Experimental Study on the Effects of Temperature and Concentration on the Thermal Conductivity of Graphene Nanoplatelets/DW Nanofluid

MASOUD VAKILI

Abstract: - In this paper, an experimental study on the effects of temperature and concentration on the thermal conductivity of Graphene Nanoplatelets/Deionized Water nanofluid is presented. The experiments were carried out for weight percentages of 0.00025, 0.0005, 0.001 and 0.005 in temperatures ranging from 25 °C to 50 °C. The results revealed that the thermal conductivity ratio enhances with increasing the solid volume fraction and temperature. Results also showed that, at higher temperatures, the variation of thermal conductivity ratio with solid weight percentages was more than that at lower temperatures. Moreover, the effect of temperature on the thermal conductivity ratio was more noticeable at higher solid volume fractions.

Key-Words: - Thermal conductivity; Graphene; Nanofluid; Experimental; Weight Percentage; Temperature

I INTRODUCTION

In the past decade, ethylene glycol, water and oil were being widely used as heat transfer fluids in different industries and heat exchangers [1]. According to the importance of thermal properties and also heat transfer coefficients of fluids in thermal systems, the desire for increasing the heat transfer characteristics of fluids is growing [2].Nanofluids are one of the innovations which can increase the thermal properties of conventional fluids because of their unique thermal and physical properties [3-4]. These fluids are constructed from a specific base fluid and particles with dimensions between 1 to 100 nm. Nanofluids are better thermal conductors in comparison to conventional fluids, because of the existence of nanoparticles which are commonly metals or metal oxides or nanotubes [5-7]. More stability with increased heat transfer area and also having less weight are the reasons of decreasing the dimensions of these particles to the scale of nano [8]. In recent years, most of the research studies are carried out in the field of carbon structurs including single wall and multi wall nanotubes, graphene oxide and graphene nanoplatelets as working particles in nanofluids [9-12].Because of inherent conduction, less density and also stronger covalent bonds of carbon nanostructures in comparison to metals and their oxides, they have higher thermal conductivities [13]. Experimental results have indicated that different carbon structures such as carbon nanotubes, ghraphite nanoparticles, exfoliated graphite nanofibers, diamond and graphene and also graphene oxide nanoparticles are suitable choices for nanofluids [14-19]. Because of the costs and also time consumption of experimental measurements, researchers are trying to find a theoretical relation for the purpose of predicting the thermal conductivity of nanofluids.

According to importance of different nanofluids and also their influence in increasing the thermal conductivity, in this research study it is aimed to investigate the thermal conductivity of graphene nanoplatelets/deionized water nanofluid in different weight fractions and also temperatures using Experimental measurements.

The author is with the Mechanical Engineering Department, Iran University of Science and Technology, Narmak, Tehran, 1684613114, IRAN
Msd.vakili@gmail.com

II. EXPERIMENTAL METHOD

II.a MATERIAL AND METHOD OF PREPARING NANOFLUIDS

In this research, graphene nanoplatelets with diameter less than 2 micrometer and platelet width of 2 nm and specific surface area of 750 square meters for each gram as agent particle have been used. These materials (Type C has been used) are produced by XG Sciences Company, which is

located in Michigan, USA. Moreover, the base fluid used for diffusing nanoparticles is deionized water.
Preparing sustainable nanofluid with uniform distribution of particles is one of the effective factors on thermophysical properties of nanofluid. Among available methods for preparing nanofluid, two-step method has been used. In this method, Ultrasonic Probe (Q700 Sonicator, Qsonica, LLC., USA), which its power and frequency are 700 W and 20 KHz respectively, has been used for diffusing nanoparticles with weight percent of 0.00025, 0.0005, 0.001 and 0.005. Duration of ultrasonic for preparing samples is 1 hour with power of 95%. It should be noted that for preventing fluid overheating, the mixture becomes pulsar ultrasonic.

II.b METHOD OF INVESTIGATING THE PROPERTIES

In this study, for material analysis and assessing structures of nanoparticles, 2 methods have been used of which one is Transmission Electron Microscopy (TEM) method, which is used for evaluating morphology of structures of graphene nanoplatelets. In this method, Transmission Electron Microscopy (TEM, EM900, Zeiss, Germany) with accelerating voltage of 80 KW has been used. Picture of graphene nanoplatelets is depicted in Fig. 1.

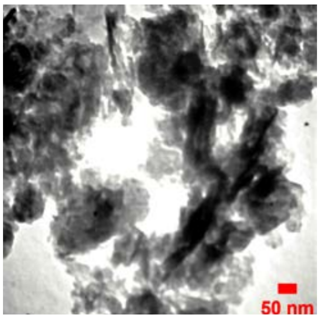

Fig. 1. TEM picture of graphene nanoplatelets

Another method which has been used for studying crystal structures of nanoparticles is X-Ray Diffraction method. In this method, PANalytical (PANalytical, X'Pert Pro MPD, Netherland), which has angle range of 0.6 to 157 degrees, has been used. The result is shown in Fig.2.

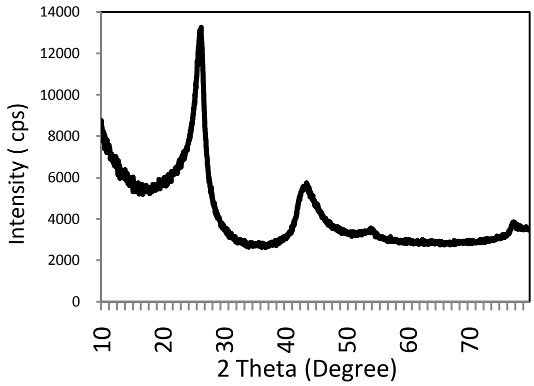

Fig.2. Results of X-Ray Diffraction of graphene nanoplatelets

Furthermore, in present research, Transient Hot Wire method has been used for determining thermal conductivity coefficient of nanofluids, measured by KD2 Pro device (KD2 Pro, Decagon devices Inc., USA). This device has the ability to measure thermal conductivity with accuracy of ±5%. Thermal conductivity of prepared samples has been determined in temperature range of 25 to 50 °C. It is worth mentioning that in current study, the device has been calibrated by pure base fluid before doing each experiment. After that, in order to measure thermal conductivity coefficient, sample has been poured in special container of device (cell). Exclusive thermocouple of the device is located exactly in its center. For reaching desired temperature, a temperature control bath has been used. After thermal equilibrium of sample and temperature of bath which is reached after a while, thermal conductivity coefficient has been measured. In each experiment and for each nanofluid sample, 3 distinct measurements with time interval of 15 minutes has been done and at last, their arithmetic mean, has been calculated and reported as sample thermal conductivity coefficient.

III. RESULTS AND DISCUSSION

Hence Nano particles has more contact than micro particles and other big particles and also increased level of contact will increase effective surface of thermal conductivity, in this part we are investigating the importance of increase in nanofluids weight percent in compared with increase in thermal degree than thermal conductivity coefficient. The Results of experimental measurement is shown in Fig. 3.

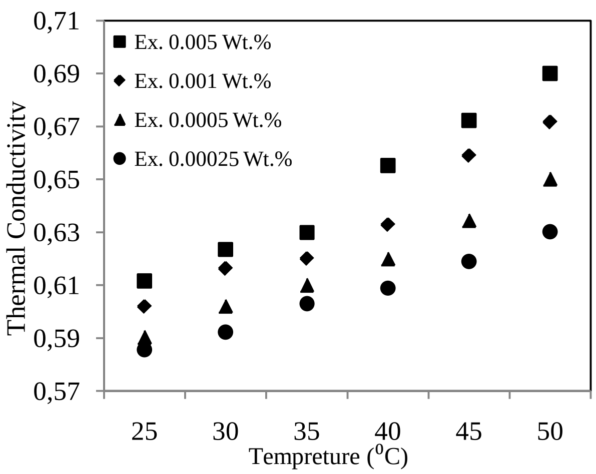

Fig.3. the amount of thermal conductivity of nanofluids sample at different temperatures.

As shown in Fig.3, thermal conductivity depends on thermal degree that means by increasing temperature of nanofluid, thermal conductivity will increase too. Among the reasons for this dependency to temperature we can point to the very motion of nanoparticles with an increase in temperature which is due to the phenomenon of Brownian motion. Base fluid viscosity decreases with increasing temperature and Brown or scrambled movement of nanoparticles increases. The morphology of nanoparticles used in this study is in plate form so these plates are like bridges for heat transfer and by increasing nanofluids weight percent, the amount of thermal conductivity coefficient will increase either. The amount of thermal conductivity coefficient at 25 and 50 ° C based on the weight of nanofluids are shown in Fig.4.

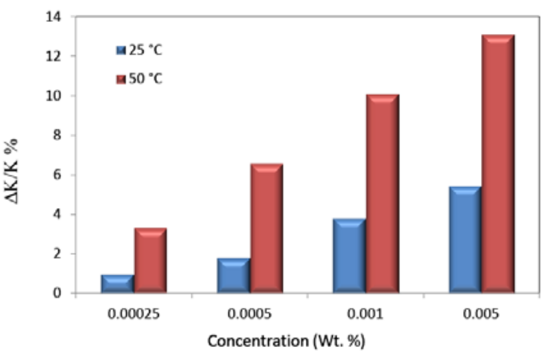

Fig.4. increase in thermal conductivity of nanofluids with different weight percent at 25 and 50 ° C

As you can see in the picture, by increasing weight percent, the amount of increased thermal conductivity coefficient at high temperatures is more visible than low temperatures. The reason, apart from increasing thermal conductivity coefficient of basic nanofluid with temperature, is that by increasing temperature of nanofluids, thermal conductivity coefficient will increase too.

IV CONCLUSION

In the present study, the thermal conductivity of f-Graphene Nanoplatelets/Deionized Water nanofluids in temperature ranging from 25 °C to 50 °C for various samples of nanofluids with weight percentages of 0.00025, 0.0005, 0.001 and 0.005 in was examined. Experimental finding revealed that the thermal conductivity enhances with increasing the weight percentages and temperature. Results also showed that, at higher temperatures, the variation of thermal conductivity ratio with weight percentages was more than that at lower temperatures.

References

[1] Esfe, Mohammad Hemmat, et al. "Experimental study on thermal conductivity of DWCNT-ZnO/water-EG nanofluids." International Communications in Heat and Mass Transfer 68 (2015): 248-251.

[2] Colangelo, Gianpiero, et al. "Experimental test of an innovative high concentration nanofluid solar collector." Applied Energy 154 (2015): 874-881.

[3] Kulkarni, Devdatta P., Debendra K. Das, and Ravikanth S. Vajjha. "Application of nanofluids in heating buildings and reducing pollution." Applied Energy 86.12 (2009): 2566-2573.

[4] Mo, Songping, et al. "Investigation on crystallization of TiO 2–water nanofluids and deionized water." Applied Energy 93 (2012): 65-70.

[5] Sankar, N., Nithin Mathew, and C. B. Sobhan. "Molecular dynamics modeling of thermal conductivity enhancement in metal nanoparticle suspensions." International Communications in Heat and Mass Transfer 35.7 (2008): 867-872.

[6] Zakaria, Irnie, et al. "Experimental investigation of thermal conductivity and electrical conductivity of Al 2 O 3 nanofluid in water-ethylene glycol mixture for proton exchange membrane fuel cell application." International Communications in Heat and Mass Transfer 61 (2015): 61-68.

[7] Wusiman, Kuerbanjiang, et al. "Thermal performance of multi-walled carbon nanotubes (MWCNTs) in aqueous suspensions with surfactants

SDBS and SDS." International Communications in Heat and Mass Transfer 41 (2013): 28-33.
[8] Chol, S. U. S. "Enhancing thermal conductivity of fluids with nanoparticles." ASME-Publications-Fed 231 (1995): 99-106.
[9] Vakili, M., et al. "Photothermal properties of graphene nanoplatelets nanofluid for low - temperature direct absorption solar collectors." Solar Energy Materials and Solar Cells 152 (2016): 187-191.
[10] Gómez, Abdul O. Cárdenas, Antônio Remi K. Hoffmann, and Enio P. Bandarra Filho. "Experimental evaluation of CNT nanofluids in single-phase flow." International Journal of Heat and Mass Transfer 86 (2015): 277-287.
[11] Ijam, Ali, et al. "Stability, thermo-physical properties, and electrical conductivity of graphene oxide-deionized water/ethylene glycol based nanofluid." International Journal of Heat and Mass Transfer 87 (2015): 92-103.
[12] Arzani, Hamed Khajeh, et al. "Experimental and numerical investigation of thermophysical properties, heat transfer and pressure drop of covalent and noncovalent functionalized graphene nanoplatelet-based water nanofluids in an annular heat exchanger." International Communications in Heat and Mass Transfer 68 (2015): 267-275. [13] Baby, Tessy Theres, and Sundara Ramaprabhu. "Enhanced convective heat transfer using graphene dispersed nanofluids." Nanoscale research letters 6.1 (2011): 1-9.
[14] Xie, Huaqing, and Lifei Chen. "Adjustable thermal conductivity in carbon nanotube nanofluids." Physics Letters A 373.21 (2009): 1861-1864.
[15] Zhu, Haitao, et al. "Preparation and thermal conductivity of suspensions of graphite nanoparticles." Carbon 45.1 (2007): 226-228.
[16] Vakili, M., et al. "Experimental investigation of graphene nanoplatelets nanofluid-based volumetric solar collector for domestic hot water systems." Solar Energy 131 (2016): 119-130.
[17] Xie, Huaqing, Wei Yu, and Yang Li. "Thermal performance enhancement in nanofluids containing diamond nanoparticles." Journal of Physics D: Applied Physics 42.9 (2009): 095413.
[18] Mehrali, Mohammad, et al. "Effect of specific surface area on convective heat transfer of graphene nanoplatelet aqueous nanofluids." Experimental Thermal and Fluid Science 68 (2015): 100-108.
[19] Mehrali, Mohammad, et al. "Heat transfer and entropy generation for laminar forced convection flow of graphene nanoplatelets nanofluids in a horizontal tube." International Communications in Heat and Mass Transfer 66 (2015): 23-31.
[20] Hajjar, Zeinab, Ali morad Rashidi, and Ahmad Ghozatloo. "Enhanced thermal conductivities of graphene oxide nanofluids." International Communications in Heat and Mass Transfer 57 (2014): 128-131.