# Investigation of $Al_2O_3$ Nanofluid by Diluted Ethylene Glycol for Heat Transfer Application

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**Abstract**

Alumina based nanofluidsis a potential cooling medium for the various applications like electronic, transport and, industrial cooling applications etc.. In addition, alumina based nano fluids can be used as a coolant in satellite systems application. Alumina based Nanofluids can be synthesized by two different techniques such as single step and two-step method. In this work, two-step process was adopted for synthesis of nanofluid. Initially alumina particles were integrated by sol-gel method. By employing SEM, EDX and XRD, the synthesized alumina powder particle size, chemical composition and phase analysis were verified, respectively. For synthesis of nanofluid, the nano alumina particles were mixed with ethylene glycol and mixture of ethylene glycol and water by using ultrasonicator. The synthesised alumina based nanofluids properties were studied such as thermal conductivity, pH, viscosity and density using thermal properties analyser, pH meter, viscometer and specific gravity bottle, respectively. The comparison of both the nanofluids shows that thermal conductivity of ethylene glycol and mixture of ethylene glycol and water base nanofluid has average of 24 % higher efficiency over a range of temperature than other nanofluids.

*Keywords*:
*Nanofluid;Alumina; Ethylene glycol;Nano particles;Thermal conductivity.*

**Nomenclature**

| | |
|---|---|
| Kα | The high intensity nearly monochromatic x-rays |
| v | Volume of water H2O |
| m | mass |
| ρ | Density of nanofluid |
| T | Temperature |
| $k$ | Thermal conductivity |

*Greek symbols*

| | |
|---|---|
| $\alpha, \beta, \gamma$ | Thermal conductivity coefficients factors |

## 1. Introduction:

The fast growth of technology focuses on the efficiency and minimization of the products or process. On controversy, it elevates the heat dissipation from machines/microelectronics which restricts the usage of product for long run. Technological support required for faster cooling medium to absorbs the dissipated heat. Conventionally, heat transfer problem solved by increasing heat dissipation area, then it moved to usage of fluid for heat transfer. Scientist tried various techniques to enhance the heat transfer. In 1873, Maxwell [1] proposed the composite fluids i.e. suspension of the particles in fluid, by considering thermal conductivity of solids is always higher than liquid. The coarser particle resists the movement of the fluid and tried to settle at the bottom. Based on the type of motion and nature particle, it may erode or corrode based on the nature of particles. In 1995, Choi [2] proposed the nanoparticles suspended fluid, coined the word nanofluids for heat transfer. Nanofluid overcome the technical

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hitches of conventional fluid, due to nano size, high surface area, able to suspend in liquid and high thermal conductivity of nanoparticles.

Nanofluids are synthesized by two techniques such as single stage and two stage method. The availability of various nanopowders, the cost effective two stage method was preferred for synthesis of nanofluids. The nanopowders are selected based on the ability to have stable and uniform suspensions, no reactivity with fluid and/ container etc. Several investigators studied influence nanopowders such as metals (Fe, Cu, Ag, Au etc.), ceramics ($Al_2O_3$, CuO, MgO etc.), coated metal powders (Au coated with thoriate, Ag coated with citrate etc.) and carbon based materials (single wall and multiwall nanotubes, graphene, graphene oxide etc.) in thermal conductivity of nanofluids [3]. The overall results indicate that quantity, shape, size and nature of nanoparticles plays a vital role. The thermal conductivity of nanofluids also depends on the specific heat capacity, viscosity, density and pH of the fluid. Several investigators studied about alumina based nanofluid in the water medium [4-7, 10], ethylene glycol [6, 8-10] and mixture of ethylene glycol and water mixture [10]. Reported that thermal conductivity of nanofluid is directly propositional to the volume fraction of nano particles. On controversy, volume fraction of nano particles reduces the viscosity of nanofluid. Based on this information, the focuses changes towards the size of nanoparticle [9].

In this work, the thermal conductivity of nanofluid is starting with the synthesis of alumina nanoparticles using sol-gel method. The effect on alumina particles in the thermal conductivity of base fluid of Ethylene Glycol (EG) and Ethylene Glycol + Water (EG-$H_2O$) mixture was studied over a range of temperature.

## 2. Experimental setup

### *2.1Materials and methods*

Intially, nano$Al_2O_3$particles were synthesized using raw materials such as aluminium chloride ($AlCl_3$), sodium carbonate ($Na_2CO_3$) and distilled water. Commercial high purity $AlCl_3$ and $Na_2CO_3$were mixed together in 1:1 in100 ml distilled water. To obtain the gel, the solution was heated at 150˚C in an oven for 10 hrs. To remove the volatile components in the gel, it was heated once again in a muffle furnace at 900˚C for 3 hrs under ambient atmosphere which results in white colour alumina powders. During the process, the following reactions were expected to taking place.

$$2AlCl_3 + 3Na_2CO_3 + 3H_2O \rightarrow 2Al(OH)_3 + 3CO_2 + 6NaCl$$

$$Al(OH)_3 \rightarrow Al2O_3 + H_2O$$

The surface morphology, particle size and chemical composition of the $Al_2O_3$nanoparticles were investigated by SEM and EDS of Tescan Vega SBH model. Using Cu Kα as a source, the crystalline phase of synthesis $Al_2O_3$ nanoparticles were obtained using Rigakuminiflex 600 XRD.

Concentrated Ethylene Glycol (EG) and the equal mixture of Ethylene Glycol and distilled water (EG-$H_2O$) were used a base fluid. The nano fluid were prepared by adding 1% volume concentration of nano $Al_2O_3$ particles into base fluid such as EG and EG-$H_2O$.Thesolution underwent ultrasonication for one hour at 50˚C to increase the stability and uniform dispersion of the particles in the medium. The properties of $Al_2O_3$-EG and $Al_2O_3$-EG-$H_2O$nanofluids such thermal conductivity, pH, viscosity and density were studied using KD2 Pro Analyzer , pH meter, Ubbelohde viscometer and specific gravity bottle, respectively. Figure 1 shows the overall synthesis and study process of alumina nanofluid using flowchart.

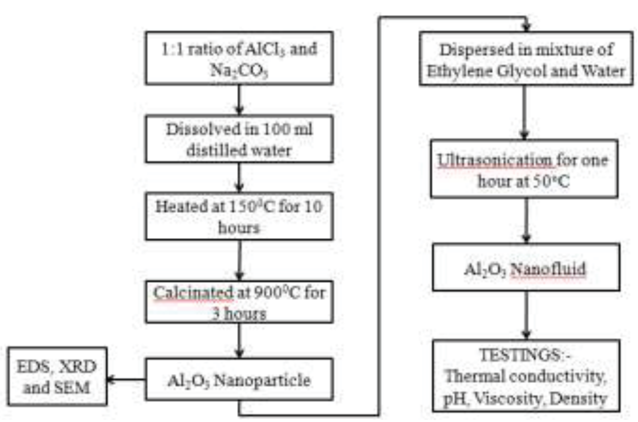



Fig.1.Various steps of in synthesis of $Al_2O_3$-EG-$H_2O$ and $Al_2O_3$-EGnanofluids.

*2.2. Characterization of Nanoparticles*

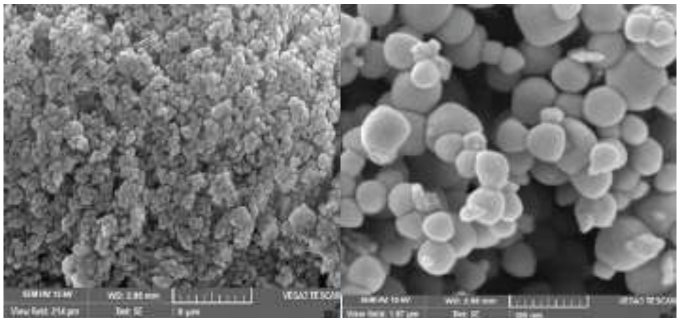


Fig. 2 Surface morphology of the $Al_2O_3$ nanoparticles with respect to two different magnifications

The surface morphology of synthesis alumina particles was shown in figure 2. It clearly shows that present sol-gel produces spherical alumina particle. The particle sizes were analyzed using Image J software. The particles sizes vary between 17 to 46nm and average of 30nm. Figure 3 shows the chemical composition so-gel synthesized $Al_2O_3$ nanoparticle. In addition, of aluminum and oxygen, reasonable quantity of sodium and chlorine was present in the product. It indicates that calcinations temperature or time was not sufficient to remove the unwanted volatile components.

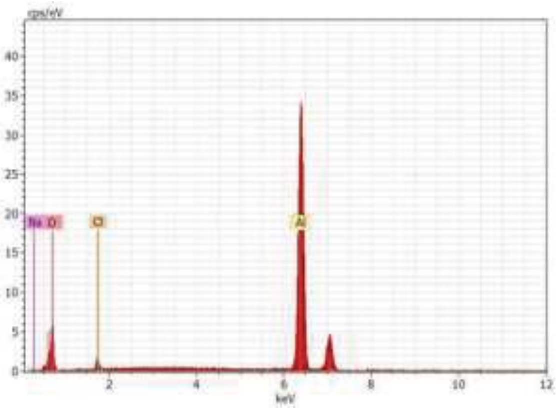



Fig.3Chemical composition of synthesis $Al_2O_3$ nnanoparticles using EDS

Table 1. $Al_2O_3$ Chemical Composition details in percentage

| Element | Weight% | Atomic% |
|---|---|---|
| Al | 46.85 | 39.20 |
| O | 44.83 | 35.24 |
| Na | 5.79 | 21.49 |
| Cl | 2.53 | 4.07 |
| Total | 100.00 | 100.00 |

Thermal conductivity can be measured using thermal property analyzer i.e. KD2 Pro by way of the usage of KS-1 sensor needle. Thermal conductivity of the nanofluid can be measured at specific degrees of temperature such as from 30˚C to 90˚C and information calculated by means of test is mentionedinTable2. Figure 4 show the XRD pattern of $Al_2O_3$ nanoparticles. It also revealed presence of other phases due to sodium and chlorine.

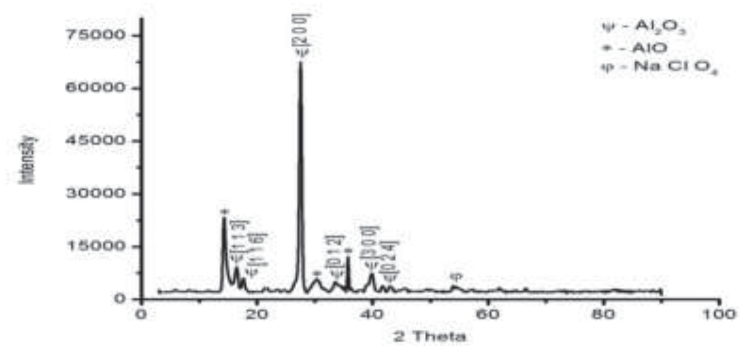



Fig.4. XRD pattern of $Al_2O_3$ Nanoparticle

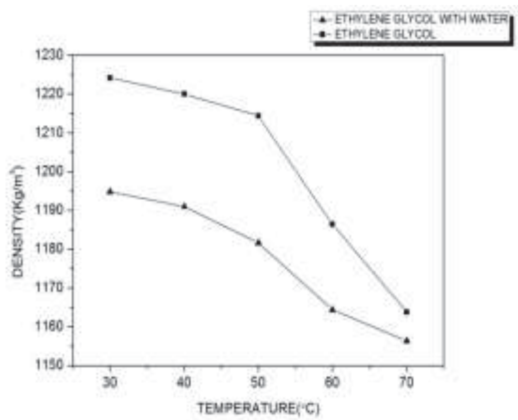
*2.3. Physical Properties of Nanofluids:*

Thermal conductivity can be measured using thermal property analyzer i.e. KD2 Pro by way of the usage of KS-1 sensor needle. Thermal conductivity of the nanofluid can be measured at specific degrees of temperature such as from 30˚C to 90˚C and information calculated by means of test is mentionedinTable.3.

The volume of measured quantity of alumina nanofluid in concentrated and diluted ethylene glycol was measured with the help of gravity bottle at temperature from 30 to 70˚C. The mass (m) of water ($H_2O$), ethylene glycol ($C_2H_6O_2$) and alumina ($Al_2O_3$) were fixed. The density of nanofluid (ρ) is calculated by the formula, which is given below.

$$\rho = \frac{m}{V}$$

Figure 5 shows the measured density of alumina nanofulid in concentrated and diluted ethylene glycol. Due to volume expansion of solution with respect to temperature, density of nano alumina dispersed fluid decreases irrespective of the medium. The atomic mass of ethylene glycol is 3.45 times greater than water. Hence, alumina in diluted ethylene glycol is lower than concentrated ethylene glycol.



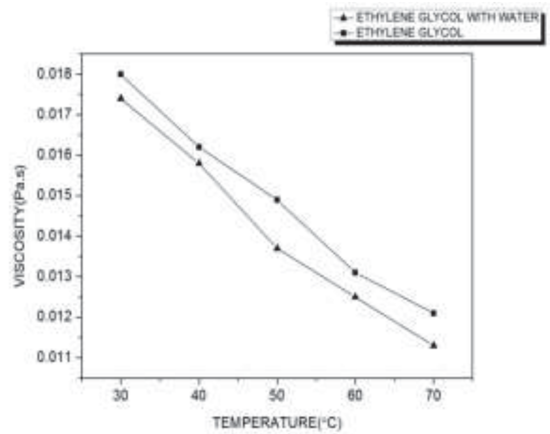




Fig.5Calculated density of $Al_2O_3$-EG-$H_2O$ and $Al_2O_3$-EG

Fig.6. Measured viscosity of of$Al_2O_3$-EG-$H_2O$ and $Al_2O_3$-EG.

Viscosity of concentrated and diluted ethylene glycol based nano fluid compared with respect to temperature between 30˚ to 70˚C. The density and temperature influences the viscosity, which reflects in the figure 6. As the expansion of fluid due to temperature raise, the resistance against the flow falls.

The ethylene glycol pH value lies normally between acidic and neutral such as 8 to 5.5 based on the water content. The measured pHvalueof$Al_2O_3$basednanofluids in the medium of concentrated and diluted ethylene glycol is 9 and 8.5 respectively. It may be due to presence of sodium and chlorine ions also possible in the present scenario.

Thermal conductivity of $Al_2O_3$-EG-$H_2O$and $Al_2O_3$-EGwas compared in figure 7. The standard thermal conductivity of ethylene glycol, water and solid alumina at 25°Cis 0.253, 0.613and 40W/(m.K), respectively [3]. As per rule of mixture, equal preposition of ethylene glycol and water thermal conductivity is 0.433W/(m.K). Hence, ethylene glycol and water based fluid even with small quantity of alumina induces the thermal conductivity. When nano alumina particles were added to fluid, partially the heat energy was absorbed by particles, which impacts on the vibration and diffusion rate of particles in the fluid. In addition, the size and spherical shape of the nanoparticles also soundlessly contributes for thermal conductivity of nanofluids. High fluidity and volume of EG-$H_2O$ fluid significantly raised the diffusion of alumina nano particles which reflects in thermal conductivity. The thermal conductivity efficiency of $Al_2O_3$-EG-$H_2O$ nanofluid as an average of 24% higher than $Al_2O_3$-EG nanofluid.

Using regression analysis, the variation of thermal conductivity (k) as the function of temperature (T) yields the polynomial relationship of second order equations as,

$$k = \alpha + \beta T + \gamma T^2$$

The coefficients α, β and γ for $Al_2O_3$-EG-$H_2O$and $Al_2O_3$-EG are listed in table 2. The deviation around the temperature 50 ° to 70° C may be due to presence of impurity phase present in the nanoparticles. Thermal conductivity purely depends on the nano particle size and the comparison values are listed in table 3.

Table 2. The coefficients α, β and γ for $Al_2O_3$-EG-$H_2O$and $Al_2O_3$-EG

| Nanofluid | Coefficients in W/(m.K) | | | R2 |
|---|---|---|---|---|
| | α | β | γ | |
| $Al_2O_3$-EG-$H_2O$ | 0.6816 | -0.0049 | 0.0001 | 0.9942 |
| $Al_2O_3$-EG | 0.2603 | 0.0048 | 0.00002 | 0.9948 |

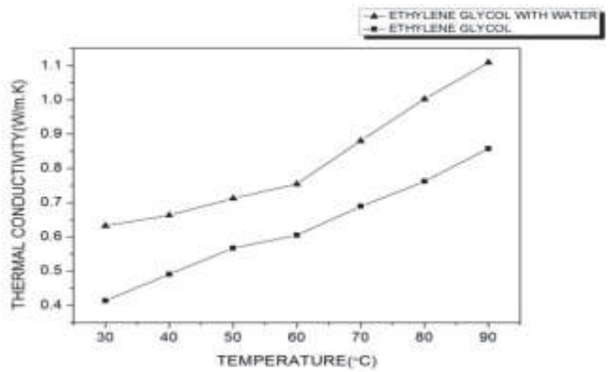



Fig.7.Measured thermal conductivity of $Al_2O_3$-EG-$H_2O$and$Al_2O_3$-EG nanofluid.

### 3. Result and discussion

In the present study, the alumina nano particles was synthesized by using sol gel method. The chemical composition analysis revealed that significant quantity of sodium and chlorine in addition to aluminium and oxygen. It indicates the calcination temperature has to be identified using differential thermal analysis. The thermal conductivity of the nanofiluid is depands on the nano practical size and the average particle size of synthesized $Al_2O_3$ nanoparticles is 30nm. Due to presence of impurities such as Na and Cl, additional phases are identified by XRD analysis. Using ultrasonicator, then a no $Al_2O_3$ particles were dispersed uniformly in ethylene glycol (EG) and ethylene glycol-water (EG-$H_2O$) for synthesis of nanofluid. The nanofluid of $Al_2O_3$-EG-$H_2O$ and $Al_2O_3$-EG properties such as density, viscosity, pH and thermal conductivity with respect to temperature 30°C to 90°C was measured.

Table.3 Thermal conductivity values in different nano particle size

| S.No | Nanofluid Particle | Base fluid | NanoFluid particle Size (nm) | Maximum % of enhancement | References |
|---|---|---|---|---|---|
| 1 | $Al_2O_3$ | Water/EG | 38.4 | 10 | Lee S,ChoiSUS[5] |
| 2 | $Al_2O_3$ | Water/EG | 28 | 16 | WangX,XuX [9] |
| 3 | $Al_2O_3$ | Water/EG | 60.4 | 23 | Xie H,WangJ [23] |
| 4 | $Al_2O_3$ | Water/EG | 38 | 11 | Kim SH [24] |
| 5 | $Al_2O_3$ | Water | 8-282 | 20 | Beck M,YuanY [25] |
| 6 | $Al_2O_3$ | EG | 12-282 | 19 | |
| 7 | $Al_2O_3$ | EG | 17-46 | 24 | Present work |

### 4. Conclusion

The following conclusions are derived from the observations.

- As expected, density and viscosity of nanofluids are decreases with temperature. The nanofluid $Al_2O_3$-ethylene glycol-water mixture nanofluid has low density and viscosity compared to $Al_2O_3$- ethylene glycol irrespective of temperature due to physical properties of water.
- Thermal conductivity of $Al_2O_3$-ethylene glycol-water mixture nanofluid has higher thermal conductivity than $Al_2O_3$-ethylene glycol due to density, viscosity, particle size and shape.

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