the development of computer technology, the work carried out by computers is also getting heavier and must be able to complete several complicated tasks. The results of computer work are determined by microprocessor or commonly known as CPU (Central Processing Unit). Microprocessor is a CIP found on a computer that functions to process data, usually determined from clock speed. Clock speed is the speed of the microprocessor in processing data with the unit is Hertz (Hz) [1].

Central Processing Unit (CPU) is part of the hardware on a computer that runs commands from computer programs, such as arithmetic, logical, and basic input/output operations of a computer system. CPU technology is one of the technologies that developed very fast with a small size of equipment and light equipment but still maintaining performance in order to work better and more efficiently. The development of speed processing data from a microprocessor increases, this is certainly directly proportional to the increase in heat produced by the microprocessor itself. So that the longer and the more severe the work done by the microprocessor will be the higher the temperature produced by the microprocessor [2]. Observing the temperature produced when the computer works is one of the important aspects in carrying out maintenance of computer components. Along with the duration of computer use, the temperature will also increase adjusting the performance of the computer, so that computer performance is maintained, it is necessary to be a cooler that is in accordance with the location and work of the computer. Using an additional cooler on a computer can help reduce the temperature produced by computer components while working [3].

There are several ways that can be used to cool the computer, namely by using gas fluid (air) and liquid fluid. On conventional computers, usually using the type of air cooling driven by fans. Some types of coolers found on computers such as fans, heatsinks, and liquid coolers. Waterblock is one of the tools used to cool computer components and is quite easy to get on the market and the price is not too expensive. Waterblock used as a cooler with a working fluid is a liquid that is in direct contact with the CPU and is designed with a small pipe size to pass through the fluid [4].

Nanofluid is a suspension of nanoparticles with basic fluids that was first coined in 1995 by researchers Choi and Eastman who described the colloidal suspension of nanoparticles that are <100 nm. Nanofluids are useful in several heat transfer applications such as electronic equipment, heat exchangers, heat pipes, solar collectors, and so on. Nano technology has created a new and rather special fluid class, called nanofluid, which appears as a fluid that has a great potential for cooling application and has been proven to have thermal properties of a mixture that forms significantly higher than the basic fluid [5]. Some kinds of nanoparticles commonly used as nanofluids such as Al_2O_3, ZnO, TiO_2, SiO_2, Fe_2O_3, CuO, Cu, and AG [6]. From the advantages possessed by nanofluids there are still several problems related to agglomeration, where when conductivity is high but there is a very fast agglomeration or vice versa.

From this problem, the researchers are currently starting to develop and observe hybrid nanofluids. Hybrid is a combination of two or more nanoparticles into the basic fluid. Hybrid nanofluid offers the advantage of heat transfer performance and has superior heat transfer properties compared to conventional cooling base fluids such as ethylene glycol, water, oil and nanofluids with a single nanoparticle [7].

In previous studies a study was conducted on the effect of adding nanoparticles Al_2O_3 into the basic fluid of water on increased heat transfer in the cooler of electronic devices. From this study it was found that an increase in heat transfer occurred by 40% at the time of nanoparticle concentration by 6.8% when compared to its basic fluid, the greater the concentration of nanoparticles used can reduce the heat of the component better, and the smaller nanoparticle size has a better heat transfer coefficient [8]. As for the previous research on nanofluids with ZnO nanoparticles and water basic fluids tested in vehicle radiators, can increase heat transfer by 46% at a 0.2% solution concentration [9].

In this study the author tries to mix between two types of nanoparticles, namely Al_2O_3 with ZnO in a volume fraction of 0.5% and variations of Nanoparticles Ratio Al_2O_3: ZnO is 25%: 75%, 50%: 50%, and 75%: 25%. While distilled water as a basic fluid, so that it can find out the differences in the characteristics of the heat transfer.

2. Material dan Method

The synthesis of hybrid nanofluid is carried out by a two-stage method [10], which is carried out with nanoparticle preparation with a volume fraction of 0.5% and varying the mixture ratio between the two nanoparticles, namely Al_2O_3: ZnO with a ratio of 25%: 75%, 50%: 50%, 75%: 25 %, and mixed into the basic fluid specifically distilled water. In the synthesis process of hybrid nanofluid, the first stage was to create a mono nanofluid, by mixing each nanoparticle with distilled water into a beaker, then each nanofluid was stirred using a ultrasonic cleaner for 3 hours [11]. After being deposited for 18 hours, each nanofluid was mixed according to the ratio used, then stir again for 1 hour using a ultrasonic cleaner. Figure 1. the following displays the process of making hybrid nanofluids.

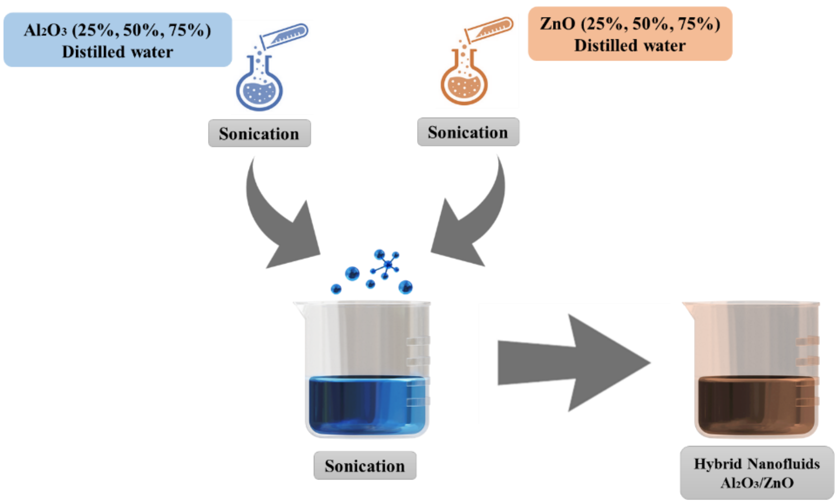

Figure 1. Steps for Making Hybrid Nanofluids

The number of nanoparticles and basic fluids used as constituents of hybrid nanofluids is obtained based on a set volume fraction of 0.5%. Based on the volume fraction obtained the number of nanoparticles and basic fluids can be seen in the following **Table 1**.

Table 1. Composition of Hybrid Nanofluids

No.	Composition	Al_2O_3 (gram)	ZnO (gram)	Distilled water (ml)
1.	Distilled water	-	-	600
2.	Distilled water + (25% Al_2O_3 + 75% ZnO)	2.91	12.6	597
3.	Distilled water + (50% Al_2O_3 + 50% ZnO)	5.82	8.4	597
4.	Distilled water + (75% Al_2O_3 + 25% ZnO)	8.73	4.2	597

Hybrid nanofluid testing is carried out on waterblock designed to determine the effect of hybrid nanofluid as a cooling fluid used on computers. **Figure 2**. displays a cooling system design using waterblock for hybrid nanofluid testing. Hybrid nanofluids that have been made will be tested on a cooling system experimental setup as illustrated in **Figure 3.**

Figure 2. Design of Testing Tools

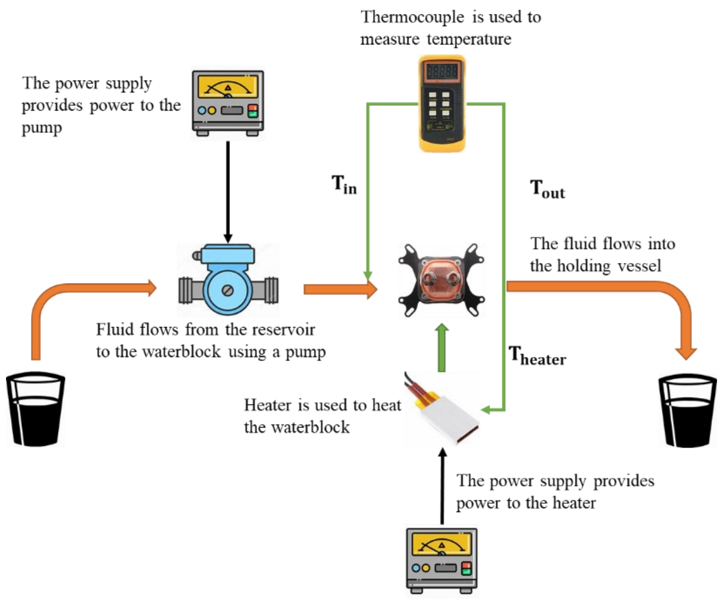

Figure 3. Test scheme

3. Results and Discussions

The synthesis of hybrid nanofluids was done by sonication using an ultrasonic cleaner for 3 hours, after sonication, nanofluids are deposited for 18 hours as shown in **Figure 4**. After being deposited for 18 hours, nanoparticles that do not dissolve in the basic fluid were precipitated at the bottom of the container. Thus, nanoparticles that are not soluble were first separated to find out the mass of the precipitate, and from the mass of the sediment, the quantity of nanoparticles dissolved in the base fluid could be determined. The first step before weighing the mass of the precipitate was to dry the precipitate until it is completely dry so that accurate data will be declared.

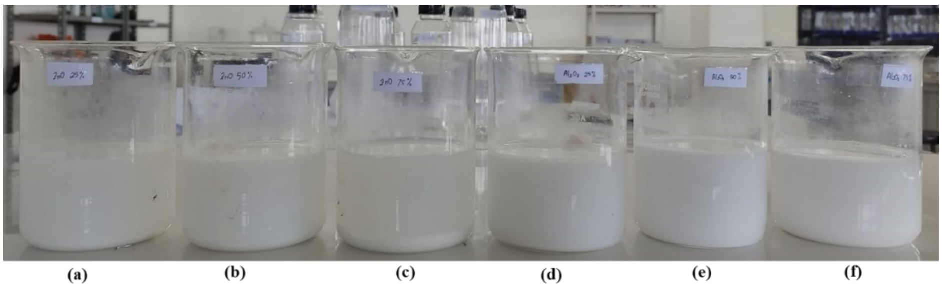

Figure 4. Nanoparticle sonication results. (a) 25% ZnO, (b) 50% ZnO, (c) 75% ZnO, (d) 25% Al_2O_3, (e) 50% Al_2O_3, (f) 75% Al_2O_3

Nanofluid testing of Al_2O_3-ZnO/Distilled water is carried out using commercial waterblock and given a variation of flow rates to determine the effect of flow rates on cooling that occurs. The amount of flow given is 0.7-1.9 liters per minute (L/min) with an interval of 0.3 liters per minute (L/min). The following results obtained after testing.

3.1 The Effect of Decreased Temperature on Time

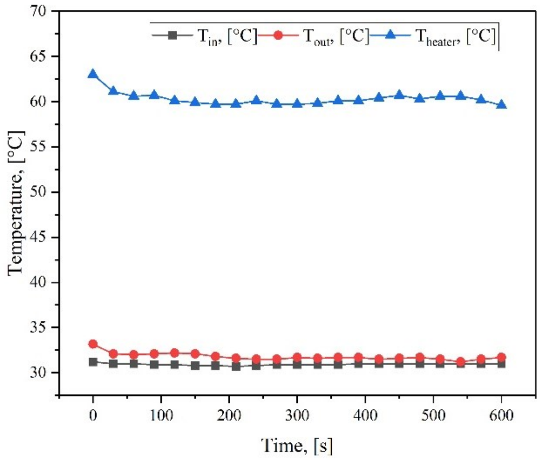

Figure 5. Decreased Graph of Temperature for Nanofluid Hybrid 50% Al_2O_3: 50% ZnO at a flow rate of 1.9 liters/minute

Figure 5. displays the graph of the relationship between changes in temperature and time. The test was carried out for 600 seconds or 10 minutes with data collection every 30 seconds, the heating plate was heated first until it reached a temperature of 65 ℃. The X axis displays the length of time of the testing, and the Y axis displays the temperature when the fluid enters and exits the waterblock and a decrease in the temperature of the heating plate. From the graph above, it is known that starting from 240 seconds the temperature in the heating plate has begun to be stable with an average temperature of 49.86 ℃, while at the entry and temperature of the waterblock exit is stable at the time starting from 0 seconds. At the inlet, the average temperature is 29.18 ℃, while at the outlet the average temperature value is 33.88 ℃. Based on experimental data, it shows that the temperature reaches a steady state after 600 seconds. This shows that the temperature characteristics are able to reach a stable condition which requires a certain amount of time [12]. So from this data, it can be carried out a calculation analysis based on the existing steady state conditions.

3.2 The Difference Between the Heating Plate Temperature to The Flow Rate

Figure 6. displays a graph of the temperature difference to the flow rate at distilled water and each nanoparticle ratio. The x-axis displays the flow rate used in this study, and on the y-axis displays the difference in heating plate temperature with a temperature around the waterblock on distilled water and hybrid nanofluids for each nanoparticle ratio. The difference in heater plate temperature with a temperature around the waterblock in distilled water is the highest compared to hybrid nanofluid. At a flow rate of 1.3 L/min, distilled water has a temperature difference of 20,35 ℃, hybrid nanofluids with a nanoparticle ratio of Al_2O_3: ZnO (25%:75%) has a temperature difference value of 11,35 ℃, in the ratio of Al_2O_3: ZnO (50%:50%). The temperature difference is 11.1℃, and in the ratio of Al_2O_3: ZnO (75%:25%). The temperature difference value is 10,56 ℃.

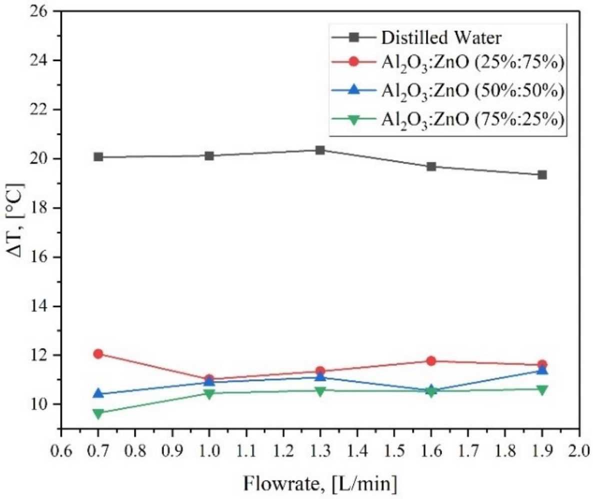

Figure 6 Difference Temperature Heating Plate to Flow Rate

The difference in temperature in the three hybrid nanofluids ratios is not too significant, the same result is obtained by Afrand [13] in his study where the temperature changes in the nanofluid variation used have a difference that is not too significant. There is no significant change in temperature at each flow rate that can be caused by basic fluid properties that are more dominating than nanoparticles, and can be seen in the distilled water trend without a mixture of nanoparticles also no significant changes in temperature. As for the greater the flow rate used, the type of flow will be closer to the type of turbulent flow, which in turbulent flow can produce Brownian motion. Brownian Motion is a random movement of a particle in the flow of fluid, these moving particles will collide with each other and as a result of the collision will increase the coefficient of heat transfer from the fluid [14].

According to the above works, lower temperature differences occur in the hybrid nanofluid mixture for all ratio variations. This shows that the ability to reduce the temperature of the heater is better than only using base fluid [15]. This happens because the properties of each nanoparticle contained in the hybrid nanofluid have a higher thermal conductivity value so that the temperature reduction mechanism at the heating source is more effective than just base fluid. In addition to the analysis above, Rafati. et. al. (2012) [16], explained that the higher the value of the flow rate used, the lower the difference in fluid temperature. Nevertheless, with the expectation that the device can operate at a lower flow rate so that the use of pump power is also low to produce performance close to higher performance for variations in flow rates according to the test.

3.3 Comparison of The Heat Transfer Coefficient with Reynolds Number

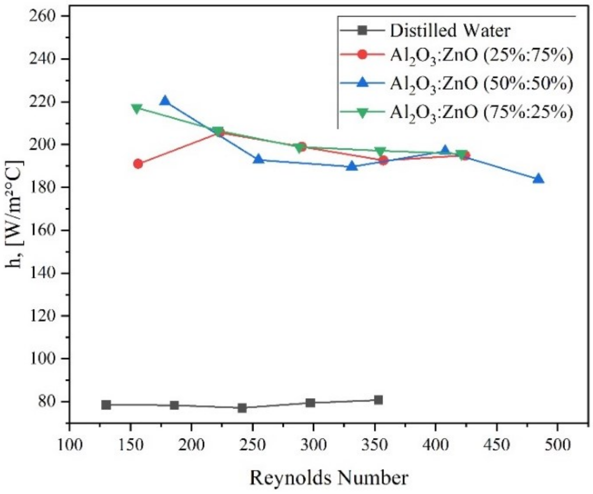

Figure 7. The comparison of the heat transfer coefficient to the Reynolds Number

Figure 7. Displays the comparison between Reynolds Number and the coefficient of convection heat transfer for distilled water and each variation of hybrid nanofluids ratio. The X axis displays the value of Reynolds Number for distilled water and hybrid nanofluids in each ratio, while the Y-axis displays the value of the heat transfer coefficient for distilled water and hybrid nanofluids in each ratio. Distilled water has the lowest heat transfer coefficient value compared to hybrid nanofluids [17]. When the Reynolds Number is 178, the highest heat transfer coefficient is obtained, namely in

the nanofluid hybrid ratio Al_2O_3: ZnO (50%:50%) which is worth 220,141 W/m^2.°C. Then followed by a hybrid nanofluids ratio of Al_2O_3: ZnO (75%:25%) which is worth 212 W/m^2. °C, and nanofluid ratio of Hybrid Al_2O_3: ZnO (25%:75%) which is worth 195 W/m^2.°C. Kumar, et.al (2020) [18] conducted research on nanofluids of Al_2O_3/MWCNT-water. At Reynolds Number of 150, hybrid nanofluid with a ratio of Al_2O_3: MWCNT (40%:60%) has a higher heat transfer coefficient value compared to the ratio of Al_2O_3: MWCNT (60%:40%).

3.4 Comparison of Pump Power to Flow Rate

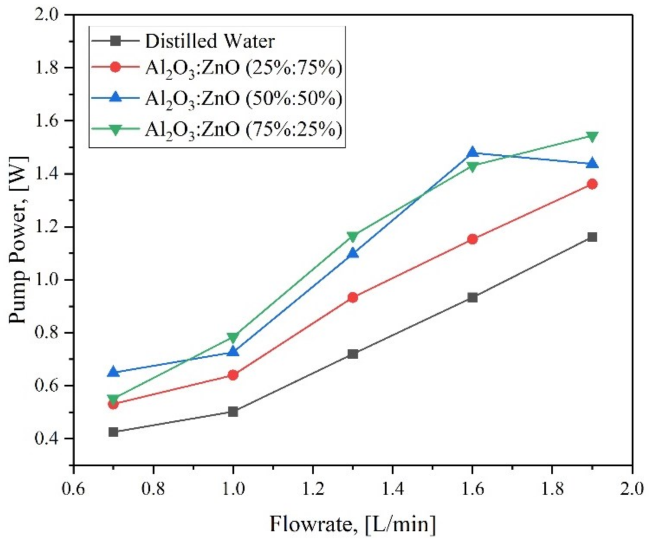

Figure 8 Pump Power Comparison Graph to Flow Rate

Figure 8. shows the graph of the comparison of pump power needed to drain the distilled water and hybrid nanofluids at each specified flow rate. The X axis displays the flow rate used during the study, and on the Y axis displays the pump power needed to drain the distilled water and hybrid nanofluids. Distilled water needs the lowest pump power compared to several variations of hybrid nanofluids, because distilled water has a smaller viscosity and density compared to hybrid nanofluids. At a flow rate of 1.3 liters/minute, a pump of 0.72 W is needed to drain distilled water. Meanwhile, to drain hybrid nanofluids, with a ratio of Al_2O_3: ZnO (25%:75%) requires a pump power of 0.933 W, at a ratio of Al_2O_3: ZnO (50%:50%) requires a pump power of 1.098 W, and in the ratio of Al_2O_3: ZnO (75%:25%) ZnO requires power pump of 1,166 W. The experimental data depicted the greater the flow rate used, the greater the pump power needed [19].

However, in nanofluid hybrids with a nanoparticle ratio of Al_2O_3: ZnO (50%:50%) when the flow rate of 1.9 L/min pump power has decreased, this can be caused by an error when reading the voltage or current on the power supply. So that if the main trend is taken starting from the flow rate of 0.7 L/min to 1.6 L/min, the graph will continue to rise where the pump power for the flow rate of 1.9 L/min at the Al_2O_3: ZnO (50%:50%) ratio will be higher than the flow rate 1.6 1.9 L/min. The same result was obtained by Alkasmoul [20] in his study, the greater the flow rate used the greater the pump power needed. Research conducted by Suresh [21], compared the friction factor between nanofluids of Al_2O_3/CuO-water hybrids. From this study, the friction factor in hybrid nanofluids is greater than nanofluids due to greater viscosity of hybrid nanofluids, so that to flow hybrid nanofluids requires higher pump power.

4. Conclusions

The results of the Al_2O_3-ZnO/distilled water hybrid nanofluids experiment can be concluded as follows:

- Temperature drops in waterblock using nanofluids are larger than using basic fluid only. Using distilled water at the flow rate of 1.3 L/min, heater plate temperature 61.5°C. Meanwhile, hybrid nanofluids at the same flow rate can maintain the heater plate temperature at 50°C.
- Mixing nanoparticles into basic fluids increases the ability of the fluid to deliver heat due to the improvement of heat transfer coefficient. In this case hybrid nanofluid with a nanoparticle ratio of Al_2O_3: ZnO (50%:50%) has the highest heat transfer coefficient value.
- The greater the desired flow rate, the greater pumping power required. The trend of this phenomenon remains the same across all the tested fluids.

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