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Investigation of Thermo-Physical Properties of Al2O3/Water Nanofluid-An Experimental Study

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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 Al2O3 nanoparticle in base fluid water to study the behavior of thermos physical 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 coinedby Choi et al.[1] to describe this new class of nanotechnologybased heat transfer fluids that exhibit thermal properties superiorto those of their host fluids. Nanofluids are suspension of metallicor metal-oxide solid nano particles with size varying generallyfrom 1 to 100 nm, dispersed in conventional liquids such as water,ethylene glycol and engine oils etc. Nanofluid technology,a newinterdisciplinary field of great importance where nanoscience,nanotechnology and thermal engineering meet. The goal ofNanofluids is to achieve the highest possible thermal propertiesat the small possible concentration (preferably less than 1%by volume) by uniform dispersion and stable suspension ofnanoparticles (preferably less than 10 nm) in host fluids .Nanofluids(nanoparticle, fluid suspensions) is the term developed by choito describe the new class of nanotechnology based heat transferfluids that exhibit thermal properties superior to those of their hostfluids or conventional particle fluid suspensions.Nanofluids haveunique features different from conventional solid liquid mixturesin which mm or µm sized particles of metals and nonmetals aredispersed. Due to their excellent characteristics, nanofluids findwide applications in the area of heat transfer technology. Nanofluidtechnology becomes a new challenge for the heat transfer fluidsince it has been reported by Tavman et al. [2] that the thermalconductivity of nanofluid is anomalously enhanced at a very lowvolume fraction.This group observed an increase up to approximately two timesin the thermal conductivity of the fluid by the addition of ananoparticles less than 1% volumetric concentration.The effect ofparticle inclusions on the effective thermal conductivity of liquidhas attracted a great interest experimentally and theoretically. Veryrecently S.K Das et al.[3], Xie. et al.[4] provides a detailed literaturereview of nanofluids synthesis, applications, experimental andanalytical analysis of effective thermal conductivity, viscosity,specific heat. There are also various potential advantages fromnanofluid testing namely better long-term stability and thermalconductivity compared to millimeter or even micrometer sizedparticle suspensions and less pressure drop and erosion particularlyin micro channels. Though, there are still major applicationearly stages of development prospects in advanced thermalapplications, The objective of this experimental study is to discussthe dependence of thermal conductivity viscosity, density andspecific heat of Al2O3–water in temperature ranges from (30-80°C) under different volume concentrations of nanoparticlesfrom(0.1, 0.2 & 0.5%) subsequent sections the preparationand characterization of nanofluids along with results have beendiscussed in detail.

II. PREPARATION OF NANOFLUID

In general, there are two methodologies used to produce nanofluids,namely the single-step method, where nanoparticles are producedand dispersed simultaneously into the base fluid, and the two-stepmethod, where the two aforementioned processes are accomplishedseparately. Wang et al.[5], Zhu et al.[6] suggests that A single-stepmethod is usually employed for metal nanofluid preparation In thismethod nanoparticle manufacturing and nanofluid preparation aredone concurrently. The single-step method is a process combiningthe preparation of nanoparticles with the synthesis of nanofluids,for which the nanoparticles are directly prepared by PhysicalVapor Deposition (PVD) technique or a liquid chemical method(condensing nanophasepowders from the vapor phase directlyinto a flowing low-vapor–pressure fluid is called VEROS)., whilea twostep method applies better for nanofluids containing oxidenanoparticles. The main advantage of the single-step technique isthe minimization of nanoparticle agglomeration. In this method,dry nanoparticle are first produced, and then they are dispersedin a suitable liquid host, but as nanoparticles have a high surfaceenergy, aggregation and clustering are unavoidable and willappear easily. Afterward, the particles will clog and sediment at thebottom of the container. Thus, making a homogeneous dispersionby two step method remains a challenge. In the two step methodslow agglomeration and stabilization of the nanofluid are the majorconcerns. To produce an even and stable suspension severaltechniques are applied, such as use of ultrasonic equipment, pHcontrol or addition of stabilizers. The material of nanoparticles ischosen as Al2O3 because it is chemically more stable and its cost isless than their metallic counterparts and also it is easily available.Al2O3/water nanofluid is prepared by two step method.

Table 1: Properties of Nanoparticle

Particle	Aluminium Oxide Nanopowder (Al2O3)(Gamma)
Avg. particle dia	20 nm (gamma)
Density	3880 Kg/m3
Purity	99.99 %

III. PARTICLE SIZE CHARACTERIZATION

Imaging analysis of nanofluids is done using electron microscope(TEM, TEM being preferred over SEM for nanofluids) and mostof the reported studies makes use of TEM for characterizing nanofluids. Cryogenic transmission electron microscopy mightprovide a powerful characterization method, but few laboratoriesare equipped to apply this technique Hunter [7]. Several (morethan 6) different places are observed and averaged informationis obtained and analyzed. The stable nanofluids have differentshapes after preparation as are shown in TEM image.

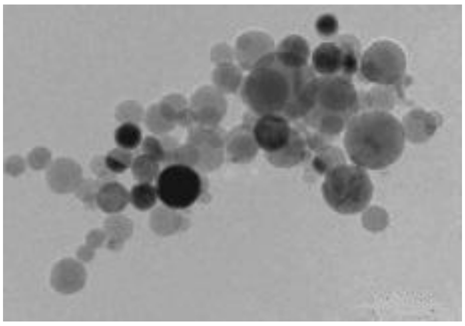

Fig. 1: TEM Photograph of Al2O3 Nanoparticles

IV. THERMAL CHARACTERISATION OF NANOFLUIDS

The thermal physical properties of Al2O3/water nanofluid is findout experimentally with different equipments.

A. Thermal Conductivity

There are so many method to find out the thermal conductivityof nanofluid transient hot-wire method, KD2 Pro method FeiDuan [8],Murshed et al.[9] But KD2 is the best suited methodfor measuring thermal conductivity. The thermal conductivity ismeasured by using a KD2 Pro thermal properties analyzer (DecagonDevices, Inc., USA). It consists of a handheld microcontroller andsensor needles. The KD2's sensor needle contains both a heatingelement and a thermistor. At the end of the reading, the controllercomputes the thermal conductivity using the change in temperature(T) – time data from

B. Viscosity

DV-III Ultra Viscometer is used for measuring viscosity ofnanofluids. It contains of a small adaptor and adapter furtherconsists of a cylindrical sample holder, a water jacket and a spindle.The viscometer drives the spindle immersed into the sample holdercontaining the test fluid sample. It measures viscosity by measuringthe viscous drag of the fluid against the spindle when it rotatesEastman et al.[10], Chandrasekar et al.[11]. The spindle CPE-42is used. The sample holder can hold a small sample volume of1 mL and the temperature of the test sample is monitored by atemperature sensor embedded into the water bath. Other equipmentused is sonicator, which sonicate the solution by using ultrasonicvibrations.

C. Specific Heat

A heat flux type differential calorimeter is used (TA DSC Q20) isused to measure the specific heat capacity of nanofluid. DSC, isa thermal analysis technique that looks at how a material's heatcapacity (Cp) is changed by temperature. A sample of knownmass is heated or cooled and the changes in its heat capacity aretracked as changes in the heat flow Harryet al.[12]. The termdifferential scanning calorimeter refers to both the technique ofmeasuring calorimetric data while scanning as well as a specificinstrument design. The technique can be carried out with othertypes of instruments. Range of DSC is (-50 to 350°C).

D. Specific Gravity Bottle

Specific gravity bottle or Pycnometer is used to measure thedensity of any fluid. Relative density or specific gravity is theratio of the density (mass of a unit volume) of a substance to thedensity of a given reference material. Specific gravity usuallymeans relative density with respect to water. Relative Density(RD) or Specific Gravity (SG) is a dimensionless quantity, as itis the ratio of either densities or weights. A specific gravity bottle holds a known volume of liquid at aspecified temperature. The bottle is weighed, filled with a liquidwhose specific gravity is to be found and then again weighed. Thedifference in weights is divided by the weight of an equal volumeof water to give the specific gravity of the liquid.

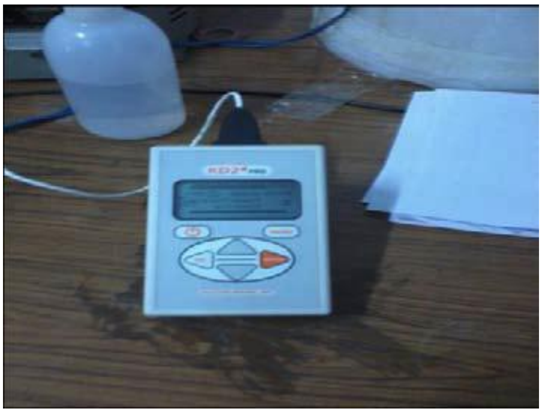

Fig. 2: KD2 Pro Thermal Property Analyzer

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 withwater as the base fluid.
1. The weight measurement of Al2O3 nanoparticles is done tocalculate its volume fraction.
2. Al2O3 -water is sonicated for 3 hours and checked for anysettling of nanoparticles.
3. Thermal conductivity is measured at required temperatureby taking nanofluid in test tube and dip KS1 needle of KD2pro in it properly.
4. Measurement of viscosity is done with sample in Viscometer(Brookfield DV-III Rheometer) and in the temperature rangefrom 20-500C.
5. Viscosity is measured by changing the r.p.m of the motorfrom 20 to 70.
6. Specific heat of nanofluid is measured with DifferentialScanning calorimeter (TA DSC Q20).
7. Density of nanofluid is measured with Specific gravitybottle.

V. RESULTS AND DISCUSSION

Various experiments are performed thesis work with the help ofvarious apparatus and techniques as mentioned above. Thermalconductivity of nanofluid is measured by KD2 PRO with KS1sensor needle is preferred for low viscosity fluid at differentranges 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 thermalconductivity of nanofluids increases with increase in temperature as well as with increase in concentrations of particles. The thermalconductivity of nanofluid is more than the base fluid (water).Themeasurement shows that particle concentration and temperature are the major parameters of thermal conductivity. Viscosity of thenanofluids used in the experiment is measured by the Cone andPlate type Brookfield programmable viscometer (model: LVDVIII-Pro) connected to a temperature controlled bath which canvary the fluid temperature between -10 and 100°C with the spindleused in the setup is CPE-42. But the range of temperature fornanofluid Al2O3/water is 30 to 80°C. From the fig. 6 the abovedata it seems that viscosity is gradually decreased with increasein temperature as well as with increase in nanoparticle volumefraction. As compared with the viscosity of nanofluids with water,It shows that nanofluids becomes less viscous than water. Fromfig. 7 Specific heat decreases with the concentration as increases.(0.1 to 0.5%). The fig. 5.5 shows the behavior of density ofnanofluid Al2O3/water at different concentration 0.1%, 0.2%,0.5%. The graphical data shows that the temperature has alsoimpact on density of nanofluid. Density of Al2O3/water nanofluid ishigher than the base fluid (water) and with increase of temperature;density of nanofluid goes on decreasing. Further if nanoparticlevolume concentration increases from 0.1% to 0.5% density isincreased.

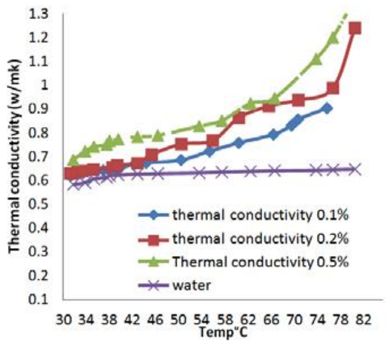

Fig. 6: Thermal Conductivity V/s Temperature

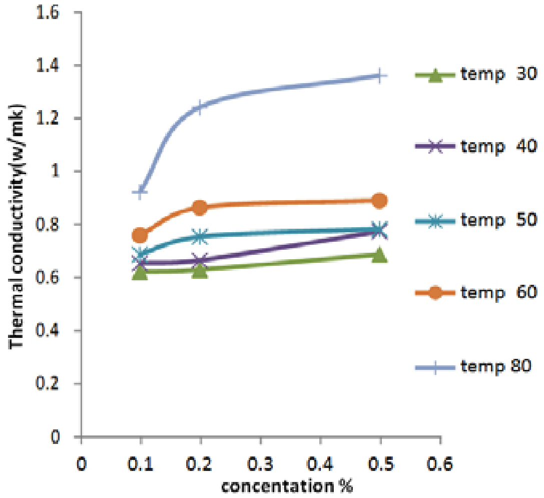

Fig. 7: Thermal Conductivity V/s Concentration

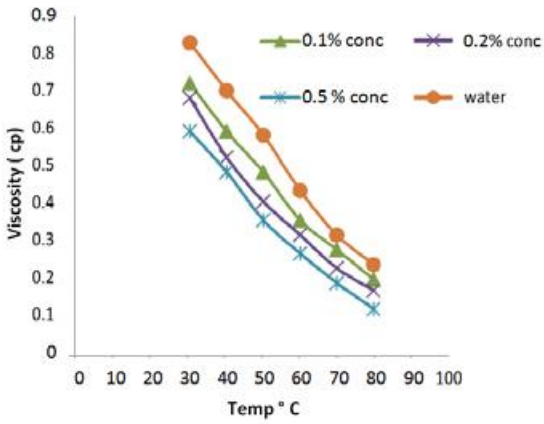

Fig. 8: Viscosity V/s Temp at Different Concentration

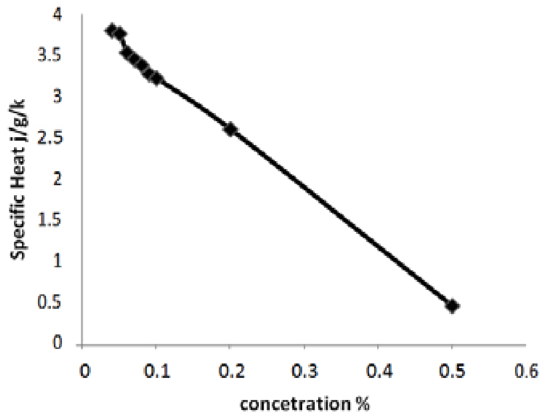

Fig. 9: Variation of Specific Heat V/s Concentration

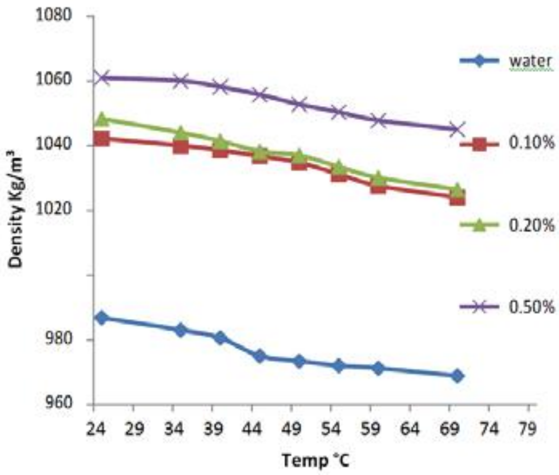

Fig. 10: Variation of Density V/s Temperature

VI. CONCLUSION

It is observed that the thermal conductivity of water is not muchchange with temperature. As we go for higher concentration (0.1to 0.5%).the thermal conductivity increases but at temperature54°C drop in conductivity is observed. It is found that the thermal conductivity increases significantly with the nanoparticle volumefraction. With an increase of temperature, the thermal conductivityincreases for a certain volume concentration of nanofluids, but theviscosity decreases. The temperature and volume fractions havesignificant effects on the thermal conductivity and viscosities areinvestigated. Addition of small amount of alumina nanoparticlestransforms the Newtonian behavior of nanofluid to a non-Newtonian fluid and it behaves as Bingham plastic with small yieldstress. Viscosity of nanofluid (Al2O3/water) is less than base fluidwater.Specific heat of nanofluid decreases with the concentrationas increases. (0.1 to 0.5%). Density of nanofluid (Al2O3/water)decreases with temperatures but the density of nanofluid is higherthan base fluid's density.The density of nanofluid increases withconcentrations.

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