Effect of Sonication Time, Concentration, Shape and Size of Nano Particle on Thermal Conductivity of Al_2O_3 /Water Nano Fluid

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***Abstract*— In the present investigation, effect of sonication time, nano particle concentration, shape and size of the nano particles on thermal conductivity of Alumina (Al_2O_3) nano particle in water was investigated. It was found that, thermal conductivity of the nano fluids increased with increasing sonication time, nano particle concentration. However, thermal conductivity of nanofluids was increased with decreasing particle size.**

***Keywords*— Al_2O_3, Nano particle, Nano fluid, thermal conductivity, Scanning electron microscope(SEM), X-ray diffractometry(XRD).**

I INTRODUCTION

Use of micro or macro particles settle rapidly, abrade and clog each other in fluids. These problems are highly not acceptable for many practical cooling applications. However, nano-particles stay suspended much longer and possess a much higher surface area. The surface/volume ratio of nano-particles is 1000 times larger than that of micro-particles [1]. The high surface area of nano-particles enhances the heat conduction of nano-fluids, since heat transfer occurs on the surface of the particle [1]. The number of atoms present on the surface of nano-particles, as opposed to the interior, is very large [1, 2]. Therefore, these unique properties of nano-particles can be adopted to develop nanofluids with an extraordinary combination of the two features most highly desired for heat transfer systems: extreme stability and ultrahigh thermal conductivity [3].

Nanofluids, are a colloidal mixture of nanoparticles (1–100nm) and a base liquid (nanoparticle fluid suspensions). [4], these heat transfer fluids exhibit thermal properties superior then base fluids or conventional particle fluid suspensions**.** In other words, nanofluids are nanoscale colloidal suspensions containing condensed nano materials. Nanofluids possess excellent thermos-physical properties such as thermal conductivity, thermal diffusivity, viscosity, and convective heat transfer coefficients compared to those of base fluids like oil or water [5]. The key driving force for nanofluids research is their use in wide range of applications.

The investigations on nanofluids behaviour under forced convective also have reported enhancement in heat transfer characteristics except for very few studies [6, 7]. Wang et al [8] concluded that the particle shape or aspect ratio of the particle is a significant parameter to affect the thermal performance of nanofluids. However different experimental results have been observed by Putra et al. [9].

To this background Alumina (Al_2O_3) nanofluids of different concentrations and size of nano particle are prepared and their effects on thermal conductivity characteristics were investigated. The reasons for using Alumina nano-fluids are that, Al_2O_3 nano particles are widely used in this research area owing to requirements such as stable, uniform and continuous suspension without any outstanding chemical change of the base fluid and also that the physical properties of alumina nanofluid have been well documented.

II EXPERIMENTAL AND METHODOLOGY

In the present work, Al_2O_3 spherical nano particles of two different sizes procured from US Research Nanomaterials, USA had been used. The size of the spherical nano particles was found to be 20nm and 80nm respectively. The cylindrical Al_2O_3 nano particles (100nm x 6nm) also had been procured from Shree Durga Laboratory equipment supplies, Mangalore. Characterization of procured nano particles to ensure the size, the following characterization was done using following two methods.

- Scanning electron microscope [SEM] study
- X-ray diffractometer [XRD] study

III DETERMINATION OF THERMAL CONDUCTIVITY

Thermal conductivity of the nanofluid is determined by using KD2 process using KD2 PRO thermal conductivity meter (experiments were conducted at Dept of chemistry, NITK Surathkal). In the present investigation, the thermal conductivity of Al_2O_3 nanofluids was measured at different sonication times (1hr, 2hr, and 3hr) and at different concentrations (0.1, 0.15 and 0.2vol%). The prepared sample of Al_2O_3, at different sonication was taken in a 30ml beaker and placed in the instrument. The sensor was completely inserted into the solution and the instrument was switched on. It automatically calculates the value and displaces the thermal conductivity of the sample at that particular temperature. Thermal resistivity was computed as the reciprocal of thermal conductivity. Effect of nano particle size on thermal conductivity of nanofluids was also investigated. Water was considered as heat transfer fluid.

IV RESULTS AND DISCUSSIONS

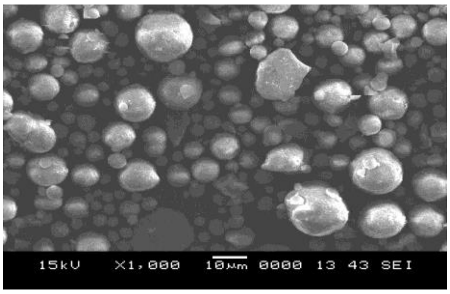

Fig. 1: SEM image showing procured Al_2O_3 (20nm) nano particles were in spherical shape.

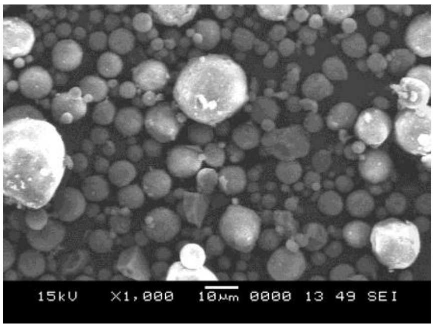

Fig. 2: SEM image showing procured Al_2O_3 (80nm) nano particles were in spherical shape.

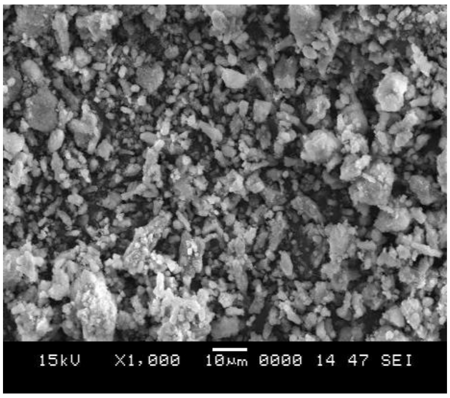

Fig. 3: SEM image showing procured Al$_2$O3 (100nm x 6nm) nano particles in cylindrical shape.

Figure 1, Figure 2 and Figure 3 show the SEM images of Al_2O_3 nano particles having a broad size distribution. Figure 1 clearly indicates the presence of Al$_2$O3 nano particles in spherical shape which is agreed with data procured from the manufactures. The same trend was found in Figure 2. However Figure 3 shows the nano particles of cylindrical shape. SEM characterisation concludes that procured nano particles were in spherical and cylindrical form.

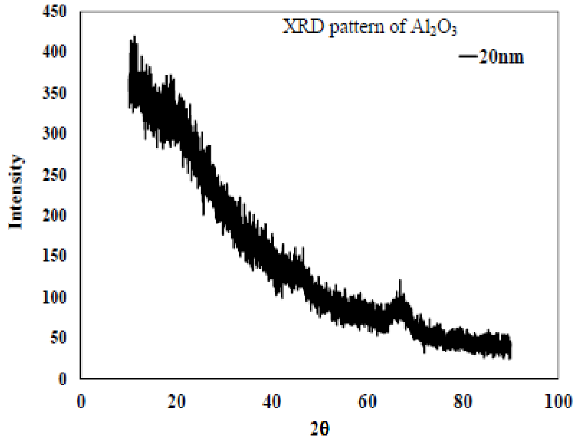

Fig 4: XRD pattern of Al_2O_3 spherical nano particle (20nm)

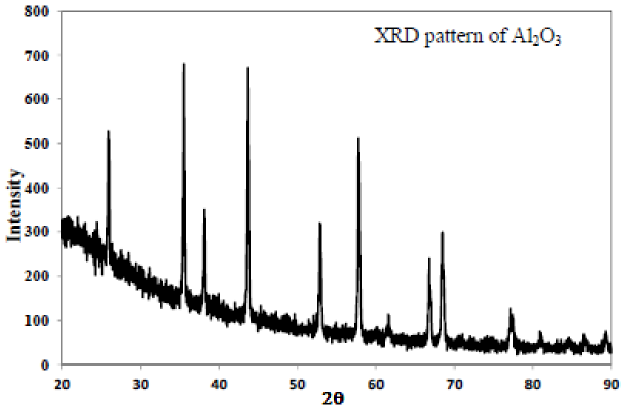

Fig 5: XRD pattern of Al_2O_3 spherical nano particle (80nm)

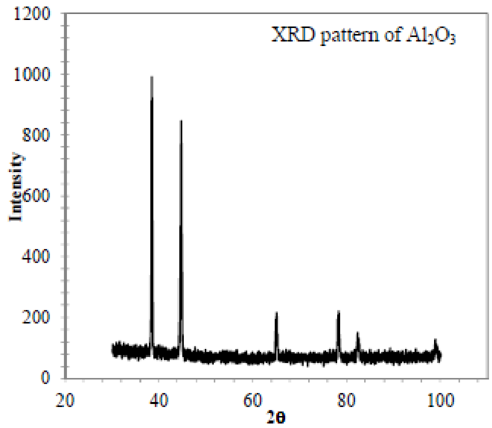

Fig 6: XRD pattern of Al_2O_3 cylindrical nano particle (100nm x 6nm)

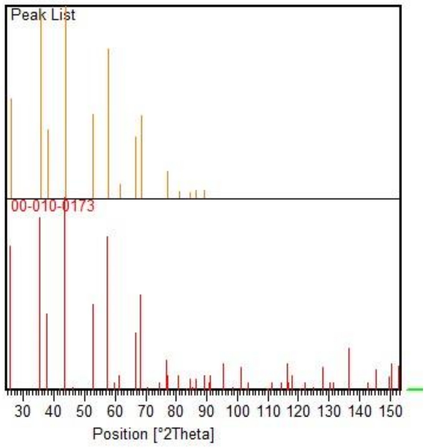

Fig 7: XRD pattern of Al_2O_3 (80nm) comparing with standard pattern

Figure 4, 5 and 6 represent the X-ray diffraction (XRD) patterns of Al_2O_3 nanoparticles respectively. The XRD result shows that Al_2O_3 nanoparticles are formed in a structure. The Figure 7 shows the standard peak pattern of 80nm Al_2O_3. By comparing the standard pattern Figure 7 with the obtained pattern Figure 5 it concludes that procured nano particles were of Al_2O_3 80nm size.

Considering the peak at degrees, average particle size had been estimated by using Debye-Scherrer formula also.

$$D = 0.9\lambda/\beta \cos\theta$$

$$\mathbf{2\theta=43.64}$$

$$\mathbf{\beta=(43.80-43.64)x3.14/180=0.0059\ radian}$$

where

'λ' is wave length of X-Ray (0.1541 nm),

'β' is FWHM (full width at half maximum),

'θ' is the diffraction angle and 'D' is particle diameter size.

$$\mathbf{D = 0.9\ x\ 0.1541/0.0059\ x\ cos(21.82) =25nm}$$

Size of nano particle (nm)	Concentration	Thermal conductivity W/mk
20	0.1	0.543
80	0.1	0.538
Cylindrical	0.1	0.393

Table 1: Measured thermal conductivity values for 1 hour sonication time at 0.1concentration

Size of nano particle (nm)	concentration	Thermal conductivity W/mk
20	0.1	0.707
80	0.1	0.545
Cylindrical	0.1	0.553

Table 2 : Measured thermal conductivity values for 2 hour time at 0.1concentration

Size of nano particle (nm)	Concentration	Thermal conductivity W/mk
20	0.1	0.649
80	0.1	0.542
Cylinder	0.1	0.312

Table 3: Measured thermal conductivity values for 3 hour time at 0.1concentration

Size of nano particle (nm)	Concentration	Thermal conductivity W/mk
20	0.15	0.604
80	0.15	0.510
Cylinder	0.15	0.469

Table 4: Measured thermal conductivity values for 1 hour sonication time at 0.15concentration

Size of nano particle (nm)	Concentration	Thermal conductivity W/mk
20	0.15	0.691
80	0.15	0.567
Cylinder	0.15	0.612

Table 5: Measured thermal conductivity values for 2 hour sonication time at 0.15concentration

Size of nano particle (nm)	Concentration	Thermal conductivity W/mk
20	0.15	0.638
80	0.15	0.532
Cylinder	0.15	0.580

Table 6: Measured thermal conductivity values for 3 hour sonication time at 0.15concentration

Size of nano particle (nm)	concentration	Thermal conductivity W/mk
20	0.2	0.559
80	0.2	0.476
Cylinder	0.2	0.535

Table 7: Measured thermal conductivity values for 1 hour sonication time at 0.2concentration

Size of nano particle (nm)	Concentration	Thermal conductivity W/mk
20	0.2	0.584
80	0.2	0.539
Cylinder	0.2	0.561

Table 8: Measured thermal conductivity values for 2 hour sonication time at 0.2concentration

Size of nano particle (nm)	Concentration	Thermal conductivity W/mk
20	0.2	0.686
80	0.2	0.556
Cylinder	0.2	0.439

Table 9: Measured thermal conductivity values for 3 hour sonication time at 0.2concentration

Table 1 to 9 indicate the values of thermal conductivities of Al_2O_3 nano particles of different sizes, at different concentration and at different sonication time. Table 1 to 3 shows the effect of sonication time at 0.1 concentrations on thermal conductivity. Table 4 to 6 shows the effect of sonication time at 0.15 concentrations on thermal conductivity. Table 7 to 9 shows the effect of sonication time at 0.2 concentrations on thermal conductivity.

The measured values of thermal conductivity of Al_2O_3 nanofluids in water clearly indicate that as the size of the nano particle decreases the thermal conductivity increases. This is due to the large surface to volume ratio of smaller nano particle (20nm) compared with larger size nano particle (80nm). However the work done by Michael et. al. [10] showed that the thermal conductivity of nanofluid decreases as the particle size decreases below 50nm. In their work they have used nano particles of size 8nm to 282nm in water or ethylene glycol nano fluid. Study carried out by Ali et al. [11] also found that, the thermal conductivity and thermal diffusivity of nanofluids increases as the particle size increases, In their investigation, 11, 25, 50 and 63 nm diameter Al_2O_3 nanoparticles in distilled water was used.
Baheta and Woldeyohannes [12] reported that, as the nanoparticles size increases the thermal conductivity decreases, which is agreement with current investigation. Generally thermal conductivity is affected by the size of the nano particle. The result obtained in the current study needs some more experiments to ensure the effect of size of nano particle on thermal conductivity.

In the present study it was also found that, Al_2O_3 nanofluid in which nano particles were in cylindrical shape exhibited lower thermal conductivity at different sonication times (1hr, 2hr, and 3hr) and at different concentrations (0.1, 0.15 and 0.2vol%) compared to spherical nano particles. This concludes that the shape of the nano particle also play a role for improving the thermal conductivity of nano fluids.

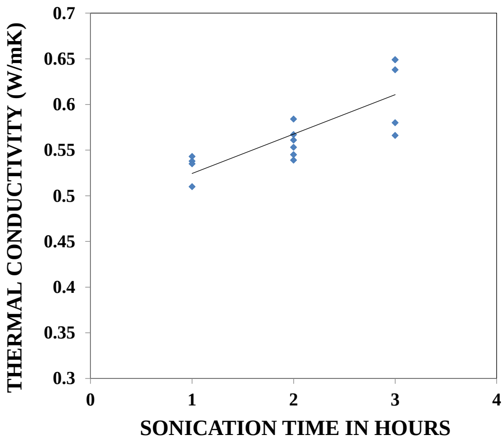

Fig 8: Thermal conductivity vs. sonication time

Figure 8 shows the graphical representation of themal conductivity vs sonication time of nanofluid for 1,2 and 3 hours respectively. From the graph it can be inferred that with the increase in sonication time of the nanofluid, the corresponding thermal conductivity of the nanofluid increases respectively. Hence, increase in sonication time increases the thermal conductivity of the nano particles. The main reason for this is thorough dispersion of nano particles in the nano fluid.

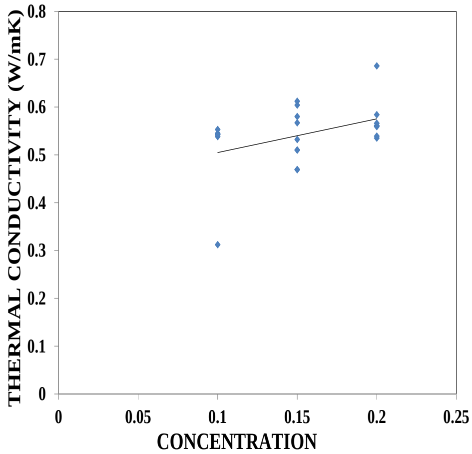

Fig 9: Thermal conductivity vs. concentration of nano particle in nanofluid

Figure 9 shows the graphical representation of thermal conductivity vs concentration of nanofluid for 0.1, 0.15 and 0.2 concentrations respectively. The graph clearly indicates that as the concentration is increased thermal conductivity linearly increases. A trend shows that thermal conductivity increased with the increase in volume fraction. The reason is as the volume concentration in fluid increases the suspension of smaller nano particles compared to larger nano particle increases and also as reported already the surface to volume ratio increases as the particle size decreases.

V CONCLUSION

Based on the results and discussions the following conclusions were made,

The average thermal conductivity of Al_2O_3 particle of size 20nm in nano fluid is higher than 80nm.

Cylindrical shape nano particles exhibited lower thermal conductivity than spherical nano particles at different sonication times (1hr, 2hr, and 3hr) and at different concentrations (0.1, 0.15 and 0.2vol%).

Irrespective of size and shape, the thermal conductivity of nano fluid increases with increase in concentration.

Irrespective of size and shape, the thermal conductivity of the nano fluid increases with increase in sonication time.

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