BORNEO JOURNAL OF SCIENCES AND TECHNOLOGY (BJoST)
VOL. : 7, ISSUE: 1, 57-65
DOI: http://doi.org/10.35370/bjost.2025.7.1-07
e-ISSN: 2672-7439 © 2018, UTS Publisher.

University of
Technology
Sarawak

ORIGINAL ARTICLE

Effect of Nanoparticles Size on the Dispersion Stability of Hybrid Nanofluids Containing Graphene Nanoplatelet and Multi-Walled Carbon Nanotube

*¹Anas Sabirin Abdul Latiff and ¹,²Sebastian Dayou

¹School of Engineering and Technology, University of Technology Sarawak, 96000 Sibu, Sarawak, Malaysia
²Centre for Research of Innovation & Sustainable Development (CRISD), University of Technology Sarawak, 96000 Sibu, Sarawak, Malaysia

ABSTRACT - Carbon-based hybrid nanofluids, which combine graphene nanoplatelet (GNPs) and multiwall carbon nanotubes (MWCNTs), offer promising potential for enhancing heat transfer performance, but the effect of nanoparticle size on their stability remains underexplored. This study investigates the influence of nanoparticles size on the dispersion stability of hybrid nanofluids comprising graphene nanoplatelets (GNPs) and multi-walled carbon nanotubes (MWCNTs) in the presence of gum arabic (GA) surfactant. The nanofluids were prepared utilizing distinct nanoparticles sizes of GNP (5 µm and 25µm in diameter) and MWCNT (0.5 - 2.0 µm and 10 - 30 µm in length). An ultraviolet-visible spectrophotometer was used to evaluate the dispersion stability of the prepared nanofluid. The findings show that the highest nanofluid stability overall was obtained with the combination of GNP 5µm and long MWCNT. This result shows the importance of choosing the right nanoparticles size for the design and development of effective heat transfer fluids using hybrid nanofluid.

ARTICLE HISTORY
Received: 27 Sept 2024
Revised: 26 Nov 2024
Accepted: 10 Dec 2024

KEYWORDS
Hybrid Nanofluid,
Graphene,
Carbon Nanotube,
Dispersion Stability,
Nanoparticle Size.

INTRODUCTION

Heat exchangers are essential in many industrial processes, and their performance is influenced by the effectiveness of the heat transfer fluids (HTFs) used. In order to reduce cost and energy consumption, there is a great demand for the use of a compact heat exchanger. This calls for a more effective HTF, such as nanofluids, to be developed because of the inherent heat transfer limitation of conventional HTF such as water, oil or ethylene glycol. Nanofluids are essentially formed by suspending nanoparticles into the conventional HTFs, which enhances their thermophysical properties.

Recent research has moved from single-type nanofluids to hybrid nanofluids, which contain multiple types of nanoparticles [1]. This is due to their improved thermophysical properties resulting from synergistic effects between the different types of nanoparticles which are present in the hybrid nanofluid solution [2]. Among the various types of nanoparticles available, carbon-based nanoparticles are more attractive considering their low density and high thermal conductivity [3].

While hybrid nanofluids show improved heat transfer performance, achieving long-term dispersion stability remains a challenge [4]. A study on the dispersion stability of hybrid nanofluids is particularly important because of its significant influence on heat transfer performance [5]. Technique such as addition of surfactants is typically employed to enhance dispersion stability of nanofluid [4; 6]. As demonstrated in the past studies involving unitary nanofluids [7], the size of nanoparticles is also a critical factor affecting dispersion stability. However, the effect of nanoparticles size on the dispersion stability of hybrid nanofluid containing carbon-based nanoparticles, particularly within the size ranges of MWCNT lengths (0.5 - 2.0 µm and 10 - 30 µm) and GNP platelet diameters (5 µm and 25 µm), is still not

---

*Corresponding Author: Anas Sabirin Abdul Latiff. University of Technology Sarawak (UTS),
email: meg21120001@student.uts.edu.my

well-reported by other researchers. To bridge this knowledge gap, the present study investigates the effect of nanoparticles size on the dispersion stability of carbon-based hybrid nanofluid containing graphene nanoplatelet (GNP) and multi-walled carbon nanotube (MWCNT). This study aims to contribute to the development of a more effective and stable nanofluids for heat transfer applications.

MATERIALS AND METHODOLOGY

Materials and Preparation of Hybrid Nanofluid

The prepared hybrid nanofluid samples were consist of GNP and MWCNT nanoparticles and gum arabic (GA) surfactant. GA surfactants were acquired from Sigma Aldrich, USA. Two different GNP diameters of 5 µm and 25 µm having the same thickness of 6 – 8 nm and specific areas of 120–150 m^2/g, were obtained from XG Science Inc., Michigan, USA. Besides, two different MWCNT lengths of 0.5 – 2.0 µm and 10 – 30 µm having similar specific surface area of at least 110 m^2/g, and an outer diameter and inner diameter of 20 - 30 nm and 5 – 10 nm, respectively, were obtained from Texas, US Research Nanomaterials, Inc., Texas, USA. The morphologies of these nanoparticles were confirmed through electron microscopy examinations using the field emission scanning electron microscopy (FESEM) (Hitachi SU8010, Japan) as shown in Figure 1 and high-resolution transmission electron microscopy (HRTEM) (FEI Tecnai G2 20 S-TWIN, Netherlands) as shown in Figure 2.

Four distinct configurations of hybrid nanofluid samples were prepared and they are named according to the different size combinations of GNP and MWCNT. For instance, GNP5-MWCNTlong, refers to samples containing 5 µm GNP and MWCNT length of 10–30 µm. A total of 20 hybrid nanofluid samples were prepared with varying volumetric concentrations from 0.01 to 0.05 vol.% by ultrasonication for 1 h. Surfactant concentrations were similar to the volumetric concentration of the nanoparticles used, and the weight of MWCNT and GNP was kept at a 1:1 ratio.

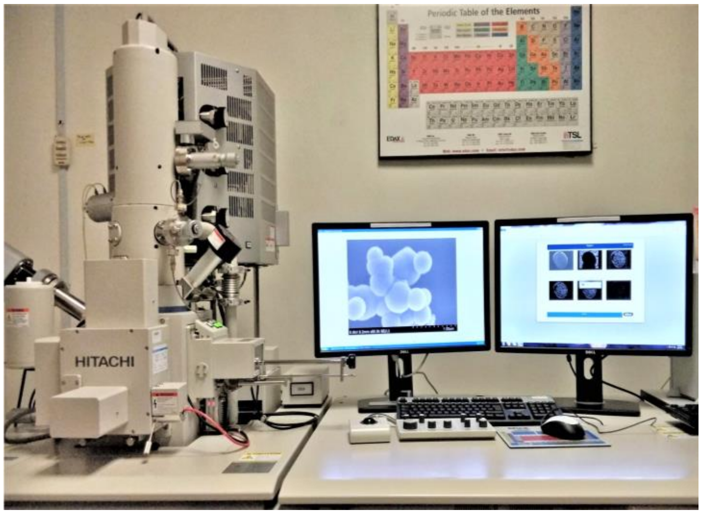

Figure 1. The FESEM and instrument that was used to examine the morphology of carbon nanoparticles [8].

Figure 2. The HRTEM instrument that was used to examine the morphology of carbon nanoparticles [9].

Dispersion Stability Test

The dispersion of the nanofluid samples was assessed using a UV-Vis spectrophotometer (Agilent Cary 60 G6860A, USA) in addition to visual observation. For UV-Vis measurements, a cuvette was employed to enable the passage of light for the measurement of their optical properties. A blank measurement using distilled water was first carried out to eliminate the effects of background noise. Besides, a 1:15 dilution ratio of nanofluid-to-distilled water was utilized. This was necessary to ensure that the samples fall within the instrument's measurement range, avoiding signal saturation and allowing precise assessment of their optical characteristics. Scanning was conducted across a range of wavelengths from 200 to 800 nm. The nanofluid samples were tested after an hour of preparation and their stability were measured by retaining them in a static condition for 30 days. Figure 3 shows the process flow involved in the dispersion stability experiment using UV-Vis.

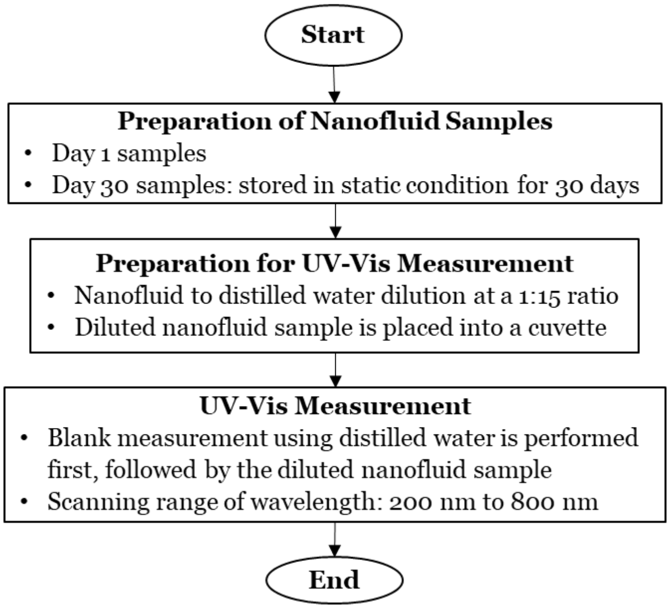

Figure 3. Process flow for the dispersion stability experiment conducted using UV-Vis spectrophotometry.

RESULTS AND DISCUSSION

Characterization of GNP and MWCNT

Figure 4 shows the images of GNPs used in the present study, which were captured under FESEM and HRTEM. The images display crumpled and folded platelets with discernable edges, which are typical morphology of a thin GNP. The feature of 5 µm GNP, as shown in Figures 4(a) and 4(c), exhibits surface wrinkles, edges, and defects due to their smaller lateral size [10], with the difference between Figures 4(a) and 4(c) being the magnification of the same sample size. For the 25 µm GNP, as shown in Figures 4(b) and 4(d), which also differ in magnification for the same sample, a rather smooth surface is revealed due to its larger lateral size [11].

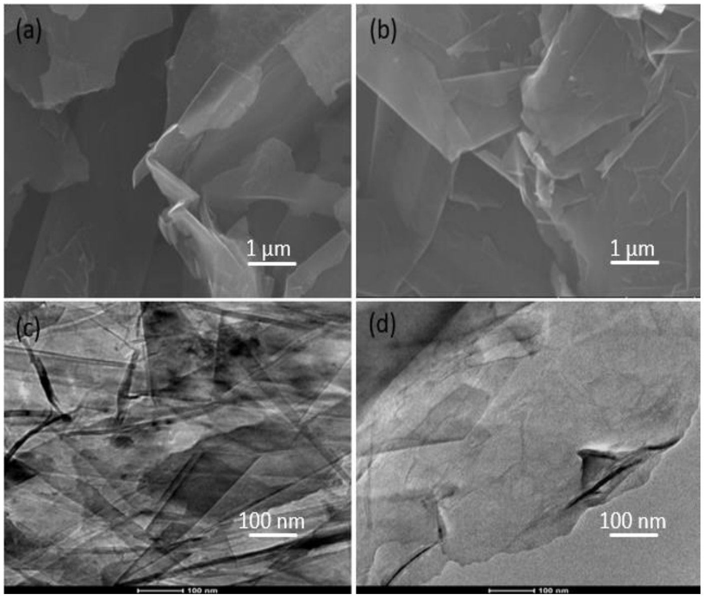

Figure 4. Images of GNPs with lateral sizes of 5 µm (a, c) and 25 µm (b, d) observed under FESEM and HRTEM, respectively.

Figure 5 shows the FESEM and HRTEM images of MWCNTs used in the present study. It reveals distinctive fiber-like structure, which is the typical morphology of a MWCNT. The noticeable difference in length between the short and long MWCNTs is evident upon close examination. It is also observed that the shorter MWCNTs, as shown in Figures 5(b) and 5(d), display a greater tendency to clump together and form clusters or agglomerates more readily in comparison to the longer MWCNTs, shown in Figures 5(a) and 5(c). This is in agreement with the findings from previous study [12]. Shorter MWCNTs are more prone to agglomeration due to their lower aspect ratio and higher surface energy that could lead to stronger Van der Waals forces, resulting to clustering.

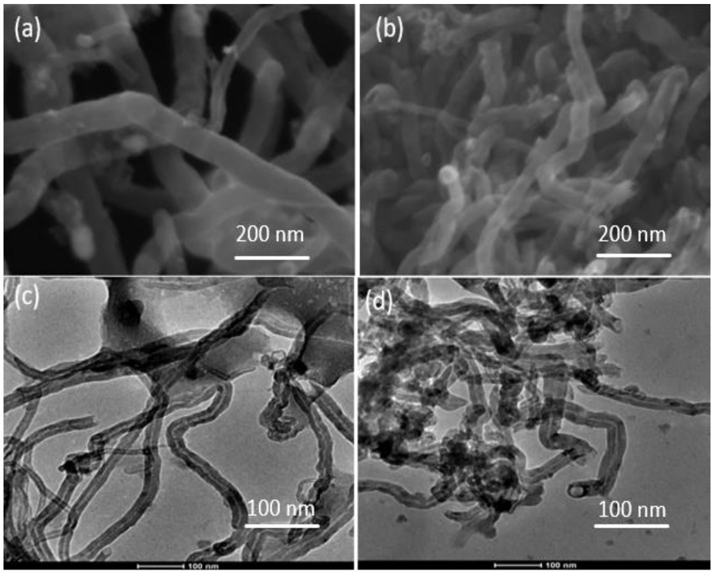

Figure 5. Images of (a, c) and short MWCNT (b, d) observed under FESEM and HRTEM, respectively.

Figure 6 shows photographs of hybrid nanofluids samples with different configurations which were taken during the first day. It can be visually observed that all the samples are well-dispersed. This underscores the influence of the GA surfactant in facilitating and maintaining effective dispersion of the nanofluid samples.

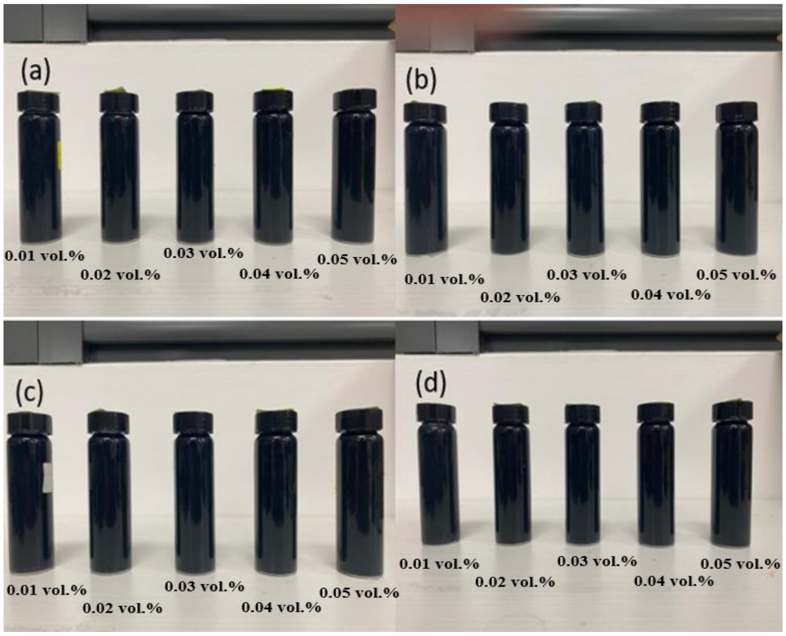

Figure 6. Nanofluid samples with different GNP-MWCNT configurations on the 1st day; (a) GNP5-MWCNTlong; (b) GNP25-MWCNTlong; (c) GNP5-MWCNTshort; (d) GNP25-MWCNTshort.

Figure 7 shows photographs of the same samples, which were taken during the 30th day. It can be observed that the dispersion is maintained except for the hybrid nanofluids containing GNP25-MWCNTshort, especially at 0.02 and 0.03 vol.%, which appeared to be the least stable.

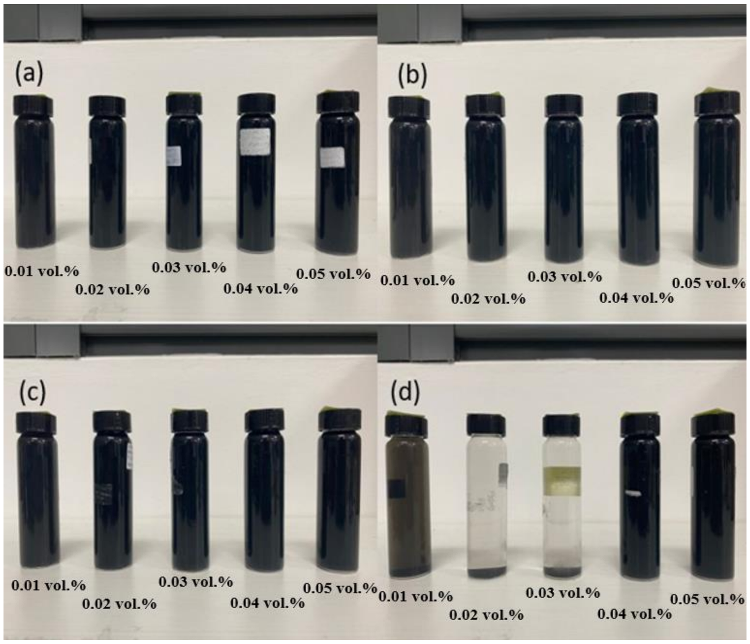

Figure 7. Nanofluid samples with different GNP-MWCNT configurations on the 30th day; (a) GNP5-MWCNTlong; (b) GNP25-MWCNTlong; (c) GNP5-MWCNTshort; (d) GNP25-MWCNTshort.

Figure 8 shows the UV-Vis absorption spectra of GNP5-MWCNTlong during the first day. It can be observed that the maximum absorbance occurs at the wavelength of 250 - 270 nm. Similar range is observed for the peak absorbance of the other hybrid nanofluid configurations. This wavelength range is the characteristics for peak UV absorbance for carbon-based nanofluid, as also evidenced in other study [13]. The peak absorbance values demonstrate a direct correlation with volumetric concentration, which complies with Beer-Lambert law [14]. Hence, the peak absorbance value from the UV-Vis spectra will be used to measure the dispersion of nanofluid, whereby a higher peak absorbance value indicates better dispersion of nanoparticles in the fluid.

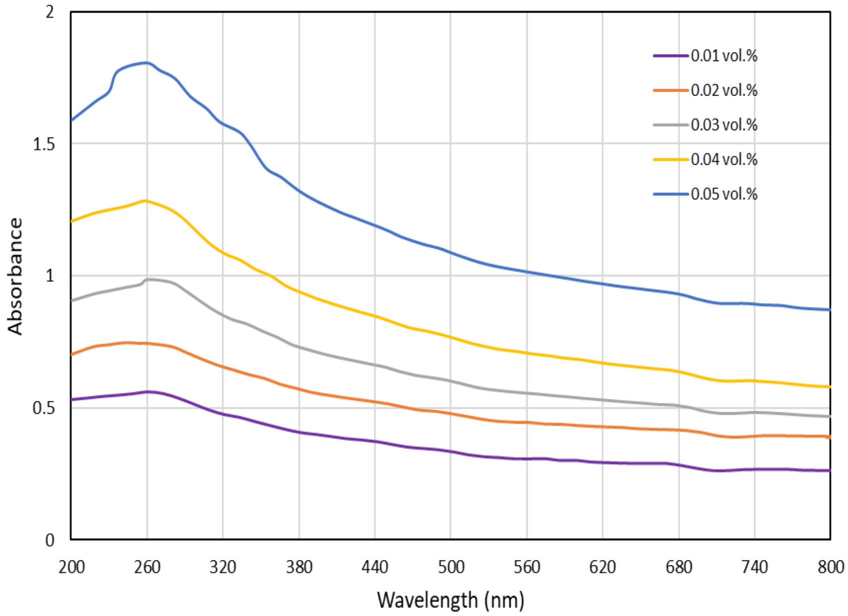

Figure 8. UV-Vis absorption spectra of GNP5-MWCNTlong.

Figure 9 displays the peak absorbance of hybrid nanofluid with different GNP and MWCNT size combinations. The comparison of absorbance results between Day 1 and Day 30 reveals changes in the optical properties of nanofluid samples. As compared to Day 1, notable reduction in absorbance values were observed across the samples during Day 30, which typically associated with inferior dispersion quality due to settling of nanoparticles over time that had altered their optical properties. Besides, the absorbance values vary with concentration and nanoparticles size combination, and the highest absorbance values were observed with GNP5-MWCNTlong configuration at 0.05 vol.% during both Day 1 and Day 30.

In order to provide better clarity on the nanofluid dispersion stability results, a relative peak absorbance values between Day 30 and Day 1 are plotted as shown in Figure 10. The relative peak absorbance is the ratio between the peak absorbance values of Day 30 (A30) to Day 1 (A1). This relative absorbance value reflects the dispersion stability of nanofluid, in which high relative absorbance represents high dispersion stability. The figure shows relative peak absorbance of various GNP-MWCNT size combinations at different concentrations. It is clear that GNP5-MWCNTlong configuration shows the highest dispersions stability overall that becomes more pronounced with increasing concentration. In contrast, GNP25-MWCNTshort yields the lowest stability overall. This is consistent with the photograph images in Figure 7. In general, it is observed that hybrid nanofluid samples containing short MWCNTs often exhibit lower dispersion stability. This phenomenon arises due to the greater tendency of short MWCNT to clustering as observed in the microscopy images in Figure 5. Shorter MWCNTs tend to have weaker dispersion forces and surface energy, which hinder their uniform distribution [15]. For GNP, as compared to GNP5, GNP25 has larger contact area that can cause greater attractive interactions between nanoparticles that will lead to agglomeration [16].

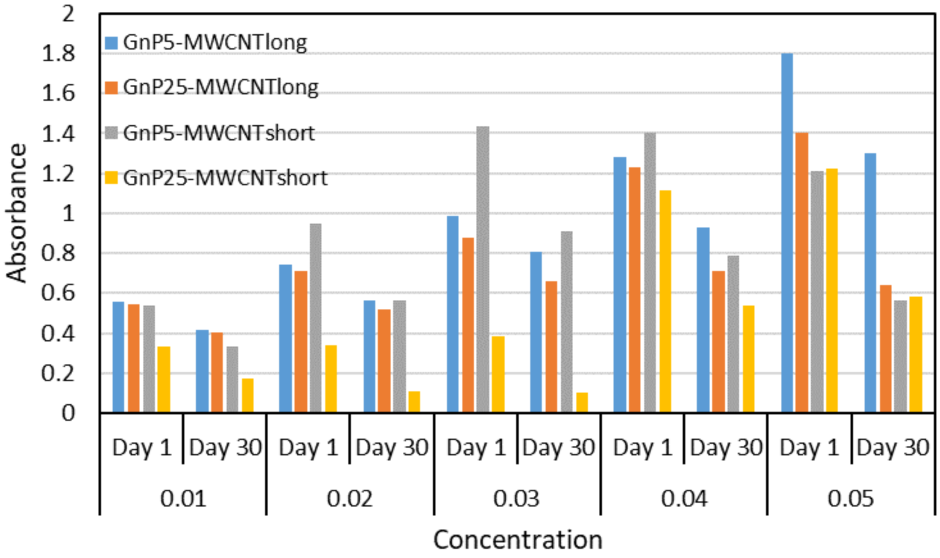

Figure 9. UV-Vis absorbance value during Day 1 and Day 30 of various nanofluid samples with different GNP-MWCNT size combinations at various concentrations.

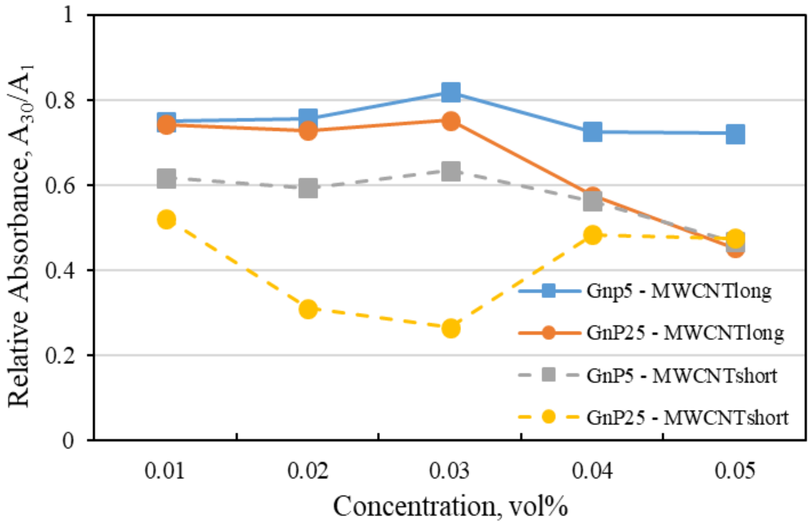

Figure 10. Relative absorbance of nanofluid samples containing various GNP-MWCNT size combinations.

Except for GNP25-MWCNTshort, nanofluid with the concentration of 0.03 vol.% appears to be the most effective concentration for improving the stability in other configurations. This suggests that there is an optimal concentration that produces the best dispersion stability in GNP-MWCNT hybrid nanofluid. Beyond this optimal concentration, the inter-particle distance becomes smaller, thus increases the probability of interactions between nanoparticles leading to increased tendency for agglomeration [17]. This finding underscores the critical importance of choosing the right concentration for producing nanofluids with the best dispersion stability.

CONCLUSION

In this study, the dispersion stability of GNP-MWCNT hybrid nanofluids with different size configurations were compared. The highest dispersion stability was produced by GNP5-MWCNTlong and the lowest was produced by GNP25-MWCNTshort. The study also revealed that the GNP5-MWCNTlong hybrid nanofluid exhibited optimal stability at a concentration of 0.03 vol.%. These findings underscore the important role of nanoparticles size and their concentration on the dispersion stability of GNP-MWCNT hybrid nanofluids.

ACKNOWLEDGEMENT

This research is made possible through financial assistance by University of Technology Sarawak via the University Research Grant (3/2021/01).

REFERENCES

[1] Gupta, N., Gupta, S.M., and Sharma, S.K. (2021). Synthesis, characterization and dispersion stability of water-based Cu–CNT hybrid nanofluid without surfactant, *Microfluidics and Nanofluidics*, 2021. 25(2): 14. doi: 10.1007/s10404-021-02421-2.

[2] Che Sidik, N.A., Adamu, I., and Muhammad, M. (2016). Preparation Methods and Thermal Performance of Hybrid Nanofluids, *J. Adv. Rev. Sci. Res.*, 2016. 24: 13-23. doi: 10.37934/aram.66.1.716.

[3] Phan Ngoc, H., Dang Nhat, M., Nguyen Van, H., Phan Ngoc, M., and Phan Hong, K. (2017). Carbon Nanotube and Graphene Aerogels – The World's 3D Lightest Materials for Environment Applications: A Review, *International Journal of Materials Science and Applications*, 2017. 6(6): 277-283. doi: 10.11648/j.ijmsa.20170606.12.

[4] Ali, N., Teixeira, J.A., and Addali, A. (2018). A Review on Nanofluids: Fabrication, Stability, and Thermophysical Properties, *Journal of Nanomaterials*, 2018. 2018: 6978130. doi: 10.1155/2018/6978130.

[5] Du, Y. and Yuan, X. (2020). Coupled hybrid nanoparticles for improved dispersion stability of nanosuspensions: a review, *Journal of Nanoparticle Research*, 2020. 22(9): 261. doi: 10.1007/s11051-020-04991-8.

[6] Arora, N. and Gupta, M. (2021). Stability evaluation and enhancement methods in nanofluids: A review, *AIP Conference Proceedings*, 2021. 2341(1). doi: 10.1063/5.0050106.

[7] Xing, M., Yu, J., and Wang, R. (2015). Experimental study on the thermal conductivity enhancement of water based nanofluids using different types of carbon nanotubes, *International Journal of Heat and Mass Transfer*, 2015. 88: 609-616. doi: 10.1016/j.ijheatmasstransfer.2015.05.005.

[8] Monash University Malaysia. (2024, March 22). *Field Emission Scanning Electron Microscope (FE-SEM)*. https://www.monash.edu.my/engineering/research/research-infrastructure/Nano-Analytical-Platform/ultra-high-resolution-fe-sem

[9] Monash University Malaysia. (2024, March 22). *High Resolution Transmission Electron Microscope (HR-TEM)*. https://www.monash.edu.my/engineering/research/research-infrastructure/Nano-Analytical-Platform/hr-tem

[10] Pacakova, B., Vejpravova, J., Repko, A., Mantlikova, A., and Kalbac, M. (2015). Formation of wrinkles on graphene induced by nanoparticles: Atomic force microscopy study, *Carbon*, 2015. 95: 573-579. doi: 10.1016/j.carbon.2015.08.043.

[11] Guest, J., Kinloch, I.A., and Young, R.J. (2023). The role of filler aspect ratio in the reinforcement of an epoxy resin with graphene nanoplatelets, *Journal of Materials Science*, 2023. 58(23): 9473-9485. doi: 10.1007/s10853-023-08603-3.

[12] Rebrović, L., Jukić, A., and Faraguna, F. (2023). Influence of MWCNTs geometry and surface oxidation on rheological and thermal properties of PEG nanofluids, *Journal of Thermal Analysis and Calorimetry*, 2023. 148(4): 1351-1364. doi: 10.1007/s10973-022-11558-3.

[13] Sarsam, W.S., Amiri, A., Kazi, S.N., and Badarudin, A. (2016). Stability and thermophysical properties of non-covalently functionalized graphene nanoplatelets nanofluids, *Energy Conversion and Management*, 2016. 116: 101-111. doi: 10.1016/j.enconman.2016.02.082.

[14] Rabbi, H.M.F., Sahin, A.Z., Yilbas, B.S., and Al-Sharafi, A. (2020). Methods for the Determination of Nanofluid Optical Properties: A Review, *International Journal of Thermophysics*, 2020. 42(1): 9. doi: 10.1007/s10765-020-02762-0.

[15] Awotunde, M.A., Adegbenjo, A.O., Ayodele, O.O., Okoro, A.M., Shongwe, M.B., and Olubambi, P.A. (2021). Influence of ball milling parameters on the dispersion characteristics and structural integrity of MWCNTs in nickel aluminide matrix powders, *Particulate Science and Technology*, 2021. 39(3): 298-311. doi: 10.1080/02726351.2019.1708519.

[16] Md Ali, A., Omar, M.Z., Salleh, M.S., Hashim, H., Mohamed, I.F., and Wakhi Anuar, N.F.B. (2022). Mechanical Behaviour and Morphology of Thixoformed Aluminium Alloy Reinforced by Graphene, *Materials*, 2022. 15(19): 6791.

[17] Yu, F., Chen, Y., Liang, X., Xu, J., Lee, C., Liang, Q., Tao, P., and Deng, T. (2017). Dispersion stability of thermal nanofluids, *Progress in Natural Science: Materials International*, 2017. 27(5): 531-542. doi: 10.1016/j.pnsc.2017.08.010.