

# Experimental Study of Thermophysical Properties of Al<sub>2</sub>O<sub>3</sub>/Water Nanofluid

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## Abstract

Nanofluids are a new class of solid-liquid composite materials consisting of solid nanoparticles, with sizes typically on the order of 1–100 nm, suspended in a heat transfer liquid. In recent years nanofluids have attracted great interest owing to their greatly enhanced thermal properties. The experimental work has been done at different temperature range (30 to 80°C) with varying different volume concentration (0.1%, 0.2%, 0.5%), 20nm size of Al<sub>2</sub>O<sub>3</sub> nanoparticle in base fluid water to study the behaviour of thermophysical properties of nanofluid and compare with the base fluid.

## Keywords

Viscosity, Nanoparticles, Thermal Conductivity, Specific Heat

## I. Introduction

Nanofluids (nanoparticles fluid suspension) is the term coined by Choi et al. [1] to describe this new class of nanotechnology based heat transfer fluids that exhibit thermal properties superior to those of their host fluids. Nanofluids are suspension of metallic or metal-oxide solid nano particles with size varying generally from 1 to 100 nm, dispersed in conventional liquids such as water, ethylene glycol and engine oils etc. Nanofluid technology, a new interdisciplinary field of great importance where nanoscience, nanotechnology and thermal engineering meet. The goal of Nanofluids is to achieve the highest possible thermal properties at the small possible concentration (preferably less than 1% by volume) by uniform dispersion and stable suspension of nanoparticles (preferably less than 10 nm) in host fluids. Nanofluids (nanoparticle, fluid suspensions) is the term developed by Choi to describe the new class of nanotechnology based heat transfer fluids that exhibit thermal properties superior to those of their host fluids or conventional particle fluid suspensions. Nanofluids have unique features different from conventional solid liquid mixtures in which mm or μm sized particles of metals and non metals are dispersed. Due to their excellent characteristics, nanofluids find wide applications in the area of heat transfer technology. Nanofluid technology becomes a new challenge for the heat transfer fluid since it has been reported by Tavman et al. [2] that the thermal conductivity of nanofluid is anomalously enhanced at a very low volume fraction.

This group observed an increase up to approximately two times in the thermal conductivity of the fluid by the addition of a nanoparticles less than 1% volumetric concentration. The effect of particle inclusions on the effective thermal conductivity of liquid has attracted a great interest experimentally and theoretically. Very recently S.K Das et al. [3], Xie. et al. [4] provides a detailed literature review of nanofluids synthesis, applications, experimental and analytical analysis of effective thermal conductivity, viscosity, specific heat. There are also various potential advantages from nanofluid testing namely better long-term stability and thermal conductivity compared to millimeter or even micrometer sized particle suspensions and less pressure drop and erosion particularly in micro channels. Though, there are still major application

prospects in advanced thermal applications, they remain in the early stages of development prospects in advanced thermal applications, The objective of this experimental study is to discuss the dependence of thermal conductivity viscosity, density and specific heat of Al<sub>2</sub>O<sub>3</sub>-water in temperature ranges from (30–80°C) under different volume concentrations of nanoparticles from (0.1, 0.2 & 0.5%) subsequent sections the preparation and characterization of nanofluids along with results have been discussed in detail.

## II. Preparation of Nanofluid

In general, there are two methodologies used to produce nanofluids, namely the single-step method, where nanoparticles are produced and dispersed simultaneously into the base fluid, and the two-step method, where the two aforementioned processes are accomplished separately. Wang et al. [5], Zhu et al. [6] suggests that A single-step method is usually employed for metal nanofluid preparation In this method nanoparticle manufacturing and nanofluid preparation are done concurrently. The single-step method is a process combining the preparation of nanoparticles with the synthesis of nanofluids, for which the nanoparticles are directly prepared by Physical Vapor Deposition (PVD) technique or a liquid chemical method (condensing nanophase powders from the vapor phase directly into a flowing low-vapor-pressure fluid is called VEROS), while a two step method applies better for nanofluids containing oxide nanoparticles. The main advantage of the single-step technique is the minimization of nanoparticle agglomeration. In this method, dry nanoparticle are first produced, and then they are dispersed in a suitable liquid host, but as nanoparticles have a high surface energy, aggregation and clustering are unavoidable and will appear easily. Afterward, the particles will clog and sediment at the bottom of the container. Thus, making a homogeneous dispersion by two step method remains a challenge. In the two step methods low agglomeration and stabilization of the nanofluid are the major concerns. To produce an even and stable suspension several techniques are applied, such as use of ultrasonic equipment, pH control or addition of stabilizers. The material of nanoparticles is chosen as Al<sub>2</sub>O<sub>3</sub> because it is chemically more stable and its cost is less than their metallic counterparts and also it is easily available. Al<sub>2</sub>O<sub>3</sub>/water nanofluid is prepared by two step method.

Table 1: Properties of Nanoparticle

Particle	Aluminium Oxide Nanopowder (Al <sub>2</sub> O <sub>3</sub> (Gamma))
Avg. particle dia	20 nm (gamma)
Density	3880 Kg/m <sup>3</sup>
Purity	99.99 %

## III. Particle Size Characterisation

Imaging analysis of nanofluids is done using electron microscope (TEM, TEM being preferred over SEM for nanofluids) and most of the reported studies makes use of TEM for characterising

nanofluids. Cryogenic transmission electron microscopy might provide a powerful characterisation method, but few laboratories are equipped to apply this technique Hunter [7]. Several (more than 6) different places are observed and averaged information is obtained and analyzed. The stable nanofluids have different shapes after preparation as are shown in TEM image.

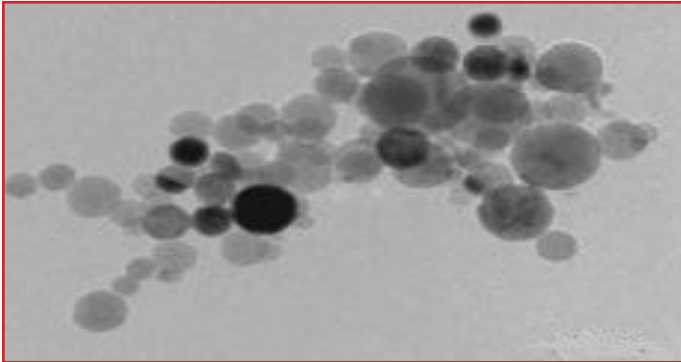


Fig. 1: TEM Photograph of Al<sub>2</sub>O<sub>3</sub> Nanoparticles

#### IV. Thermal Characterisation of Nanofluids

The thermal physical properties of Al<sub>2</sub>O<sub>3</sub>/water nanofluid is find out experimentally with different equipments.

##### A. Thermal Conductivity

There are so many method to find out the thermal conductivity of nanofluid transient hot-wire method, KD2 Pro method Fei Duan [8], Murshed et al.[9] But KD2 is the best suited method for measuring thermal conductivity. The thermal conductivity is measured by using a KD2 Pro thermal properties analyzer (Decagon Devices, Inc., USA). It consists of a handheld microcontroller and sensor needles. The KD2's sensor needle contains both a heating element and a thermistor. At the end of the reading, the controller computes the thermal conductivity using the change in temperature (T) – time data from

$$k = \frac{q (\ln t_2 - \ln t_1)}{4\pi (\Delta T_2 - \Delta T_1)}$$

Where, q is constant heat rate applied to an infinitely long and small line source in W/m<sup>2</sup>.

##### B. Viscosity

DV-III Ultra Viscometer is used for measuring viscosity of nanofluids. It contains of a small adaptor and adapter further consists of a cylindrical sample holder, a water jacket and a spindle. The viscometer drives the spindle immersed into the sample holder containing the test fluid sample. It measures viscosity by measuring the viscous drag of the fluid against the spindle when it rotates Eastman et al.[10], Chandrasekar et al.[11]. The spindle CPE-42 is used. The sample holder can hold a small sample volume of 1 mL and the temperature of the test sample is monitored by a temperature sensor embedded into the water bath. Other equipment used is sonicator, which sonicate the solution by using ultrasonic vibrations.

##### C. Specific Heat

A heat flux type differential calorimeter is used (TA DSC Q20) is used to measure the specific heat capacity of nanofluid. DSC, is a thermal analysis technique that looks at how a material's heat capacity (Cp) is changed by temperature. A sample of known mass is heated or cooled and the changes in its heat capacity are

tracked as changes in the heat flow Harryet al.[12]. The term differential scanning calorimeter refers to both the technique of measuring calorimetric data while scanning as well as a specific instrument design. The technique can be carried out with other types of instruments. Range of DSC is (-50 to 350°C).

##### D. Specific Gravity Bottle

Specific gravity bottle or Pycnometer is used to measure the density of any fluid. Relative density or specific gravity is the ratio of the density (mass of a unit volume) of a substance to the density of a given reference material. Specific gravity usually means relative density with respect to water. Relative Density (RD) or Specific Gravity (SG) is a dimensionless quantity, as it is the ratio of either densities or weights.

$$RD = \frac{\rho_{\text{substance}}}{\rho_{\text{reference}}}$$

A specific gravity bottle holds a known volume of liquid at a specified temperature. The bottle is weighed, filled with a liquid whose specific gravity is to be found and then again weighed. The difference in weights is divided by the weight of an equal volume of water to give the specific gravity of the liquid.



Fig. 2: KD2 Pro Thermal Property Analyzer



Fig. 3: DV-III Brookfield Viscometer Measurement



Fig. 4: Differential Scanning Calorimeter (TA DSC Q20)



Fig. 5: Specific Gravity Bottle

Following is the procedure adopted to do the experiments with water as the base fluid.

1. The weight measurement of  $Al_2O_3$  nanoparticles is done to calculate its volume fraction.
2.  $Al_2O_3$  -water is sonicated for 3 hours and checked for any settling of nanoparticles.
3. Thermal conductivity is measured at required temperature by taking nanofluid in test tube and dip KS1 needle of KD2 pro in it properly.
4. Measurement of viscosity is done with sample in Viscometer (Brookfield DV-III Rheometer) and in the temperature range from 20-500C.
5. Viscosity is measured by changing the r.p.m of the motor from 20 to 70.
6. Specific heat of nanofluid is measured with Differential Scanning calorimeter (TA DSC Q20).
7. Density of nanofluid is measured with Specific gravity bottle.

**V. Results And Discussion**

Various experiments are performed thesis work with the help of various apparatus and techniques as mentioned above. Thermal conductivity of nanofluid is measured by KD2 PRO with KS1 sensor needle is preferred for low viscosity fluid at different ranges of temperatures from volume(0.1%,0.2%,0.5%concentration)at (30 to 80°C) From fig. 5, 6, it can be conclude that thermal conductivity of nanofluids increases with increase in temperature. As well as with increase in concentrations of particles. The thermal conductivity of nanofluid is more than the base fluid (water).The measurement shows that particle concentration and temperature

are the major parameters of thermal conductivity. Viscosity of the nanofluids used in the experiment is measured by the Cone and Plate type Brookfield programmable viscometer (model: LVDV-III-Pro) connected to a temperature controlled bath which can vary the fluid temperature between -10 and 100°C with the spindle used in the setup is CPE-42. But the range of temperature for nanofluid  $Al_2O_3$ /water is 30 to 80°C. From the fig. 6 the above data it seems that viscosity is gradually decreased with increase in temperature as well as with increase in nanoparticle volume fraction. As compared with the viscosity of nanofluids with water, It shows that nanofluids becomes less viscous than water. From fig. 7 Specific heat decreases with the concentration as increases. (0.1 to 0.5%). The fig. 5.5 shows the behaviour of density of nanofluid  $Al_2O_3$ /water at different concentration 0.1%, 0.2%, 0.5%. The graphical data shows that the temperature has also impact on density of nanofluid. Density of  $Al_2O_3$ /water nanofluid is higher than the base fluid (water) and with increase of temperature, density of nanofluid goes on decreasing. Further if nanoparticle volume concentration increases from 0.1% to 0.5% density is increased.

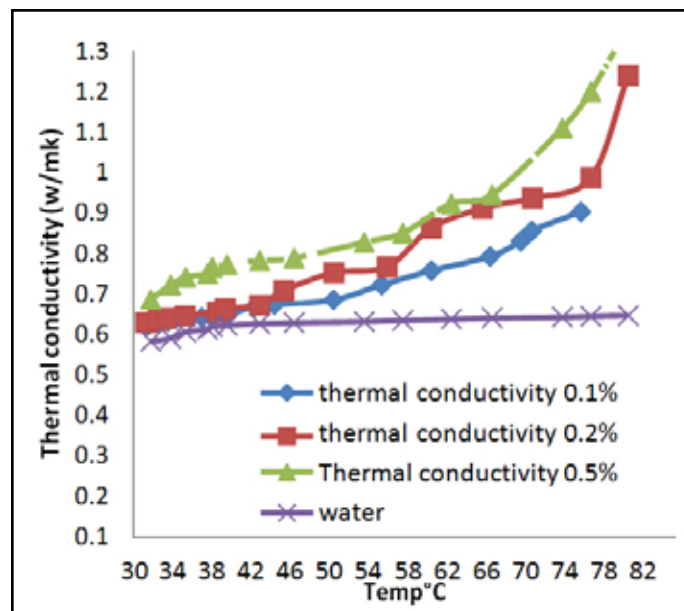


Fig. 6: Thermal Conductivity V/s Temperature

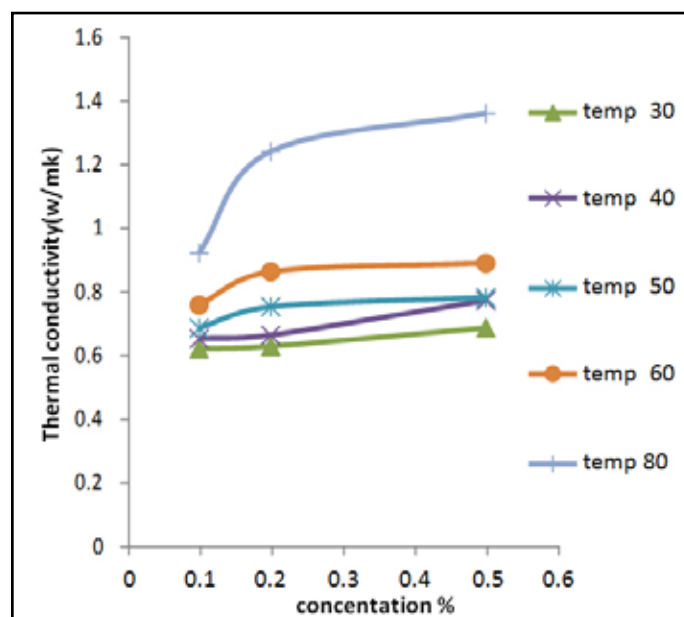


Fig. 7: Thermal Conductivity V/s Concentration

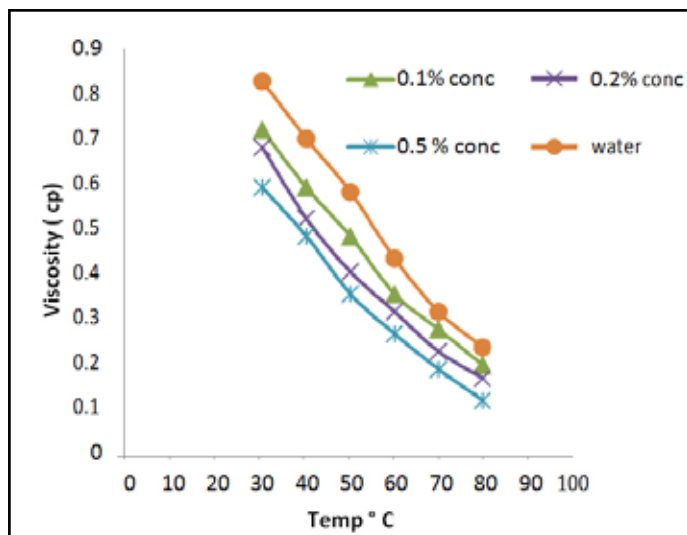


Fig. 8: Viscosity V/s Temp at Different Concentration

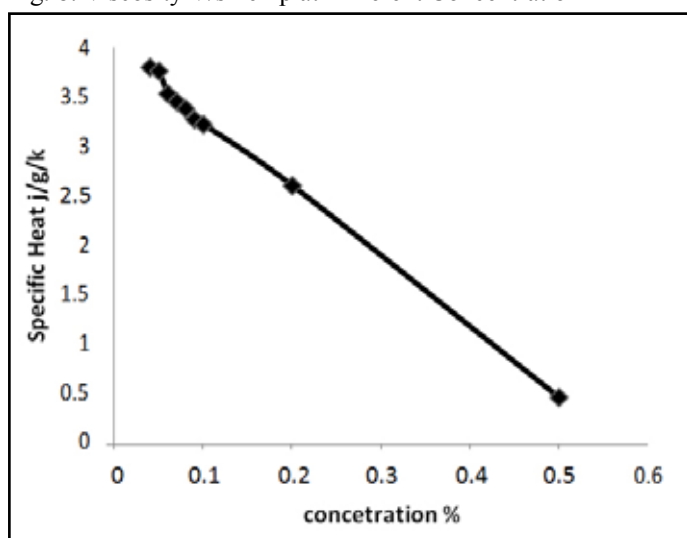


Fig. 9: Variation of Specific Heat V/s Concentration

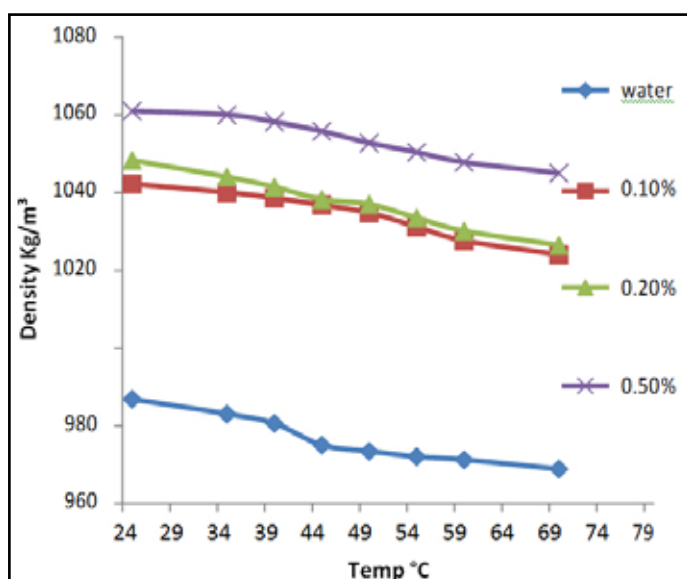


Fig. 10: Variation of Density V/s Temperature

## VI. Conclusion

It is observed that the thermal conductivity of water is not much change with temperature. As we go for higher concentration (0.1 to 0.5%), the thermal conductivity increases but at temperature 54°C drop in conductivity is observed. It is found that the thermal

conductivity increases significantly with the nanoparticle volume fraction. With an increase of temperature, the thermal conductivity increases for a certain volume concentration of nanofluids, but the viscosity decreases. The temperature and volume fractions have significant effects on the thermal conductivity and viscosities are investigated. Addition of small amount of alumina nanoparticles transforms the Newtonian behaviour of nanofluid to a non-Newtonian fluid and it behaves as Bingham plastic with small yield stress. Viscosity of nanofluid ( $\text{Al}_2\text{O}_3/\text{water}$ ) is less than base fluid water. Specific heat of nanofluid decreases with the concentration as increases. (0.1 to 0.5%). Density of nanofluid ( $\text{Al}_2\text{O}_3/\text{water}$ ) decreases with temperatures but the density of nanofluid is higher than base fluid's density. The density of nanofluid increases with concentrations.

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