Characteristic analysis of De-Ionized water and Ethylene Glycol based Aluminum Oxide Nanofluid

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ABSTRACT

Abstract - In this work, the characteristics of nanofluids is analyzed. Both the de-ionized water (DI) and ethylene glycol (EG) is used as a base fluid and aluminum oxide (alumina) is a nanoparticle. An equal quantity of base fluids is taken into account for preparing Al_20_3 nanofluid at various weight fractions. The various weight concentrations of nanofluid are 0.125, 0.250, 0.375, 0.50, and 0.625% weight fractions are taken for the experimental work.This nanofluid is prepared using magnetic stirrer method and ultrasonic method. Various experiments are conducted to determine the thermophysical properties such as thermal conductivity, kinematic viscosity, dynamic viscosity, relative viscosity, specific gravity, specific heat, sedimentation, and density. The comparison is done to evaluate the effectiveness of the nanofluid preparation technique. No dispersant is used to disperse completely.

Keywords

Ultrasonic technique, Magnetic stirrer technique, Nanofluid, Concentration, De-Ionized water, Aluminum Oxide

1.0 INTRODUCTION

In most of the industrial applications such as engine cooling and heat exchanger to transfer thermal energy used in the solar collector or refrigeration system, the thermal conductivity of the heat conducting medium such as aqueous solution and ethylene glycol attend a vital role in the efficient transfer of heat energy. The heat transfer capability of this transfer fluid can be improved and is an important one to enhance the heat transfer efficiency of the fluid, in the view of saving the energy. The reason for low heat transfer of the fluid is, the thermal conduction property of the fluid. Normally liquid is having low thermal conductivity. As per the law of thermal conduction, increase in thermal conductivity will improve the thermal transfer rate. This can be achieved by combining the heat transport properties of the liquid with the high thermal conductivity of a metal. This combined system includes uniform mixing of the high thermal conductivity of metal particles in high transport fluid, which is known as nanofluid. The particles are to be in the range of 1 to 100 nm.

1.1 Preparation of Nanofluid

Based on the result obtained from the research towards the development of industrial heat transfer showed the lacking in heat transfer improvement due to the application of fluids having low heat transfer properties. This can be overcome by two ways 1. Increasing the surface area of heat transfer system 2. Increasing the thermal conductivity of heat transfer fluid. The first option is impractical or not possible at most of the time because of the geometrical improvement. Nanofluid is the best option for improved heat transfer. Nanofluid can be synthesized by two-step method or one-step method. In two-step method, the nanoparticle is fabricated and then dispersed into conventional heat transfer fluid. Ultrasonicator, magnetic stirrer, and mechanical mixer are the some of the equipment used for preparing the nanofluid under two-step method. In one step method, both the particle fabrication and nanofluid preparation are taking place simultaneously, using various techniques like chemical reduction, direct evaporation, laser irradiation, microwave and thermal decomposition. The nanofluids were prepared by ultrasonic and magnetic technique at various weight fractions for the purpose of conducting the experiments. The result obtained from the experiments is used to evaluate the preparation technique.

2.0 INFLUENCING PARAMETERS

The thermal conductivity of nanofluid enhancement is influenced by various parameters such as particle volume fraction, particle material, base fluid, particle size, particle shape, temperature, pH value, and clustering. All these parameters are having certain level of effect baded on the nature of nano particle and basefluid. Thermal conductivity is measured by the different method such as transient hot-wire method [1-4], steady-state parallel plate technique, temperature oscilloscope method, micro hot strip method, and optical beam deflection [5-8]. Many researchers worked and achieved the beneficial result for thermal conductivity enhancement using various techniques.

2.1 Particle Volume Fraction

The first experimental work carried out [9] for measuring the thermal conductivity of nanofluids containing aluminum oxide, silver dioxide, titanium dioxide of particular size nanoparticles. They used water as a base fluid and undertake two-step method for nanofluid preparation. Thermal conductivity enhancement of 32.4% for the volume fraction of 4.3%. It was observed that the thermal conductivity enhancement is parallel to volume fraction. The experimental study of the thermal conductivity Al_2O_3 and CuO(copper oxide) [9-11], MWCNT(multiwall carbon nanotube)[12] and TiO_2(titanium oxide) [13] based nanofluid. The relationship between thermal conductivity and the particle volume fraction was linear. Sometimes it was nonlinear, due to low volume concentration. This nonlinear relationship is showed the insufficient interaction between particles and fluid.

2.2 Particle Material

The result showed that the particular material had an influence in thermal conductivity enhancement. Thermal conductivity study of [10] of Al_2O_3 and CuO based nanofluid and it was found CuO provided good result than Al_2O_3. Clustering character of Al_2O_3 is higher than CuO, which resulted in the reduced thermal conductivity, due to a reduced surface area. They [14] considered the thermal conductivity of Al_2Cu and Ag_2Al nanoparticle dispersed into water and EG. 1% volume fraction of oleic acid was used as a dispersant. The Ag_2Al based nanofluid showed little higher thermal conductivity than Al_2Cu. They [12] discussed the oil (synthetic poly oil) based nanofluid where MWCNT used as nanoparticles for thermal conductivity measurement. It was compared CNT nanofluids such as DWCNT and MWCNT. CTAB and nanosphere AQ were used as a surfactant. The thermal conductivity of MWCNT was somewhat higher than DWCNT, for 0.6% MWCNT produced 34% enhancement, where for 0.75% fraction, DWCNT availed only 3% enhancement.

2.3 Base fluid

According to all theoretical thermal conductivity model, thermal conductivity ratio is increased with the decrease in thermal conductivity of base fluid. Influence of base fluid on thermal conductivity of nanofluid depends on the viscosity and Browninan motion of the particle[15]. It was examined that the electric double layer effect[16] around the particles on thermal conductivity. Finalizing the effect of base fluid on thermal conductivity is a complex one. Experimental work validated the merely hopeful results. Some of the researchers carried out the experimental work to prove the influence of base fluid on thermal conductivity. The Al_2O_3 and CuO nanofluid were prepared [5] using several base fluid such as water, EG, pump oil and engine oil. Al_2O_3/water nanofluid showed a better result than Al_2O_3/EG in terms of thermal conductivity ratio. Engine oil and pump oil as base fluid showed descending order. They [17,18] also discussed the Al_2O_3 nanofluid as using DI water, EG and pump oil as the base fluid for different concentrations. They studied EG and synthetic poly oil [19] water and EG [14] based nanofluid for reviewing the influence on thermal conductivity.

2.4 Particle size

Nanoparticle size is also one of the influencing factors on the thermal conductivity. They studied the CuO_3 nanofluid [20] dispersed in EG by one step method and obtained [10] 20% enhancement in thermal conductivity for 23.6 nm CuO_3/EG mixture nanofluid and. They [21] Prepared $Al_{70}Cu_{30}$ nanofluid using EG as the base fluid. Increase in particle size decreased the thermal conductivity enhancement. For 0.5% volume fraction of nanofluid, the thermal conductivity enhancement was decreased from 38% to 3% when increasing the particle size from 9 to 83nm. It was investigated the effect of the particle size such as Al_2Cu and Ag_2Al [14] particle dispersed into water and EG, Al_2O_3/water and Al_2O_3/eg[22] particle size vary from 30-120nm for Al_2Cu and Ag_2Al,8 and 282 nm for Al_2O_3. They [23,24] measured the thermal conductivity of Al_2O_3 nanofluid and compare with [25-27] which showed that there was not much difference in the thermal conductivity of the particle size 80,38.4 and 47nm.

2.5 Particle shape

Spherical and cylindrical is the two types of nanoparticle geometry. The major quantity of research work was carried out on cylindrical geometry nanoparticles, which has the higher length to diameter ratio. They [28] proved experimentally that the cylindrical shape nanoparticle produced a good result than spherical type nanoparticles. SiO nanoparticle dispersed into distilled water and EG. Both the cylindrical and spherical shape nanoparticle of 60 and 26nm. Spherical type nanoparticle of 4.2% volume fraction produced 15.8% thermal conductivity enhancement where for 60nm cylindrical nanoparticle exhibits 23% enhancement. The result obtained [34] was compared with Hamilton-Crosser [29] model, which showed the good relationship. For TiO_2 and di water nanofluid, the spherical shape produced only 29.7% and 33%, for cylindrical type nanoparticles of same volume fraction.

2.6 Temperature

In a liquid and solid particles (millimeter or micrometer) mixture, the thermal conductivity of mixture depends on temperature only, but in the case of nanofluid (solid particle size is in the range of 1-100nm), the thermal conductivity depends on Brownian motion and clustering of particles which in turn depends on temperature[30]. They discussed the thermal conductivity of Al_2O_3,SiO_2 and TiO_2 [9,31] nanofluid, Al_2O_3 and CuO [26,32] at a different temperature range from 21ºc and 51ºC. Thermal conductivity was enhanced 2% at 21ºC to 10.8% at 51ºC for same volume concentration of 1%. There was a linear relationship between thermal conductivity ratio and temperature. As per the parameter comparison, the particle volume fraction dependence on thermal conductivity is higher than temperature dependence. Some other research works were also carried out by researcher [33-36].

2.7 Clustering

Clustering problem is always present in the nanofluid, but not arise in the case of a solid-fluid mixture of micro or millimeter size nanoparticle. Effect of clustering of Fe [36], Fe_3O_4[37] nanoparticle was analyzed, which depends upon ultrasonic vibration time duration. It may vary from 0 to several hours. Thermal conductivity ratio increased with increased ultrasonication time. But the rate of this increased become slow for longer vibration.

2.8 pH value

Very limited work was carried out to observe the effect of pH value on thermal conductivity when compared with other parameters. The thermal conductivity ratio is decreased with an increased pH value of Al_2O_3 nanofluid while using water, EG and pump oil as base fluid [38]. Al_2O_3–aqueous solution of 5% volume fraction showed the thermal conductivity enhancement 23% against the pH value 2.0, whereas, for the pH value of 11.5, the thermal conductivity enhancement became 19% for the same volume fraction. Effect of pH value of CuO /water and Al_2O_3/water was [39] investigated where sodium dodecylbenzene sulfonate was used as a surfactant. The optimum thermal conductivity was observed for the pH value of 8 (Al_2O_3) and 9.5 (CuO). For the case of TiO_2/water nanofluid [40] the thermal conductivity was decreased with increasing pH value.

3.0 EXPERIMENTAL RESULTS

In the present work, the Al_2O_3/DI water+EG nanofluid is synthesized by ultrasonication and magnetic stirrer technique at various weight fraction such as 0.125%, 0.250%, 0.375%, 0.50% and 0.625%. To compare and evaluate the characters of nanofluid prepared is used both the technique, first, the parameters are to find out by various apparatus. The various parameters include density, specific gravity, kinematic viscosity, dynamic viscosity, relative viscosity, specific heat, sedimentation and thermal conductivity, which has an influence on thermal conductivity.

Estimation of Al_2O_3 nanopartIcles for the defined concentration was calculated using a digital weighing machine. Fig. 1 and 2 shows the raw alumina nanoparticles and scanning electron microscope (SEM). For both the nanofluid preparation, the corresponding calculated nanoparticle is mixed well with a mechanical stirrer. Two batches of Al_2O_3 based nanofluid is prepared, one by ultrasonic bath and another for the magnetic stirrer. Fig.3 and 4 show the ultrasonic bath cleaner and magnetic stirrer instruments used for the preparing the nanofluid.

Fig 1: Photographic image nanoparticles

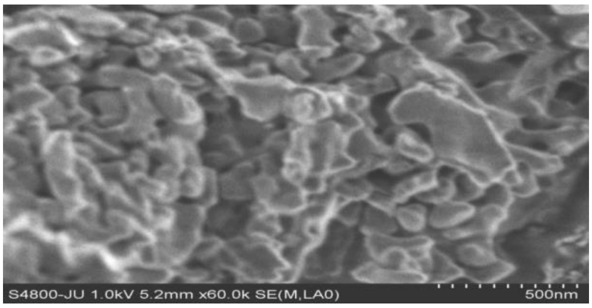

Fig 2: SEM image of nanoparticles

Fig 3: Ultrasonic bath

Fig 4: Magnetic Stirrer

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Fig. 5 and 6 show the DI water+EG based alumina nanofluid at five weight concentration from 0.125 to 0.625 sample and samples for sedimentation test to understand the effectiveness of mixing. Fig. 7 shows the test set up to determine the density and specific gravity of nanofluids. Fig.8 indicates ostwald's viscometer for measuring the viscosity. Fig 9 pH value paper strip and the corresponding samples. From fig.10,11 and 12 are showing the status and trends relative viscosity, specific gravity and thermal conductivity. Viscosity is increased from 0.713 at 0.125% to 0.823 at 0.375%. Specific gravity and thermal conductivity also are increased parallel with density and particle concentration. But specific heat is gradually decreased with increase in concentration means, it requires less quantity of heat for increasing temperature, which will lead the convective heat transfer. There is a little increment in the thermal conductivity from 0.403 to 0.409 at 0.125 to 0.625. Subsequently, enhancement of thermal conductivity happens at just 1.5%. There is a little improvement in the specific gravity from 1.156 to 1.178. Five concentrations have the same result at 7.0 in the case pH value. Specific heat is lightly decreased because the addition of nanoparticle and it is decreased in the range of 3.277 to 3.265. There is a slight increment in the density from 1.156 to1.178Kg/m^3. Enhancement of the density will increase because the adding of the nanoparticle.

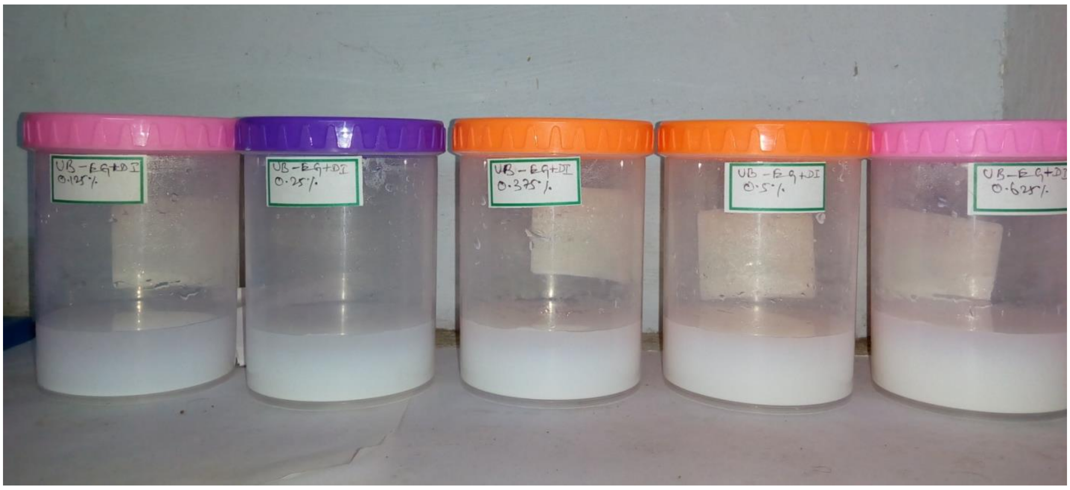


Fig 5: Alumina and De-ionized water nanofluid

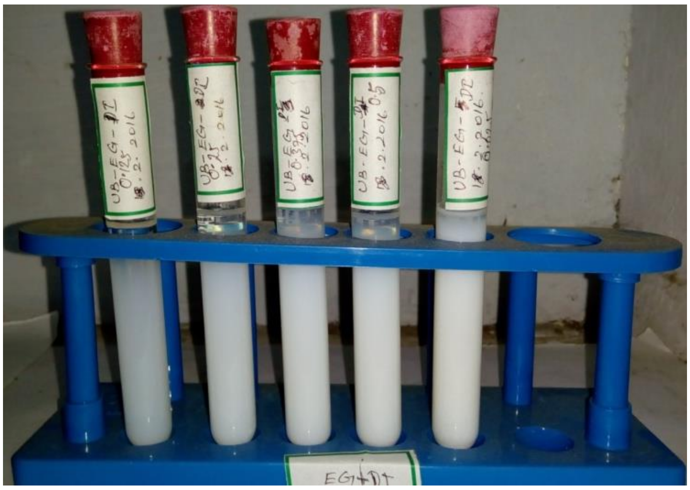


Fig 6: Sedimentation

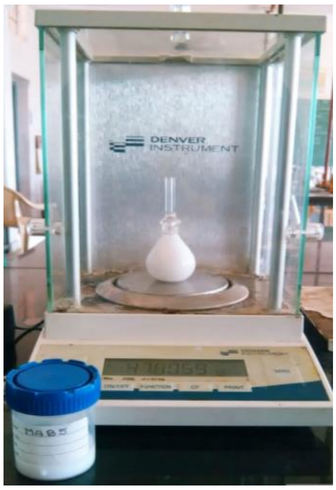


Fig 7: Density and Specific gravity

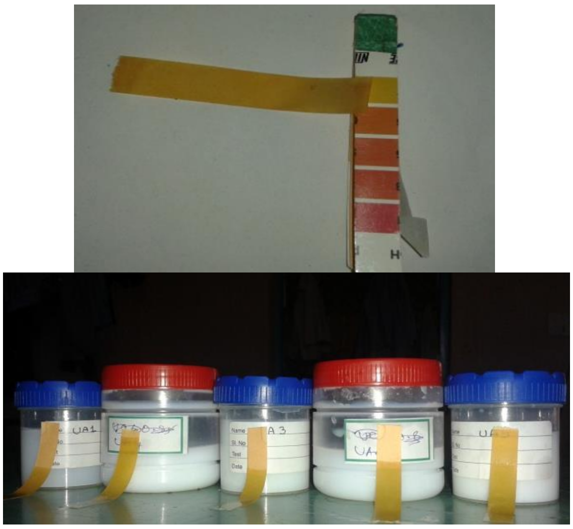
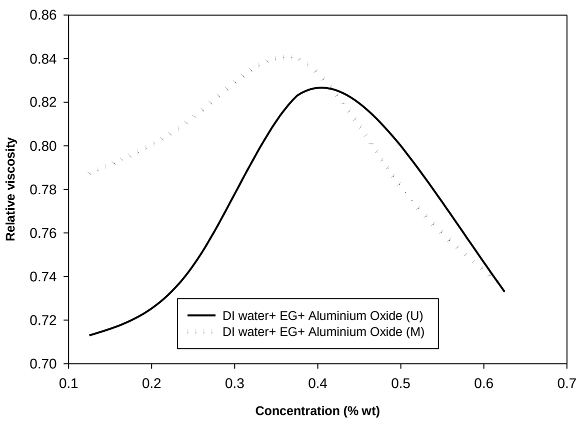
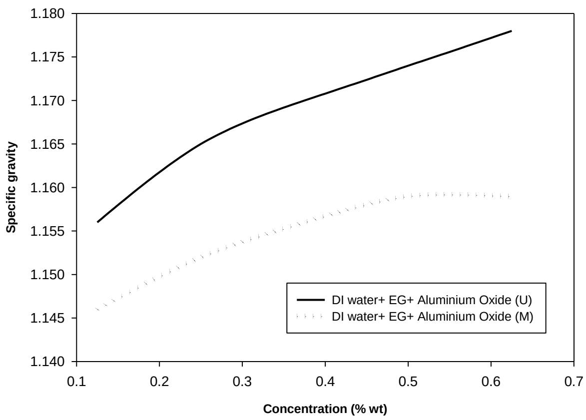


Fig 8: Viscosity test

Fig 9`: pH value





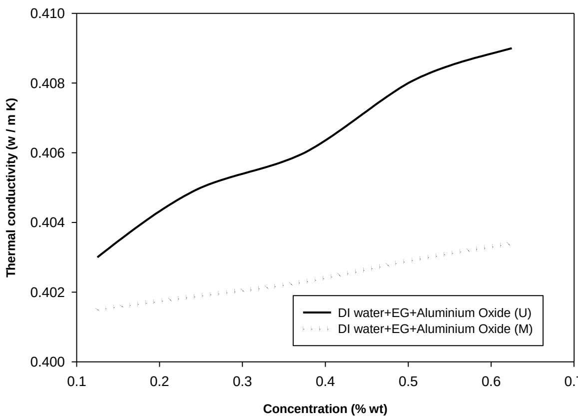


Fig 10,11 and 12 : Change of Relative viscosity, Specific gravity and Thermal conductivity with various concentration (Ultrasonic vs Magnetic Stirrer technique)

CONCLUSION

Nanofluid is a dilute colloidal suspension with nano-sized particles. It is prepared by dispersing the nanoparticles in the base fluids (DI and EG). Nanofluid of different concentrations (0.125%, 0.25%, 0.375% and 0.5% and 0.625%) are prepared using EG and DI water as base fluid. Ultrasonic and magnetic stirrer technique is used for each set of samples. One set of samples is sonicated for one-hour duration and another set of samples is prepared by magnetical stirrer technique. All results are concluded on the basis of the experiments performed for measuring the thermophysical properties like Viscosity, Density, Specific heat, pH value, Specific gravity and Thermal conductivity.

1. Viscosity and specific gravity of nanofluids are measured by Ostwald's viscometer and specific gravity bottle respectively. From the experimental results, it is observed that the increases in concentration automatically leads to the improvement in specific gravity and viscosity at atmospheric pressure and temperature condition.

2. The thermal conductivity and specific heat of nanofluid can be measured by thermal property analyzer. The experimental results show that the enhancement of thermal conductivity of EG and DI water based Al_2O_3 at constant atmospheric temperature. The results indicate that the particle volume fraction is also an important parameter for nanofluids. Increases in particle volume concentration, is also increased the thermal conductivity of nanofluid.

3. It has been found that specific heat of nanofluid decreases with increasing nanoparticle volume fraction.

4.The pH value is measured by digitalized pH meter and it is in the range of 7. As for pH value, there is no significant change between in both the method. .

5. Due to the increase in concentration of the nanofluid, the thermal conductivity, density, specific gravity of the nanofluid are increased and specific heat is decreased. And also the viscosity is decreased at certain level of concentration and then improved at high concentration.

6. Density is increased gradually along with an increase in particle concentration. This is because of particle addition in base fluids.

7. In magnetic stirrer method, the maximum increase in relative viscosity is 9%. This is due to poor mixing of nanoparticle with base fluids.

8. As per the specific gravity parameter trend, ultrasonic technique is effective in the range of 0.87% to 1.61% than magnetic stirrer technique.

9. As per the thermal conductivity point of view, the ultrasonic technique is good in the range of 0.372% to 0.911%.

SCOPE OF FUTURE WORK

The study on nanofluid is still in its infancy status. The mechanism of thermal conductivity occur in nanofluid is still unclear. The influences of the factor such as particles size, particles shape, size distribution, additives, and particle/fluid interfacial properties on the heat transfer are unclear. There exist wide discrepancies and inconsistencies in reported data of nanofluids. Hence more research should be carried out for characterization of different kind of nanofluid and its application.

NOMENCLATURE

SWCNT	Single Wall Carbon NanoTube
DWCNT	Double Wall Carbon NanoTube
MWCNT	Multi-Wall Carbon NanoTube
EG	Ethylene Glycol
DI	De-Ionized
SEM	Scanning Electron Microscope
U	Ultrasonic technique
M	Magnetic stirrer technique
Al_2O_3	Aluminum Oxide or Alumina
TiO_2	Titamium Oxide
SiO_2	Silicon dioxide
CuO	Copper Oxide

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