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Comparative Investigation of the Thermal Conductivity of Water-Based Nanofluids with and without the Combination of Alumina and Carbon Nanotubes †

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Abstract: In the present study, the thermal conductivity of two distinct water-based nanofluids of single-walled CNTs and Al_2O_3, as well as their hybrid solution, was investigated experimentally. The Al_2O_3 and CNTs nanoparticle concentrations are taken to be 2%v/v, while the hybrid solution contained 2%v/v of both Al_2O_3 and CNTs nanoparticles. A PSS (Polly styrene sulphonic acid) solution was used as a surfactant to increase the suspension time of the nanoparticles to avoid sedimentation. The dispersion and breaking of the particles of CNT and Al_2O_3 into nano size were performed employing a probe sonicator and bath sonicator. Moreover, a hot plate magnetic stirrer was used to obtain a consistent liquid mixture. The experiments are performed on the Computer Controlled Thermal Conductivity of Liquid and Gases (TCLGC) unit available in the heat transfer lab at GIKI. The results concluded that the thermal conductivity of water-based single-walled CNT nanofluids was higher compared to Al_2O_3 and their hybrid solution. Therefore, Al_2O_3 and a hybrid solution are less desirable for thermal conduction compared to CNTs.

Keywords: thermal conductivity; CNTs; Al_2O_3; hybrid solution; nanofluids

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1. Introduction

Enhancing thermophysical characteristics has been the primary concern of contemporary nanofluid technology development. This is because many industrial applications, such as those in power production, air conditioning, vehicles, and solar collectors, undoubtedly make use of heat transfer processes. The heat transfer rate in thermal systems is constrained by the low thermal conductivity of heat transfer fluids like water. Therefore, to enhance the thermal conductivity of water, a suitable volume fraction of nanoparticles can be used to improve the heat transfer process [1]. The thermal conductivity of nanofluids depend on many factors, such as the size of nanoparticles, the concentration of nanoparticles, and the shape of nanoparticles [2]. The thermal conductivity of hybrid solutions mostly shows that the hybrid solution increases the thermal conductivity of the solution. For different nanofluids, different volume ratios have been observed for maximum heat transfer, and at different temperatures, the thermal conductivity of hybrid solutions differs [3].

Al_2O_3 and water have been used to enhance the thermal conductivity of the solution. Several other tests have been conducted on Al_2O_3 to determine the optimal size and shape for maximum thermal conductivity [4,5]. The carbon nanotubes were classified based on the number of layers: single-walled and multi-walled. Their thermal conductivity was mostly dependent on their molecular network and density. The criteria for thermal conductivity in carbon nanotubes changed with the change in the number of layers [6]. In

the present study, the TCLGC was used to measure the thermal conductivity of water-based nanofluids with Al_2O_3 and single-walled CNTs and their hybrid solution to determine which solution was the best possible conductor.

2. Materials and Methods

2.1. Characterization of Nanofluids

The experiments were set up to characterize three different samples of nanofluids. A single-walled CNT 2%v/v solution was the first sample of the nanofluid, as shown in Figure 1a, and the second was a 2%v/v solution of Al_2O_3 in Figure 1b. The third one was the (2 + 2)%v/v hybrid solution of Alumina and CNTs, as shown in Figure 1c. A PSS (poly-styrene sulfonic acid) solution, as shown in Figure 2a, was used as a surfactant to avoid the occurrence of sedimentation. The PSS formed a negative charge layer, which produced electrostatic repulsion in the solution, preventing the suspension from settling out. The probe sonicator, in Figure 2b was used to break down particles into nanosize and evenly disperse them into the solution. The bath sonicator, Figure 2c, and hot plate magnetic stirrer in Figure 2d were used to mix the solution. The bath sonicator generated high-frequency waves, which produced intense mechanical forces that agitated the liquid, creating cavitation bubbles, which mixed the nanoparticles with the liquid. The magnetic stirrer continuously stirred the solution to obtain a homogenous liquid mixture. The solution was stirred at 1000 rpm for half an hour in all three samples. The settling time of the nanoparticles was found to be 72 h for Alumina and 36 h for CNTs.

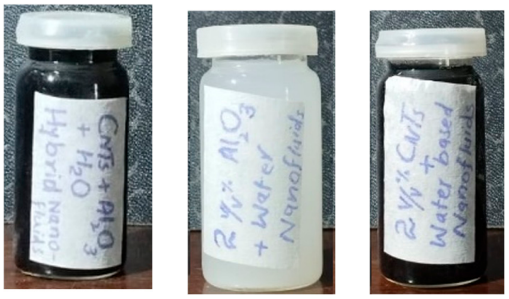
2.2. Experimental Analysis

The apparatus used for the investigation of thermal conductivity in different nanofluids is shown in Figure 3. The Computer Controlled Thermal Conductivity of Liquid and Gases Unit "TCLGC" shown in Figure 3 consists of an aluminum cylinder, a brass jacket, a heating power element, and temperature and flow sensors. The aluminum cylinder serves as the core body of the apparatus. There are three temperature sensors, ST-1, ST-2, and ST-3, which are installed at different distances of the radius. There is also a variable heating power element (AR-1) to adjust the heat generation. A brass jacket is placed on the outer radius of the cylinder, which is equipped with a cooling water system. The governing equations for heat conduction and thermal conductivity are given as follows: The heat conducted is calculated employing Equation (1)

$$\dot{Q}_{conducted} = \dot{Q}_{generated} - \dot{Q}_{lost} \quad (1)$$

The thermal conductivity is calculated using Equation (2)

$$k = \frac{\dot{Q}_{conducted}}{2\pi L(T_i - T_e)} \ln\left(\frac{r_e}{r_i}\right) \quad (2)$$



(**a**) (**b**) (**c**)

Figure 1. Samples of water-based nanofluids: (**a**) Hybrid solution (2% + 2%) v/v of Al_2O_3 and CNT; (**b**) 2%v/v solution of Al_2O_3 solution; (**c**) 2%v/v solution of single-walled CNT.



(**a**) (**b**) (**c**) (**d**)

Figure 2. Synthesis of nanofluids: (**a**) PSS; (**b**) Probe sonicator; (**c**) Bath sonicator; (**d**) Hot plate. magnetic stirrer.

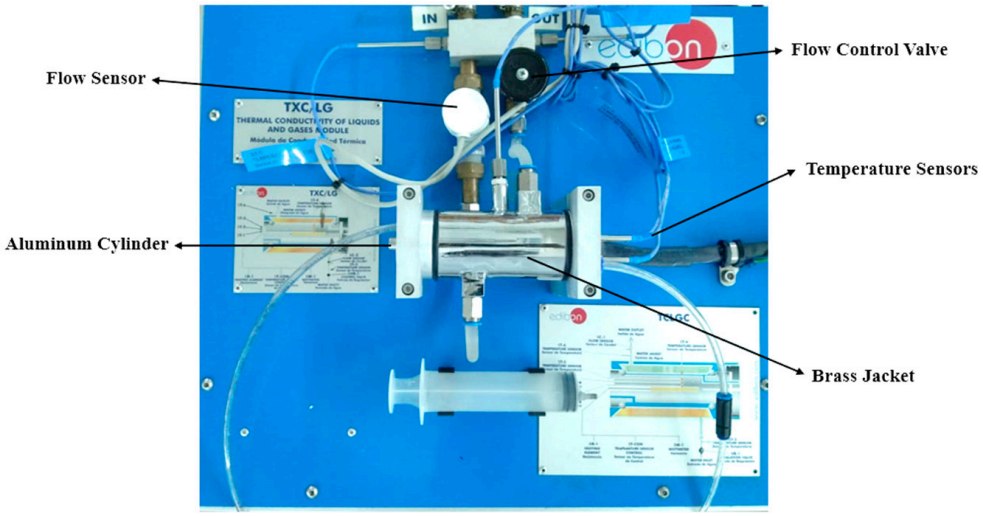
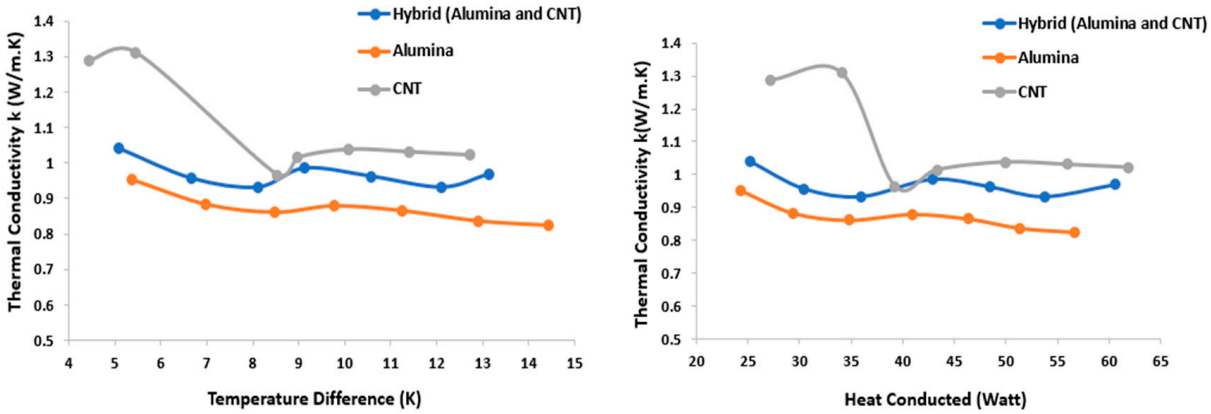


Figure 3. The Computer Controlled Thermal Conductivity of Liquid and Gases Unit.

3. Results and Discussion

Figure 4 represents the results of the experiments performed for the thermal conductivity of the different nanofluids. The relationship between temperature difference and the thermal conductivity of the nanofluids is shown in Figure 4a, whereas the relationship between the heat transferred to the working fluid and the thermal conductivity of the different samples of nanofluids is shown in Figure 4b. It can be seen from Figure 4a that at all values of temperature difference, it was evident that water-based Al_2O_3 nanofluids had a lower thermal conductivity than all the other samples because, at the nanoscale, the alumina particles experience a phonon-scattering phenomenon in fluids that reduce the thermal energy transfer capacity of water-based alumina nanofluids. For all the samples, the difference in the value of thermal conductivity in the nanofluids was greater at lower temperature differences. However, when the temperature difference increased, the variation in thermal conductivity tended to become smaller for all the samples. This is because larger heat fluxes are provided to heat transfer fluids in their flow domain and improve the rate of conduction in heat transfer. In Figure 4b, the effect of heat conduction on the thermal conductivity of different nanofluids is presented. The results show similar trends as seen in Figure 4a, as at low values of heat conduction, the value of thermal conductivity in all the samples was higher; however, as the value of heat conduction increased, the variation in the value of thermal conductivity became smaller. It can be seen from the results that the nanofluid solution of CNTs had the highest value of thermal conductivity compared to the

hybrid solution and the Alumina. Therefore, it can be concluded that water-based CNT nanofluids are suitable for thermal conduction compared to water-based Al_2O_3 nanofluids and their hybrid solution.



(**a**) (**b**)

Figure 4. Effect of heat transfer parameters on the thermal conductivity of water-based nanofluids of CNTs and Al_2O_3 and their hybrid solution: (**a**) Temperature difference; (**b**) Heat conducted.

4. Conclusions

The present study successfully examines the water-based nanofluids of CNTs and Al_2O_3 and their hybrid solution. The CNTs of water-based nanofluids showed the greatest improvement in thermal conductivity compared to the hybrid solution consisting of both CNTs and Al_2O_3 nanoparticles. However, the solution of Al_2O_3 nanoparticles showed the least improvement in thermal conductivity. Overall, the findings from this investigation highlight the potential of using nanoparticles, particularly CNTs, to enhance the thermal conductivity of water.

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Conflicts of Interest: The authors declare no conflict of interest.

References

1. Eastman, J.A.; Choi, U.S.; Li, S.; Thompson, L.J.; Lee, S. Enhanced Thermal Conductivity through the Development of Nanofluids. *MRS Online Proc. Libr. OPL* **1996**, *457*, 3. [CrossRef]
2. Jang, S.P.; Choi, S.U.S. Effects of Various Parameters on Nanofluid Thermal Conductivity. *J. Heat Transf.* **2007**, *129*, 617–623. [CrossRef]
3. Sajid, M.U.; Ali, H.M. Thermal conductivity of hybrid nanofluids: A critical review. *Int. J. Heat Mass Transf.* **2018**, *126*, 211–234. [CrossRef]
4. Beck, M.P.; Yuan, Y.; Warrier, P.; Teja, A.S. The effect of particle size on the thermal conductivity of alumina nanofluids. *J. Nanopart. Res.* **2009**, *11*, 1129–1136. [CrossRef]

5. Timofeeva, E.V.; Routbort, J.L.; Singh, D. Particle shape effects on thermophysical properties of alumina nanofluids. *J. Appl. Phys.* **2009**, *106*, 014304. [CrossRef]
6. Kumanek, B.; Janas, D. Thermal conductivity of carbon nanotube networks: A review. *J. Mater. Sci.* **2019**, *54*, 7397–7427. [CrossRef]

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