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THE EFFECT OF ZNO/CUO-WATER- HYBRID NANOFLUID CONCENTRATION RATIO ON HEAT TRANSFER CHARACTERISTICS IN ELECTRONIC EQUIPMENT COOLING SYSTEMS

Devia Gahana Cindi Alfian
Faculty of Industrial Technology, Mechanical Engineering Study Program
Institut Teknologi Sumatera
Email: devia.gahana@ms.itera.ac.id

Arvin Ade Guna Meliala
Faculty of Industrial Technology, Mechanical Engineering Study Program
Institut Teknologi Sumatera
Email: arvin.meliala12@gmail.com

T.M. Indra Riayatsyah
Faculty of Industrial Technology, Mechanical Engineering Study Program
Institut Teknologi Sumatera
Email: indra.riayatsyah@ms.itera.ac.id

Dicky J. Silitonga
Faculty of Industrial Technology, Mechanical Engineering Study Program
Institut Teknologi Sumatera
Email: dicky.silitonga@ms.itera.ac.id

ABSTRAK

Penggunaan nanofluida hibrida CuO-ZnO/air distilasi sebagai media pendingin diuji pada penelitian ini dilakukan untuk mengetahui karakteristik perpindahan panas konveksi. Proses persiapan nanofluida hibrida dilakukan terlebih dahulu dengan mendispersikan nanofluida CuO dan ZnO menggunakan ultrasonic cleaner selama 3 jam dan didiamkan selama 24 jam. Selanjutnya nanofluida CuO dan ZnO dicampurkan berdasarkan rasio yang telah ditentukan yaitu CuO:ZnO (25%:75%), (50%:50%), dan (75%:25) dengan fraksi volume 0.5% dan diaduk kembali selama 1 jam. Pengujian nanofluida hibrida CuO-ZnO/air distilasi dilakukan dengan menggunakan water block sebagai pendingin elektronik dengan variasi laju aliran 0.7–1.9 liter/menit. Dari hasil pengujian didapatkan koefisien konveksi sebagai salah satu karakteristik perpindahan panas yang merupakan kinerja alat pendingin dan hubungannya dengan bilangan Reynolds. Secara keseluruhan hasil menunjukkan bahwa laju perpindahan panas dengan nanofluida hibrida lebih tinggi dibandingkan dengan air distilasi. Pada konfigurasi rasio aliran dan nanopartikel tertentu, nanofluida hibrida memiliki koefisien konveksi 2,5 kali lebih tinggi daripada air distilasi. Selain itu nanofluida hibrida juga mampu menurunkan temperatur sekitar 40^{o}C saat melintasi water block pada daya pemanas sebesar 10 W.

Kata kunci: perpindahan panas, nanofluida, nanofluida hibrida, bilangan Reynolds, koefisien konveksi.

ABSTRACT

The use of hybrid nanofluids CuO-ZnO /distilled water as a cooling medium was tested in this study to determine the characteristics of convection heat transfer. The hybrid nanofluids preparation process was carried out first by dispersing the CuO and ZnO nanofluids using an ultrasonic cleaner for 3 hours and then allowed to settle for 24 hours. Furthermore, the CuO and ZnO nanofluids were mixed based on the stipulated ration of CuO:ZnO (25%:75%), (50%:50%) and (75%:25) with a volume fraction of 0.5% and agitated for 1 hour. Testing of the hybrid nanofluids CuO-ZnO/distilled *water was carried out using a water block as an electronic cooling device with a flow rate variation of 0.7 – 1.9 l/min. From experimental results, the convection coefficient, as one of performance parameters of cooling device, and its relation to Reynolds numbers was able to be determined. Overall, the results show that the rate of heat transfer with the hybrid nanofluids is higher compared to distilled water. At a particular configuration of flowrate and nanoparticle ratio, the hybrid nanofluid has more than 2.5 times higher coefficient of convection than distilled water. In addition, the experiment revealed that the synthesized nanofluid created a temperature drop of around 40°C across the water block at a heater power of 10 W.*

Keywords: *Heat transfer, nanofluids, hybrid nanofluids, Reynolds Number, convection coefficient.*

1. INTRODUCTION

The development of digital technologies has made human beings increasingly dependent on electronic devices in daily life. Computers have helped people to do many things such as managing financial transactions, communicating with friends and family members, or doing their work from home or remote places. Nowadays, electronic devices are used to access various services such as shopping online, banking transactions, communication via social media, etc. Due to the increased demand for electronic devices, researchers have been working to develop new technologies to get better performance [1]. Among others, the CPU is the most important part of a computer device that acts as the brain that processes instructions at an incredibly high rate. As energy is supplied to provide the computational power, a portion of it is released in the form of heat. Continuous and intensive use of the CPU demands a higher rate of energy supply and consequently excessive heat generation. If the heat is not effectively rejected, the device will overheat which in turn adversely affects the computational performance. To keep the temperature stable and avoid overheating, electronic devices usually use a fluid-based cooling system so that it does not get damaged which can lead to malfunctioning. There are several cooling fluids commonly used for removing heat, namely air and water [2].

Cooling systems on computer equipment usually use a heat sink, a component made of material that has a high thermal conductivity. Usually, the heat sink has a section consisting of fins and a base plate which functions as a heat transfer area. In a heat sink, from the base plate to the fins, heat propagates through a conduction process. From the fins surface to the environment, convection occurs, sometimes assisted by a fan to increase heat sink convection rate [3]. However, the use of this type of fan has drawbacks in terms of noise and limited cooling capacity, therefore now the researchers have devised a new idea using the water-cooled type. If designed properly, a water-based cooling system is superior in suppressing temperature level with less noise problem [4].

Water cooling is a process where the working fluid has a function to reduce excess heat. Work equipment that usually uses water cooling is a water block. This water block is usually affixed close to the motherboard which functions to help circulate hot air. The advantages of the liquid-cooled heatsink system can be seen from the higher density of the working fluid and the possibility of adjusting the temperature of the cooling fluid. The use of liquid-cooled has the cooling characteristics of using liquid fluids [5].

Many liquids are good heat transfer media. They have incompressible properties, so they can deliver almost 100% pressure supplied by the pump. The development of liquid fluid type heat exchangers is now being developed with the addition of nano-sized particles (10-100 nm) to the base fluid which can increase the value of the thermal conductivity of the working fluid. The fluid mixed with nanoparticles is called nano fluid, which expectedly has a higher thermal conductivity than plain base fluids . Since nanofluids were introduced to increase thermal conductivity, this makes the application of nanofluids continue to experience development and improvement. There are different thermal conductivity characteristics associated with nanoparticles. Currently, the use of nano-oxide particles has also begun to be widely used as a working fluid as a heat exchanger [6].

Nanofluids have many types of material compositions. Nanofluids that contain one type of nanoparticle material are called mono nanofluids, while nanofluids that have a mixture of nanoparticles of more than one constituent nanoparticle materials are called hybrid nanofluids. Mono nanofluids have the disadvantage of being easily decomposed compared to hybrid nanofluids which use two different nanoparticles mixed into one basic solution. This has a negative impact on the stability of the nanofluid which causes a decrease in its heat conducting properties [7]. Hybrid nanofluid synthetics are expected to have an effect on improving the physical-chemical properties (higher thermal conductivity of each particle property), which is not possessed by nanofluids using single nanoparticles. After analyzing CuO-ZnO nanoparticles using SEM (Scanning Electron Microscopy) it was shown that the particles obtained had high homogeneity [8].

This hybrid nanofluid is expected to have a better thermal conductivity value and not settle quickly compared to a single nanofluid. As researched by Ramachandran, et.al. 2016, increasing the thermal conductivity of hybrid nanofluids (75% CuO – 25% Al2O3-Water) compared to conventional fluids water has a significant impact on reducing the thermal resistance of heat pipes [9]. In other research Manjakuppam Malika, et al. 2020, it is stated that the optimum ratio of hybrid nanoparticle mixtures was at the ratio of 80% CuO:20% ZnO with a volume fraction of 0.1% [10]. The nanofluids resulted in a thermal conductivity enhancement of approximately 117% compared to the base fluid when the zeta potential was 41 mV.

The current study aimed to evaluate the performance of hybrid nanofluids comprising CuO and ZnO nanoparticles in distilled water, with a volume fraction of 0.5%. These nanofluids were synthesized using an ultrasonic cleaner and subjected to testing with a waterblock to mimic the cooling system of a CPU.

2. METHODS AND MATERIALS

In making nanofluid the author uses the stirring method using ultrasonic cleaner [11] with type S 30 H–ELMA. The nanoparticles were carefully weighed to determine the mass ratio required to produce each working fluid. After the nanoparticles of CuO and ZnO were stirred, each became a mono nanofluid, then allowed to settle for 24 hours to separate the solution from the precipitated, larger, nanoparticles. Hybrid nanofluid synthesis employed a two-step procedure. Initially, nanoparticles were prepared with a volume fraction of 0.5%. The mixing process involved adjusting the ratio between two types of nanoparticles, namely ZnO and CuO, at proportions of 25%:75%, 50%:50%, and 75%:25%. These nanoparticles were subsequently blended into the base fluid, which was distilled water. The production of mono nanofluids preceded the hybrid nanofluid preparation. Each type of nanoparticle was mixed separately with distilled water in a beaker glass, followed by 3 hours of stirring using a sonicator. After a 24-hour deposition period, the individual nanofluids were combined based on the specified ratio, and further stirring for 1 hour using a sonicator ensued. Figure 1 shows the process for preparing hybrid nanofluids.

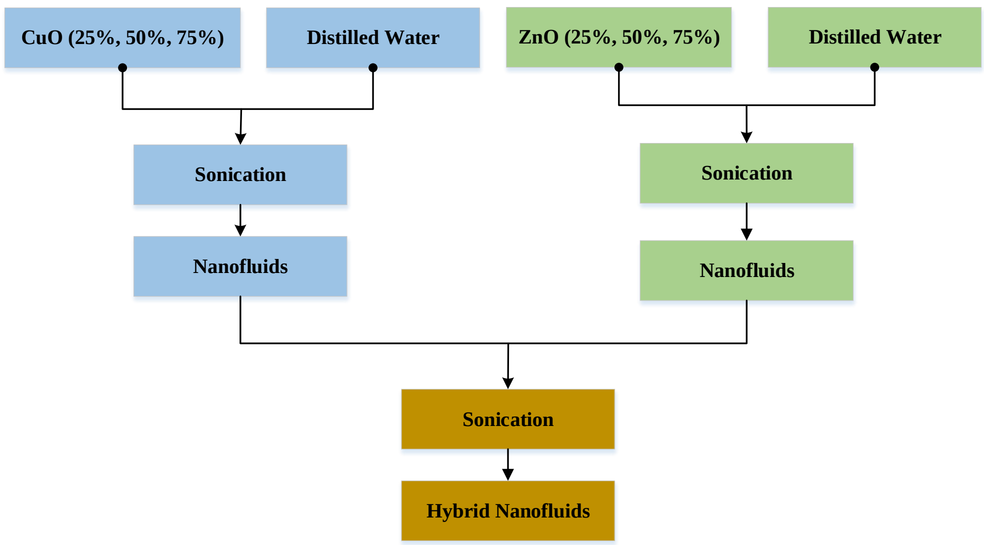

Figure 1. Nanofluid Preparation Process

The amount of nanoparticles and base fluid incorporated into the hybrid nanofluid was determined according to a specified volume fraction of 0.5%. The quantities of nanoparticles and base fluid corresponding to this volume fraction are detailed in the following Table 1.

Table 1. Composition of hybrid nanofluids

No	*Composition*	*CuO (gram)*	*ZnO (gram)*	*Distilled Water (ml)*
1	*Distilled Water*	-	-	*600*
2	*Distilled Water+ (25% CuO + 75% ZnO)*	*4.73*	*12.6*	*597*
3	*Distilled Water + (50% CuO + 50% ZnO)*	*9.5*	*8.4*	*597*
4	*Distilled Water+ (75% CuO + 25% ZnO)*	*14.2*	*4.2*	*597*

Experiments evaluating the performance of hybrid nanofluids as a cooling fluid were conducted using a water block. The experimental cooling system setup is illustrated in Figure 2.

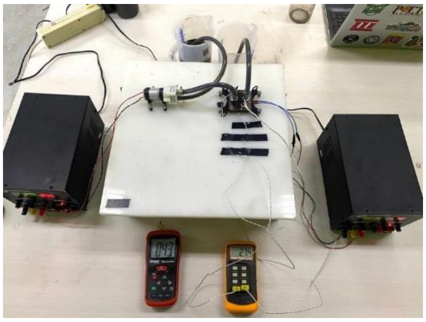

Figure 2. The testing tool scheme

The hybrid nanofluid, prepared according to the specified ratio, will undergo testing on the designed experimental cooling system setup. The testing procedure follows the scheme depicted in Figure 3 below.

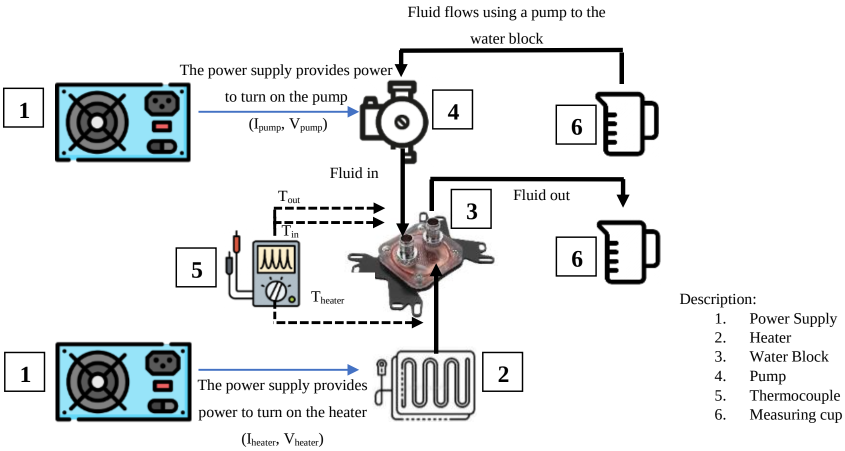

Figure 3. Schematics of the experimental setup

3. RESULT AND DISCUSSION

CuO and ZnO hybrid nanofluids were synthesized through a 3-hour sonication process using an ultrasonic cleaner. Subsequently, the nanofluids were allowed to precipitate for 24 hours (refer to Figure 4.a). After this deposition period, it was observed that some nanoparticles did not dissolve in the base fluid and settled at the container's bottom. Consequently, the undissolved nanoparticles were initially separated to ascertain the precipitate's mass. By determining the mass of the precipitate, it became possible to quantify the amount of nanoparticles dissolved in the base fluid. The first step before weighing the mass of the precipitate is to dry the precipitate until it is completely dry so that accurate data will be obtained. After weighing, it was found that the mass of the precipitated nanoparticles was 3.49 grams of a total of 4.73 grams of nanoparticles used for 25% CuO, 6.2 grams of a total of 9.47 grams of nanoparticles for 50% CuO, 9.24 grams of a total 14.2 grams of nanoparticles for 75% CuO, 1.63 grams of a total of 4.2 grams of nanoparticles for 25% ZnO, 4.44 grams of a total of 8.4 grams for 50% ZnO, and 6.12 grams of a total of 12.6 grams of nanoparticles for 75% ZnO. Figure 4.b is the sonification result of each nanoparticle ratio.

Figure 4. (a). Nanofluids CuO and ZnO (b). Hybrid Nanofluids CuO and ZnO

Evaluation of CuO-ZnO/water hybrid nanofluids was conducted utilizing a commercial water block, with the flow rate systematically varied to assess its impact on the cooling process. The specified flow rates ranged from 0.7 to 1.9 l/min, with intervals of 0.3 l/min. The ensuing results are presented below after the testing.

3.1 The Effect of Temperature Reduction Over Time.

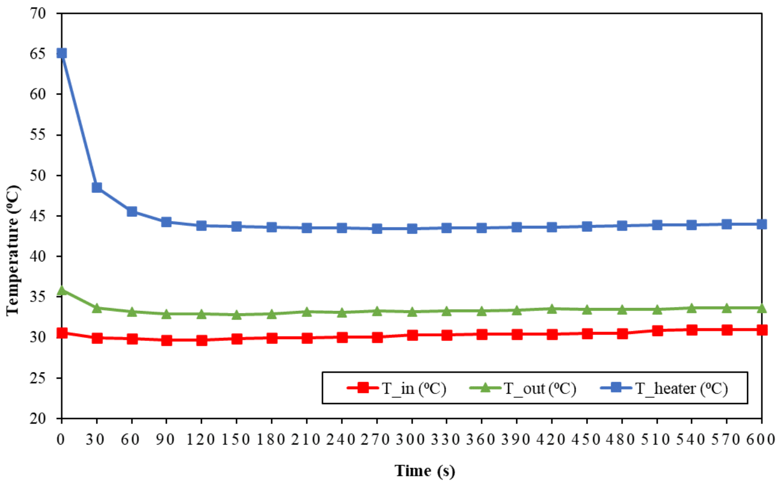

Figure 5. Temperature evolution over time (0.7 l/min with 0.5% hybrid nanofluid at ratio of CuO-ZnO (75%:25%))

Figure 5 shows the typical temperature evolution graph over time. As an example shown there is in the case of hybrid nanofluid with the ratio CuO-ZnO (75%:25%), however other fluid samples behave similarly. For this sample, initial temperature of the heater is 65.1°C and there is a significant decrease in temperature until 120 seconds, which is 43.8°C, and from 150 seconds to 600 seconds, the heater temperature is stable with an average temperature range of 43.66°C. In this case the ability of hybrid nanofluids CuO-ZnO (75%:25%) as a cooling medium for 600 seconds can reduce the heater temperature by 21.44°C. At the inlet temperature, the situation is stable starting from 0 seconds to 600 seconds with an average temperature of 30.88°C, while at the exit temperature the situation is stable starting from 60 seconds to 600 seconds with an average temperature of 33.6°C.

Beyond the transient phenomena observed at the start of the experiment, Figure 5 indicates that the temperature reached a steady state condition after some time [12]. Any calculations and analysis being made in the following sections of this paper are based on this steady state data [13].

3.2 *Differences in Heater Temperature and Flow Rate of the Working Fluid*

Figure 6 displays a graph of the temperature difference to the flow rate in distilled water and each nanoparticle ratio. The X-axis displays the flow rate used in this study, and the Y-axis displays the difference between the temperature of the heating plate and the temperature around the waterblock in both distilled water and hybrid nanofluids.

In this paper, the temperature difference between the heater and fluid is used to describe the performance of the cooling system, instead of merely the nominal value of heater temperature. It is to compensate for the variation of ambient temperature that occurred at the different experiment sessions. Since there was variation in the ambient temperature from experiment to experiment, the heater temperature might be slightly higher or lower due to its environment's temperature. The temperature difference between the heater and fluid is the more appropriate basis for analysis in this case, because the environment affects both the heater and fluid [14], thus considering the two at the same time, as in taking the difference, normalizes the variation. When heater temperature gets closer to the fluid temperature, it means that heat is more effectively transferred from the heater to the fluid, which in turn is carried away. In fact, average fluid temperature in steady state condition was in the narrow range of 30 ºC-33 ºC in all experimental runs, for all types of tested fluids. Thus, lower heater-fluid temperature difference directly translates to lower heater temperature. In other words, lower value in Figure 6 means that the cooling system is more effective in lowering the heater temperature [15].

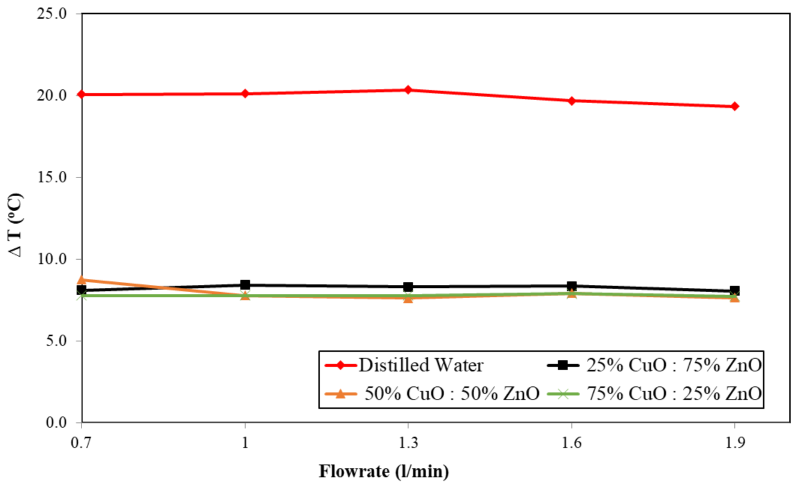

Figure 6. Temperature difference between heater and working fluid

It can be seen in the graph above that the heater-fluid temperature difference induced by the introduction of the hybrid nanofluid is roughly 12 degrees, or 60%, lower than that of distilled water. Temperature values for each ratio of hybrid nanofluids almost coincide with each other, yet the difference to the water is substantial. The temperature difference is caused by the properties of each nanoparticle present in the nanofluid which have higher thermal conductivity value that is responsible for lowering the heat source temperature [16].

A feature worth discussing from Figure 6 is that the heater-fluid temperature difference remains roughly constant even if the flow rate is increased almost 3 times from 0.7 l/min to 1.9 l/min. Theoretically, and as also reported by Kumar, et al., (2014) [17], explains the average heat transfer coefficient value increases with increasing flow rate, so it can be concluded that the higher the flow rate value used, the lower the temperature difference of the fluid. Thus, hypothetically, this constant manner is observed merely because the experimented flow rate range is so narrow that the trend does not appear. However, it can also be deduced from this observation that, practically, operating in lower flow rate, hence lower pumping power, may yield similar performance as the higher one, at least within the flow rate regime tested in our experiment.

3.3 *Comparison of the Reynolds number value with the heat transfer coefficient value*

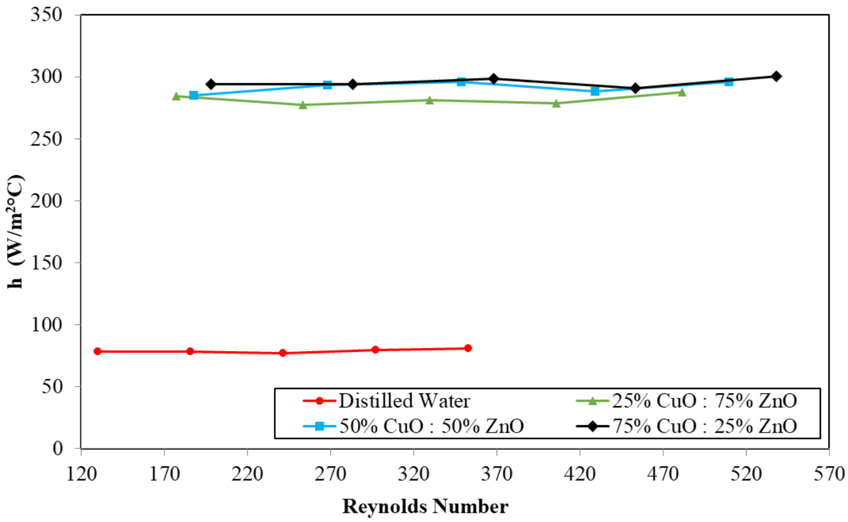

Figure 7. Comparison of the heat transfer coefficient to the Reynolds Number

Figure 7 shows the range of Reynolds number values for ratio hybrid nanofluids CuO-ZnO (75%:25%) having the highest number of Re between 198 – 538, then followed by, CuO-ZnO (50%:50%) of 188<Re<510, CuO-ZnO (25%:75%) of 177<Re<482. The lowest value using distilled water as working fluid is 130<Re<353. The difference in Reynolds Number is solely due to the variation of density caused by variation of different nanoparticle contents and compositions, while the velocity component remains uniform across all fluids [18]. In testing using this waterblock, the predicted type of flow that occurs is laminar flow, where the Reynolds Number for the flow rate used is at a Reynold Number value range of 177-538. From the data obtained in Figure 7 it can be seen that the use of nanofluid as working fluids greatly influences the Reynolds Number value. The hybrid nanofluid has the highest Reynolds Number value compared to the use of distilled water as working fluid. The results are the same as in the test by Selimefendigil et. al., 2021 [19] that the use of nanofluid as a working fluid has the highest Reynolds number compared to distilled water.

3.4 *Comparison of Pump Power Against Flow Rate*

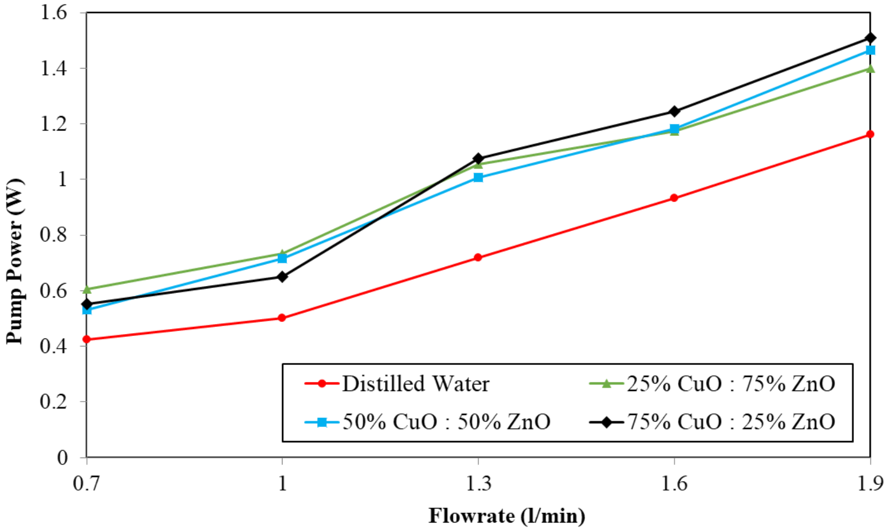

Figure 8. Comparison of pump power to flow rate

Figure 8 shows that the highest pump power value occurs in hybrid nanofluids. The flow rate used is 1.9 l/min where the pump power at the ratio CuO-ZnO (25%:75%) is 1.509 W, CuO-ZnO (50%:50%) is 1.465 W, CuO-ZnO (75%:25%) of 1.399 W. From the graphical results it is clear that the increase in pump power is directly proportional to the type of flow rate used [20]. However, the use of distilled water as a working fluid has decreased the pump power of 1.161 W. The reason for this is because distilled water has less density than nanofluids which indeed contain heavier nanoparticles [21]. The greater the flow rate used, the greater the power needed by the pump to distribute the flow. The same results were also obtained in a study conducted by Alrashed et. al., 2018 [22], where in this study the results obtained were that the higher the flow rate used, the higher the pump power required. Combining the observation on Figure 8 with the remark previously stated in the discussion of Figure 6, it can be inferred that running a lower flow rate within the tested regime is more energy efficient. Increasing the flow rate from 0.7 to 1.2 l/min raises the power consumption up to nearly 3 times, meanwhile the resulting heat rejection performance is virtually the same.

4. CONCLUSION

This work has shown that the waterblock test equipment is able to produce the data required for analyzing the performance of nanofluids. The use of working fluid is very influential on lowering the temperature of the heat source, in our case the heater. In the heat transfer process, the lowest temperature reduction value is in hybrid nanofluids with ratio of CuO-ZnO (75%:25%), at a flow rate of 1.9 liters/minute, with the result of a 7.7°C temperature difference between heater and fluid.

The highest value of heat transfer coefficient (h) of 300.73 W/m²°C was obtained by using hybrid nanofluid CuO-ZnO (75%:25%), while the lowest value was in distilled water with h = 77.1 W/m²°C. Reynolds numbers of nanofluids are obviously higher than water, which is reasonable since nanofluids has higher density. In terms of pumping power, as expected, it increases with flow rate at the same gradient for all types of tested fluids.

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