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COMPARATIVE STUDY OF VARIOUS THERMO-PHYSICAL PROPERTIES OF METALLIC & OXIDES NANOFLUIDS

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ABSTRACT
Development of Energy efficient fluids for various heating or cooling systems is one of the major reqirement for vigorously growing technology. Suspension of nano sized (usually 0-100 nm) particles into base fluids is termed as Nanofluid, a new trend of heat transfer fluids for various thermal applications. Due to enhanced thermal conductivity over conventional fluids, they became panacea for heat transfer applications. Since the metals have high thermal conductivity as compared to metal oxides, the metallic nanofluids shows superior thermal performance comparatively. In present work, Nanofluids of 0.1%(Vol.) concentration were prepared using Aluminium Oxide nanoparticles and Aluminium nanoparticles in double distilled water. Various thermo physical properties of these two nanofluids was measured at different temperature values. It was shown that the thermal conductivity of Al/water is around 47 % higher than Al2O3/water nanofluids at temperature around 60°C which makes Al/water nanofluids more feasible for high energy density applications.

KEYWORDS: Alumina, Aluminium , Nanofluids, Thermal conductivity.

INTRODUCTION
Conventional heat transfer fluids such as water, oil, and ethylene glycol cooperate a crucial function in numerous industrial applications, power plants , chemical industries, automobile cooling system, and electronic devices. Poor heat transfer performance of these conservative fluids affects the augmentation of performance and consequently the compactness of heat exchange devices. Lower thermal conductivity of conventional fluids used in various thermal systems is one of the major limitation in development of high performance heat transfer equipments and in achieving their miniaturization. In the development of energy efficient fluids, thermal conductivity plays a vital role. Nanofluids are a new window opened by choi et al.[1] in 1995, the suspension of nano sized particles into base fluids, having higher thermal conductivity as compared to conventional fluids. There are numerous attractive features of nanofluids as compared to fluids prepared by milli or micro sized particles. Nanofluid are comparatively more stable, very little pressure drop and less agglomeration problem[2]. It was discussed by Stephen et al.[3] that the metallic nanofluids have much higher thermal conductivity as compared to non metallic nanofluids. Since the thermal conductivity of metallic nanoparticles is much higher than oxide nanoparticles, it is obvious that metallic nanofluids possesses greater thermal conductivity comparatively. Thermal conductivity of various materials is tabulated in Table1. as given by stephen et al. [3] The thermal conductivity of nanofluids is strongly depends on particle concentration as compared to that of the base fluid. subsequently, the thermal conductivity augmentation of nanofluids is strongly dependent on temperature. Recently the thermal conductivity enhancement is investigated by numerous researchers and found that the thermal conductivity of the nanofluids has increased more than 20% even at small nanoparticle concentrations.[4].

Table.1: Thermal conductivity of various materials at 300K Unless otherwise noted

Materials		Thermal Conductivity (W/mK)
Metallic Solids	Silver	429
	Copper	401
	Aluminum	237

Non-metallic Solids	Silicon	148
Metallic Liquids	Sodium @644K	72.3
Non-metallic Liquids	Water Engine Oil	0.613 0145

A exhaustive learning of the thermo physical properties such as thermal conductivity, density and viscosity is essential for the development of energy-efficient heat transfer fluids. Nanofluids have unique features which are significantly different form conventional heat transfer fluids prepared by millimeter or micrometer sized particles. Chon et al. [5] showed by experiments that the Brownian motion of nanoparticles is essential for thermal conductivity augmentation with increasing temperature and falling nanoparticle sizes. The intent of nanofluid technology is to accomplish the maximum realizable thermal properties at the smallest amount of possible concentrations [6]. The thermal conductivity of nanofluids significantly reliant on its temperature, increase in temperature outcome higher thermal conductivity, which makes nanofluids more valuable for high energy-density applications. Juneja et al. [7] uncovered that thermal conductivity improved with temperature but there was major drop in viscosity and density. Das et al. [8] exposed that thermal conductivity of nanofluids improved two to four times when temperature increases from 21˚C to 51˚C. Thermal conductivity is also sturdily depends upon particle size. Honorine et al. [9] also showed that relative augmentation in thermal conductivity is more important at high temperatures and small particle diameter.

Temperature dependence of viscosity is such that it is additional as compared to base fluid which reduce the effectiveness of nanofluids in practical applications but as temperature increases viscosity of nanofluids decreases. Viscosity also depends upon particle concentration. Murshed et al. [10] recommended that understanding of temperature dependency of thermal conductivity and viscosity of nanofluid is decisive.

Density of the nanofluid slightly decreases with increase in temperature of the mixture. Vajja et al. [11] showed that at 1% (Vol.) concentration of Al2O3 nanofluid in 60:40 EG/W mixture, there is 2.51% decrement in density when temperature of fluid increases from 0˚C to 50˚C. Kamaldeep et al. [12] showed that Density of Al2O3/water nanofluid reduces with temperatures but the density of nanofluid is superior than water's density. Density have linear relationship with particle volume concentrations.

EXPERIMENTAL WORK

Preparation of Nanofluids

The optimization of nanofluid thermal properties needs booming manufacture techniques for producing stable suspensions of nanoparticles in host fluids [13]. There are two methods for nanofluid preparation namely single-step method and Two-step method. In single-step method, preparation of nanoparticles and their dispersion in host fluid are completed simultaneously. While, in two-step method first the nanoparticles are prepared using suitable nanoparticle processing technique and then they are dispersed in base fluid.

Al/Water and Al2O3/Water nanofluid was prepared using two-step method. Double distilled water in a beaker was placed on a hot plate magnetic stirrer (Fig.2) and then nano-powder in required amount for 0.1% (Vol.) concentration in 25ml solution, was slowly poured into the beaker. Nanoparticles were mixed with double distilled water by magnetic stirrer for 30 minutes. Further, to reduce the particle agglomeration and to prepare more stable nanofluids, the solution was placed in Ultrasonic water bath (Fig.3) for 2 hours.

Surfactants are mostly added to make stable nanofluids [14] .CTAB surfactant was added in same amount that of nano-powder, which provides more dispersed and stable solution. Oxide nanofluid, generally does 'not requires surfactant.

Figure.1: Magnetic stirrer with hot plate

Figure.2: Ultrasonicator Water Bath

MEASUREMENT OF THERMAL CONDUCTIVITY OF NANOFLUID

Thermal conductivity of both nanofluids of 0.1% (Vol.) concentration was measured at different temperatures. Various methods are available for thermal conductivity measurement, like; transient hot wire method [15], temperature oscillation method [16] etc.

Thermal conductivity of nanofluids was measured using KD2 Pro thermal property analyzer (Decagon Devices, Inc., USA) shown in Fig.3.

Figure.3: KD2 Pro with KS-1 needle

KD2 Pro comprises of sensor needles and hand-operated micro-controller. Sensor consists of thermostat and a heating element. To measure the thermal conductivity of fluids of range 0.2-2.0 W/mK, KS-1 needle can be used, having accuracy of ±0.5%. Thermal conductivity of nanofluids was measured at different temperatures, which was controlled by PID controller. One experimental cycle was accomplished in 90 sec. For first 60 sec. needle equilibrate to the surrounding fluid temperature. Then, for 30 sec. heating and cooling of sensor needle takes place. KD2 Pro gives the thermal conductivity values using the following formula,

$$K = \frac{q(\ln t_2 - \ln t_2)}{4\pi(\Delta T_2 - \Delta T_1)} \qquad \ldots (1)$$

Where, K is the thermal conductivity, q is the constant heat rate supplied to an infinitely long and small line source. ΔT_1 & ΔT_2 are the temperature changes at time t_1 and t_2 respectively.

MEASUREMENT OF DENSITY OF NANOFLUID

Density of prepared nanofluids was measured using Pycnometer (Fig.4) or specific gravity bottle. Ratio of density of any fluid to density of distilled water at 4^0C temperature is termed as specific gravity. Pycnometer holds a specific volume at a particular temperature. There is a capillary hole in the closely fixed ground glass cork of Pycnometer. Extra liquid is released from the capillary for top filled bottle and remaining liquid's volume and weight was measured. Now weight of empty bottle is measured, the difference in weight is divided by the weight of distilled water of equal volume, which will give specific gravity of given liquid.

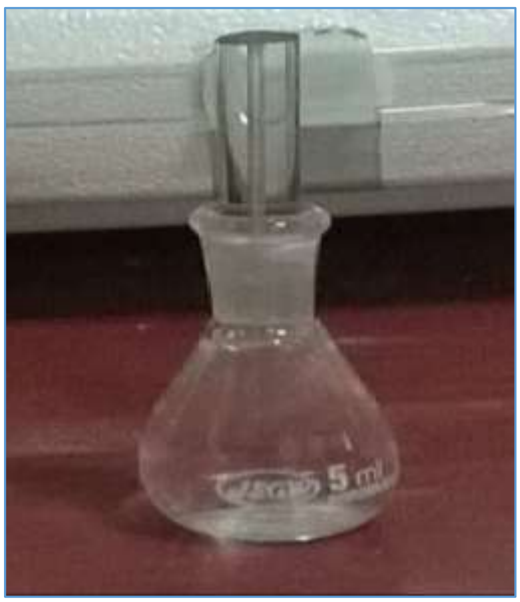

Figure.4: Pycnometer

MEASUREMENT OF VISCOSITY OF NANOFLUID

A measure of resistance occurring during flow is termed as Viscosity. Brookfield DV-III Rheometer (Fig.5) was used to measure the viscosity of prepared nanofluid sample. It provides flow factors like shear stress and viscosity at given shear rate. The device operates on the principle that the spindle is driven through a calibrated spring, which measures the viscous drag of the fluid against the spindle by the spring deflection. Spring deflection is measured by a rotary transducer. Rotational speed of the spindle measures the range of a DV-III in centipoises.

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Figure.5: Brookfield DV-III Rheometer.

EXPERIMENTAL RESULTS

Thermal conductivity variations

From experimental data , it can be seen that the thermal conductivity of Al/water nanofluid and Al2O3/Water nanofluid was significantly higher than that of water and strongly dependent on temperature of the fluid. Thermal conductivity of Al/Water nanofluid was much higher than that of Al2O3/Water nanofluid.

Fig.6 shows that the experimental values of thermal conductivity of nanofluid increases significantly with the fluid temperature. The reason is that, fluid temperature strengthens the Brownian motion of nanoparticles and also drops the viscosity of the base fluid. With a strengthened Brownian motion, the influence of micro convection in heat transport rises and in consequence increased enhancement of the thermal conductivity of nanofluids. Thermal conductivity of metallic nanofluid is much higher than oxide nanofluid because of higher thermal conductivity of Aluminium metal. It was shown that the thermal conductivity of Al/water nanofluid was around 47 % higher than Al2O3/water nanofluid at temperature around 60°C.

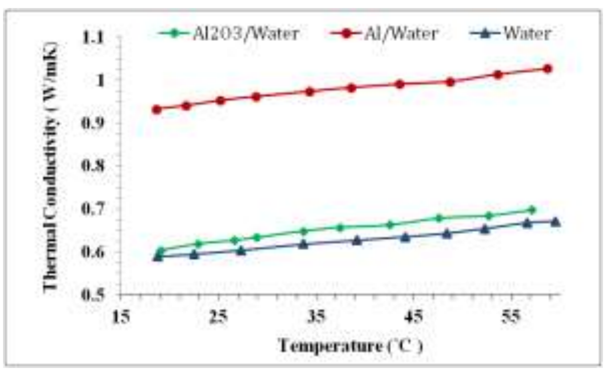

Figure.6: Thermal conductivity of Al/Water and Al_2O_3/Water nanofluid at 0.1%(vol.)

DENSITY VARIATIONS

From Fig.7 it can be seen that, the density of Al/Water and Al_2O_3/water nanofluids was significantly higher than that of water but it decreases slightly as temperature of the fluid increases. There was a variation of only 1.32% when temperature increases from 25℃ to 70℃. for Al_2O_3/water nanofluids and for Al/Water nanofluid, it was 1.67%. While the density of Al/Water nanofluid was higher than that of oxide nanofluid by 9.16% at 60°C.

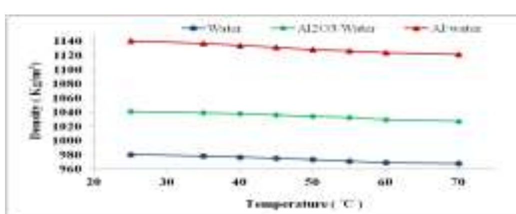

Figure. 7: density of Al/water and Al_2O_3/water nanofluids

Viscosity variations

From experimental data obtained for viscosity, graph was plotted for Viscosity vs. temperature for both the nanofluids. From fig.8, it could be concluded that viscosity of Al_2O_3/water nanofluid at 0.1% (Vol.) concentration was slightly higher than that of water, but it was significantly higher for Al/Water nanofluids, simply because when solid particles are mixed to the liquid it increases the density of the mixture and consequently the force required would be more to overcome the inertial forces, as a result viscosity increases but there was significant decrement of viscosity with temperature. Viscosity of Al/Water nanofluid was higher than Al_2O_3/water nanofluid by 22.13% at 80°C.

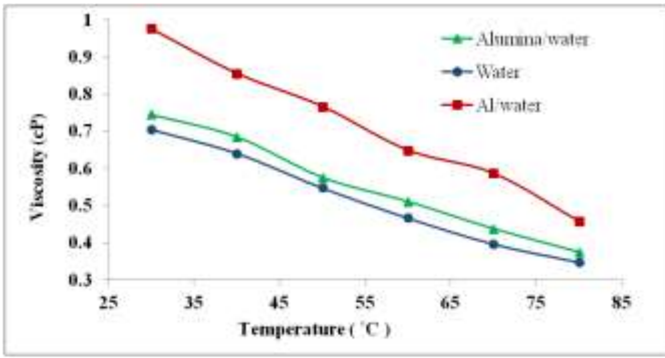

Figure.8: Viscosity of Al/water and Al_2O_3/water nanofluids

CONCLUSION

Two different nanofluids namely Al/water and Al_2O_3/Water were prepared at 0.1% (Vol.) concentration. Al/Water nanofluid was less stable as compared to oxides hence CTAB surfactant was added to improve the stability and dispersion of nanoparticles. Aim of present research was to reveal the variation of thermo physical properties of metal and oxide nanofluids with temperature. Thermal conductivity, density and viscosity was measured experimentally using KD2 Pro thermal property analyzer, Specific gravity bottle and Brookfield DV-III Rheometer respectively. Results showed that thermal conductivity of both of the nanofluids was strongly dependent upon the temperature of the fluid, which make use of nanofluids feasible for high energy-density applications. Also the thermal conductivity of metal based nanofluid was much higher which shows the applicability of metal basis nanofluids in heat transfer application to realize highly improved performance.

Viscosity of metal based nanofluid was also higher which increases the pumping power requirements, But the effect of increased thermal performance was dominant at the cost of increased pumping power. Finally concluded that application of Al/Water nanofluid in heating or cooling devices may lead to superior thermal performance of the device as compared to Al_2O_3/Water nanofluid.

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