Investigating the morphology and thermophysical properties of Al₂O₃ and CuO nanofluids

Vinay Singh¹, Munish Gupta¹, Ajay Kumar ²
¹ Department of Mechanical Engineering, Guru Jambheshwar University of Science & Technology, Hisar, 125001, India
²Department of Mechanical Engineering, KR Mangalam University, Gurugram, 122103, India

E-mail: theahlawat89@gmail.com

Abstract. Presently researches on nanofluids are high due to the owing interest and increasing day to day demand. The aim of the present investigation is to examine the size and morphology of nanoparticles using SEM and HRTEM and also calculate the thermophysical properties of alumina/water and CuO/water nanofluids. Nanofluids with weight concentration of 0.02 wt% and 0.05wt% were made using distilled water by adding appropriate amount of nanoparticle and base fluid. Thermophysical properties were measured at different temperatures using different concentration of nanofluids. Addition of nanoparticles in base fluid improves the thermal conductivity at increasing concentrations with temperature rise however, viscosity decreases with temperature increase.

Keywords: Nanofluids, SEM, UV Spectroscopy, Thermal conductivity, Viscosity

1. Introduction
In this era of modernization, energy transport is an important part in several fields that includes nuclear energy, oil and gas and also in the electrical energy. Heat transfer fluids generally comprise of water, kerosene oil, graphene and ethylene glycol. For better performance of energy systems, development of enhanced heat transfer fluids that possess superior thermophysical properties has become progressively more significant [1][2]. Choi [3] introduced the term nanofluids that deal with fluids possessing higher thermal conductivity in respect to the conventional ones [4]. Nanofluids have proved better in improving the thermophysical properties like as thermal conductivity and diffusivity, providing better stability and enhanced heat transfer coefficients [5]. However, slight increase in the pressure drop and pumping power can be observed while working with nanofluids [6]. Using high thermally conductive nanoparticles, one can observe the enhancement in the thermal properties of the heat transfer fluids [7]. Experiments were conducted by several researchers in order to study the effect of nanoparticle concentration on different thermophysical properties of nanofluids [8].

Several researchers have examined the thermophysical properties of alumina and copper oxide nanofluids. By the addition of nanoparticles in the conventional fluids like ethylene glycol and water, thermal conductivity of the fluid increases. The key factor behind this increment is the Brownian motion which is responsible for the control of the thermal behaviour of the nanoparticle-fluid mixture. Another important factor that is responsible enough is interfacial layer (also called as nanolayer). Studies on nanofluids clearly depicts that nanofluids possess greater thermal conductivity...
in respect to base fluids [9][10][11]. Experiments using different base fluids (engine oil, gear oil, methanol, and water) were conducted by the researchers and along with different nanoparticles.

Effect of variations of pH values on the thermal conductivity using water alumina nanofluids were examined by Zhu et al. [12]. They showed the dependency of enhancements in thermal conductivity and stability on the pH values and also on various surfactants concentration. Optimised value of surfactant improved the thermal conductivity of the nanofluid. Maximum 10.1% enhancement was observed on the 0.15 wt% particle loading of nanoparticles.

Thermal conductivity ratio of Al₂O₃- water nanofluid and effect of particle size and loading as well as temperature was experimentally studied by Teng et al. [13]. Small nanoparticle size, higher weight fractions, and high temperature were the favourable factors for improved thermal conductivity. Similar experiments were conducted by Chandrasekhar et al. [14]. They employed CPM (Chemical Precipitation Method) for synthesis of nanoparticles. Thermal conductivity increased by using increased concentration of nanoparticles. Distilled water was used as a dispersing media. Maximum enhancement of 9.7% was noticed at 3% volume concentration.

2. Physio-chemical properties

Samples of alumina and copper oxide nanopowder were purchased from High Purity Chemicals Limited. The description regarding the composition has been shown in Tables 1 and 2. SEM analysis of aluminium oxide and copper oxide nanopowder sample are illustrated in figure 1 and 2. HRTEM determines the size, distribution and morphology of the synthesized nanoparticles. In this process of characterization, carbon coated Cu grid is used to place a droplet of sample and drying process occurs at room temperature (RT).

TEM measurements were performed using a FEI, Technai G2 instrument (figure 3-6) operating at 200 kV accelerating voltage at NIPER, Mohali.

| Product Number | Description | Properties |
|----------------|-------------|------------|
| NX0015 | Aluminium oxide (Al₂O₃) nanopowder | |
| Molecular Formula | Al₂O₃ |
| Mean Particles size | < 80 nm |
| Specific surface area | >15-20 m²/g |
| Al₂O₃ content | > 99% |

| Product Number | Description | Properties |
|----------------|-------------|------------|
| NX0125 | Copper oxide (CuO) nanopowder | |
| Molecular Formula | CuO |
| Molecular Weight | 79.55 |
| Mean Particles size | < 80 nm |
| Specific surface area | >13 m²/g |
| CuO content | > 99% |
Table 3. Available data for thermophysical properties of nanofluids at 30°C

| Nanoparticle | Thermal Conductivity | Density | Specific Heat | Reference |
|--------------|----------------------|---------|---------------|-----------|
| Al₂O₃        | 40                   | 3980    | 780           | [15]      |
| CuO          | 33                   | 6500    | 525           | [16]      |

Figure 1. SEM image of Al₂O₃ nanoparticle sample

Figure 2. SEM image of CuO nanoparticle sample

Figure 3. HRTEM image of Al₂O₃ nanoparticle sample

Figure 4. HRTEM image of Al₂O₃ nanoparticle sample
Figure 5. HRTEM image of CuO nanoparticle sample

Figure 6. HRTEM image of CuO nanoparticle sample

Figure 7. Effect of temperature as well as concentration on thermal conductivity using Al₂O₃ and CuO nanofluids
3. Measurement of the effective thermal conductivity and viscosity of the nanofluids

KD2 Pro, Decagon Devices that works upon the principle of Transient hot wire method was employed on order to measure the thermal conductivity of nanofluids. Figure 7 demonstrates the effective thermal conductivity of alumina and CuO nanofluids with respect to water at weight concentrations of 0.02 and 0.05 wt%. With the rise in the temperature of the nanofluids, thermal conductivity also seems increasing. Linear dependency was obtained for
effective thermal conductivity enhancement with temperature. Anton Paar Rheometer was employed for measuring the viscosity of alumina and CuO nanofluids at different weight concentrations as a function of temperature. Viscosity was found to be crucial factor used for determining the eminence of heat transfer fluid. Relative viscosity of alumina and CuO nanofluids in comparison with water is depicted in figure 8. Decreasing trend of viscosity can be seen with rise in temperature. This is because of the fact that by rising temperature, motivation of nanoparticles increase and more space is created for them to move freely. It is predicted because inter molecular adhesion and inter particle forces becomes weak. Similar trend can be observed for almost all types of nanofluids.

4. UV Spectroscopy

In this process, visible light and ultraviolet is used for analyzing the chemical structure of any substance. A UV spectrophotometer is used for measuring the intensity of the light. This intensity is proportional to the wavelength. When ultraviolet light is subjected to compounds, they absorb it. Absorption capacity of different weight concentrations of Al₂O₃ and CuO nanofluids at different wavelengths is shown in Figures 9-12.

![Figure 9 Al₂O₃ 0.02 wt%](image1.png)

![Figure 10 Al₂O₃ 0.05 wt%](image2.png)
5. Conclusions

Thermophysical properties measurement of nanofluids was investigated as a function of temperature and concentrations. Following conclusions are drawn from the present study.

Thermal conductivity of nanofluid was found to be increasing with respect to temperature and concentration of nanofluid. Viscosity of the nanofluids increases with rise in the weight concentration of the nanofluids and decrease with rise in temperature. This is because rise in temperature leads to increase in motivation of nanoparticles. UV spectroscopy shows that CuO nanofluids absorb much intensity of UV light in comparison to the Al2O3 nanofluids.

Acknowledgments
The author Munish Gupta, Associate Professor, MED, GJUS&T, Hisar thanks DST PURSE for the grant provided vide letter no. CIL/2017/364.
References

[1] Mehrali, M., Sadeghinezhad, E., Latibari, S.T., Kazi, S.N., Mehrali, M., Zubir, M.N.B.M. and Metselaar, H.S.C., 2014. Investigation of thermal conductivity and rheological properties of nanofluids containing graphene nanoplatelets. *Nanoscale research letters*, 9(1), p.15.

[2] Mehrali, M., Latibari, S.T., Mehrali, M., Mahlia, T.M.I., Sadeghinezhad, E. and Metselaar, H.S.C., 2014. Preparation of nitrogen-doped graphene/palmitic acid shape stabilized composite phase change material with remarkable thermal properties for thermal energy storage. *Applied Energy*, 135, pp.339-349.

[3] Choi, S.U. and Eastman, J.A., 1995. Enhancing thermal conductivity of fluids with nanoparticles (No. ANL/MSD/CP--84938; CONF-951135--29). *Argonne National Lab.*, IL (United States).

[4] Safaei, M.R., Togun, H., Vafai, K., Kazi, S.N. and Badarudin, A., 2014. Investigation of heat transfer enhancement in a forward-facing contracting channel using FMWCNT nanofluids. *Numerical Heat Transfer, Part A: Applications*, 66(12), pp.1321-1340.

[5] Mehrali, M., Latibari, S.T., Mehrali, M., Mahlia, T.M.I., Metselaar, H.S.C., Naghavi, M.S., Sadeghinezhad, E. and Akhiani, A.R., 2013. Preparation and characterization of palmitic acid/graphene nanoplatelets composite with remarkable thermal conductivity as a novel shape-stabilized phase change material. *Applied Thermal Engineering*, 61(2), pp.633-640.

[6] Mehrali, M., Latibari, S.T., Mehrali, M., Mahlia, T.M.I., Metselaar, H.S.C., Naghavi, M.S., Sadeghinezhad, E. and Akhiani, A.R., 2013. Preparation and characterization of palmitic acid/graphene nanoplatelets composite with remarkable thermal conductivity as a novel shape-stabilized phase change material. *Applied Thermal Engineering*, 61(2), pp.633-640.

[7] Mehrali, M., Latibari, S.T., Mehrali, M., Mahlia, T.M.I. and Metselaar, H.S.C., 2013. Preparation and properties of highly conductive palmitic acid/graphene oxide composites as thermal energy storage materials. *Energy*, 58, pp.628-634.

[8] Singh, V. and Gupta, M., 2016. Heat transfer augmentation in a tube using nanofluids under constant heat flux boundary condition: a review. *Energy Conversion and Management*, 123, pp.290-307.

[9] Chen, L., & Xie, H. (2009). Silicon oil based multiwalled carbon nanotubes nanofluid with optimized thermal conductivity enhancement. *Colloids and Surfaces A: Physicochemical and Engineering Aspects*, 352(1), 136-140.

[10] Wei, X., Zhu, H., Kong, T., & Wang, L. (2009). Synthesis and thermal conductivity of Cu2O nanofluids. *International Journal of Heat and Mass Transfer*, 52(19), 4371-4374.

[11] Yu, W., Xie, H., Chen, L., & Li, Y. (2010). Enhancement of thermal conductivity of kerosene-based Fe3O4 nanofluids prepared via phase-transfer method. *Colloids and Surfaces A: Physicochemical and Engineering Aspects*, 355(1), 109-113.

[12] Zhu, D., Li, X., Wang, N., Wang, X., Gao, J., & Li, H. (2009). Dispersion behaviour and thermal conductivity characteristics of Al2O3–H2O nanofluids. *Current Applied Physics*, 9(1), 131-139.

[13] Teng, T. P., Hung, Y. H., Teng, T. C., Mo, H. E., & Hsu, H. G. (2010). The effect of alumina/water nanofluid particle size on thermal conductivity. *Applied Thermal Engineering*, 30(14), 2213-2218.

[14] Chandrasekar, M., Suresh, S., & Chandra Bose, A. (2010). Experimental investigations and theoretical determination of thermal conductivity and viscosity of Al2O3/water nanofluid. *Experimental Thermal and Fluid Science*, 34(2), 210-216.

[15] Klaus, D.S., 2010. Handbook of Nanophysics: Nanoparticles and Quantum Dots.

[16] Kamyar, A., Saidur, R. and Hasanuzzaman, M., 2012. Application of computational fluid dynamics (CFD) for nanofluids. *International Journal of Heat and Mass Transfer*, 55(15-16), pp.4104-4115.