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An Experimental Procedure to Investigate the Thermal Conductivity of Various types of Nanofluids

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Abstract: In this experimental research work, thermal conductivity of disparate types of nanofluid samples was investigated. Nanofluid has ability for enhancement in heat transfer due to their high value of thermal conductivity. KD_2 Pro instrument was used to measure the thermal conductivity, which is hinged on transient hot wire mechanism. Dissimilar nanofluids like MWCNT-H_2O, Al_2O_3-H_2O, and Al_2O_3-H_2O-C_2H_6O were fabricated with divergent volume concentration. Thermal conductivity was measured at unlike temperature by setting up the KD2 Pro at an automated mode for time interval of 15 minutes. Experimental findings showed that MWCNT- H_2O based nanofluid with 0.02wt% possess higher value of thermal conductivity among conventional and other nanofluids with different concentrations.

Keywords: KD2 Pro instrument; Thermal conductivity; MWCNTs; Al_2O_3 based nanofluids.

I. INTRODUCTION

It is necessary to insert needle sensor completely in to sample fluid along with centrally oriented and without contacting with side walls of measuring flask containing liquid sample. Suspension of nanoparticles into base fluids is simply known as nanofluid. Generally nanofluid shows better thermophysical properties as compared to conventional and micro size fluids. Nanofluid was first manufactured by choi in 1995 with the application of nanoparticles in to fluids. Nanofluid can be prepared by one step and two step method. In 2001 Choi measured the enhancement in thermal conductivity of MWCNT and poly (a-olefin) oil based nanofluid by 160 percent. There are basically two methods to measure the thermal properties i.e. steady state and transient method. Transient methods are most important among steady state method because it provides fast measurement of thermal properties of nanofluid by decreasing down the unwanted mode of heat transfer. Thermal diffusivity and thermal conductivity are measured by energy equation for thermal conduction. A.K. Singh conducted an study related to thermal conductivity of nanofluid is measured through transient hot wire method, in which increasing temperature of hot wire is directly related to the thermal conductivity of nanofluid and denoted by Keff [1]. José R et al conducted an experimental study for measurement of thermal conductivity of SiO2 and CuO in water and ethylene glycol based nanofluids at various mass fractions ≈5%. The experimental measurement is performed by multicurrent hot wire method, which shows good agreement and this experimental approach allows measuring the enhancement in thermal conductivity of nanofluids with in 2% accuracy limit. Results and outcomes from the measurement of enhancement in thermal conductivity are compared with results from previous research and also compared with the simple theoretical models that predict thermal conductivity of nanofluids [6]. Ravi Sankar.B conducted a review study on the thermal conductivity of nanofluid and concluded that enhancement in thermal conductivity is due to incremental change in particle volume fraction. Higher thermal conductivity with small particle size was expected due to Brownian motion of nanoparticles and further thermal conductivity of nanofluid was also affected by the changing temperature [5]. Elaheh K. Goharshadi et al prepared silver nanoparticles by the conventional and also due to ultrasound assisted reduction method and it has a capability to synthesize silver nanoparticles with narrower PSD as compare to non-ultrasound reduction method. This experimental

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study was conducted on electrical conductivity and rheological properties of silver-distilled water and silver- ethylene glycol based nanofluid for dissimilar volume fraction and also at different temperature. This experimental study was concluded finally that enhancement in electrical conductivity of silver-distilled water based nanofluid at 50˚C along with volume fraction of 2% [4]. Benigno Barbe´s was measured the thermal conductivity of CuO nanoparticles, which was dispersed in water and ethylene glycol and thermal conductivity was function of particle volume fraction with variation in temperature was varied between 298-338K.

This research was concluded that an enhancement in thermal conductivity was reported due to base fluid mainly rather than nanoparticles [8]. A.V. Minakov conducted a study to determine the thermal conductivity coefficient with hot wire method. In this research work, an experimental procedure has been tested on the determination of thermal conductivity of H_2O and $C_2H_6O_2$ (ethylene glycol). For experimentation, a nanofluid was prepared by mixing of alumina nanoparticles with ethylene glycol and volume concentration of nanoparticles are varied from 0.5% to 2%. Better results for thermal conductivity coefficient come out from the experimental study in comparison to other author's results [2]. María José et al conducted an experimental research to analyze the dispersion behavior and stability of Al_2O_3-ethylene glycol based nanofluid at various concentrations. Experimental procedure was adopted to determine thermal conductivity and viscosity relative to the variation in temperature between 283.15K to 323.15K with the application of hot wire method and rotational viscometer apparatus. This research work was concluded that both thermal conductivity and viscosity showed an enhancement with the increasing concentration of nanoparticles, while with the increment in temperature, viscosity of nanofluid decreases and enhancement in thermal conductivity up to 19% was observed [7]. Hyder H. Balla was conducted an experimental research to measure thermal conductivity of nanofluid at different temperatures by using transient hot wire method. Results of thermal conductivity were in good agreement and were used by author as input data for adaptive neural fuzzy inference system (ANFIS) to determine the thermal conductivity of the multi metallic nanofluid. It was found that ANFIS model better results for thermal conductivity of multi metallic nanofluid [10]. R. Karthik et al was conducted an experimental study for the measurement of thermal conductivity enhancement of CuO-deionized water nanofluid over deionized water between the temperature 15℃ and 35℃ with the help of tailor made measurement instrument that uses the 3-ω technique. Volume fraction of nanoparticles was taken 0.025%, 0.05%, 0.1% and enhancement in thermal conductivity was measured 13% to 25% over the base fluid [11].

II. EXPERIMENTAL PROCEDURE

KD2 Pro Instrument

KD2 Pro also known by thermal properties analyzer, which measures the thermal conductivity along with thermal diffusivity. It is made up from 16-bit microcontroller/AD converter and a needle sensor, which has a heating element and a thermistor. It has also consisted with battery and power control circuitry. The needle sensor was fabricated from stainless steel with 60mm length and approximate diameter 1.3mm. The needle sensor can be used to measure thermal diffusivity along with thermal conductivity within range varies from 0.2 to 2W/m-k along with accuracy limit of $\pm$5% approximately and cycle to measure thermal conductivity (K) consist of 90sec.

$$K = \frac{q}{4}\frac{(\ln t_2 - \ln t_1)}{(\Delta T_2 - \Delta T_1)} \qquad (1)$$

During the initial stage, KD2 Pro instrument will come in the state of equilibrium and take 30 second, which is then followed by heating and cooling effect of the needle sensor for 30sec each. After the completion of the process the instrument' controller evaluates the experimental thermal conductivity by using the temperature change from the experimental data i.e. ∇T. It is necessary to insert needle sensor completely in to sample fluid along with centrally

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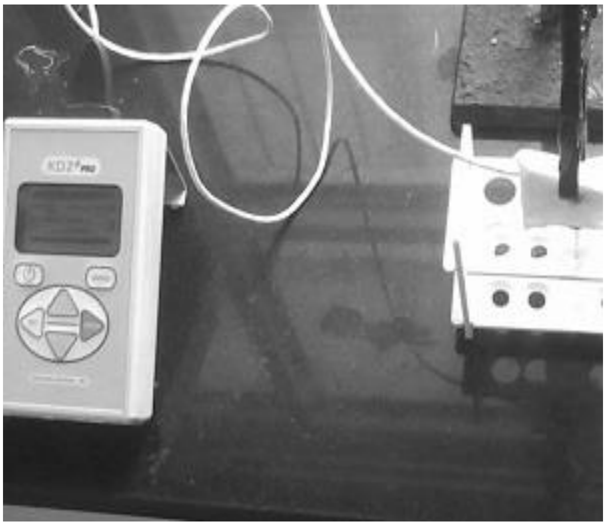
oriented and without in contact with side walls of measuring flask containing liquid sample to avoid errors in the measured data of thermal conductivity.



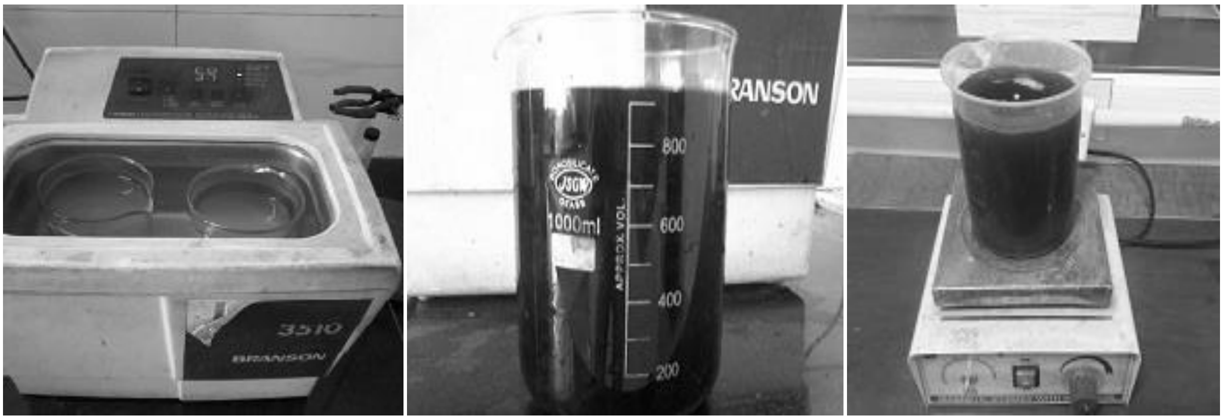
1(a)

1(b)

Figure 1(a) & 1(b): KD2 Pro instrument.

Preparation of Nano fluids

Nano fluids are prepared by the using nanoparticles in base fluid and further homogeneous and stable dispersion of nanoparticles in conventional fluid is always a challenge for the investigators and preparation of nanofluid is followed by the three common methods like sonication, PH control and surfactant [3]. In this research work MWCNTs with volume concentration 0.01% and 0.02% mixed with 6 liter distilled water. Further a surfactant Triton X-100 is also used for better dispersion of MWCNTs in base fluid. Alumina (Al_2O_3) nano particles with volume concentration 0.5%, 1%, 1.5% and 2% mixed with 6 litres distilled water and further Al_2O_3 also mixed with 6 liter ethylene glycol/distilled water (40:60) as a base fluid in the same volume concentrations for the preparation of different nanofluids. Preparation of nanofluid followed by the process of sonication along with magnetic stirrer used to increase the dispersion quality. After reviewing the previous research work, time of sonication was decided 3:30hrs for the total quantity of nanofluid. MWCNTs used of tube diameter 20-40nm along with length of tubes 1-10μm and further Al_2O_3 nanoparticles used in this research are of diameter less than 20nm.



2(a) 2(b) 2(c)

Figure 2(a), 2(b) & 2(c): BRANSON 3510 Sonication device, Sample of MWCNT/water based nanofluid and magnetic stirrer device with hot plate.

Structural characterization techniques

Research work utilizes the scanning electron microscopy (SEM) and X-Ray diffraction (XRD) to characterize and obtain the information regarding the morphology or structure and presence of MWCNTs and Al_2O_3 nanoparticles in sample material.

Scanning electron microscopy

SEM is a high resolution and powerful imaging instrument or tool for imaging and analyzes the structure of nanoparticles. SEM technique utilizes high energy electrons are used to produce image of solid surfaces and also provide the necessary information about structural arrangement and geometrical features of carbon nanotubes (CNT). This method contain a topographical image CNT sample formed due to secondary electron, when primary electron is used to scan the surface of CNT sample[9]. Figure 3(a) & 3(b) shows SEM image at different resolution (3μm & 4μm) and magnification for MWCNTs with 20-40nm diameter and length 1-10μm describe that morphology of nanotubes are randomly intertwine together and highly connect with each other, which can be probably due to vander wall's forces. Figure 4(a) & 4(b) shows SEM image at different resolution (10μm & 20μm) and magnification for Al_2O_3 nanoparticles with maximum diameter 20nm describe the nanoparticle's outer morphology.

X-Ray Diffraction (XRD)

XRD is the technique to indentify the crystal structure and atomic spacing in sample material and this technique is based upon the useful interface between monochromatic X-Rays, which are produced by cathode ray tube and crystalline sample material. Monochromatic radiations are generated and accelerated toward the sample in a collinear manner and concentrated on the sample. When incident ray interacted with sample, it produce diffracted ray and also satisfy the Bragg's law. According to this relation wavelength of electromagnetic radiation is directly proportional to diffraction angle and also atomic or lattice spacing between the crystal structures of sample material. After that all

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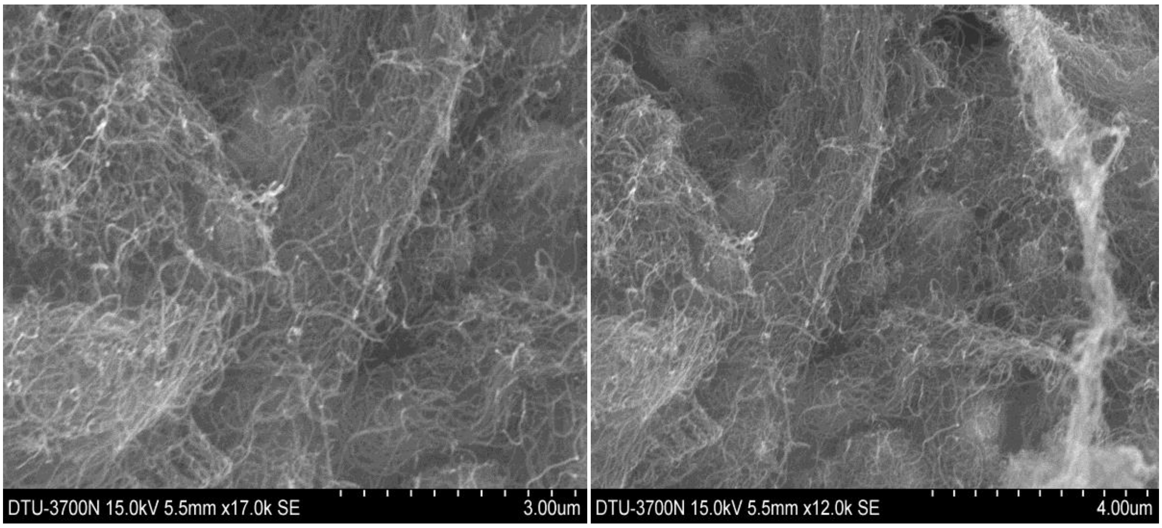
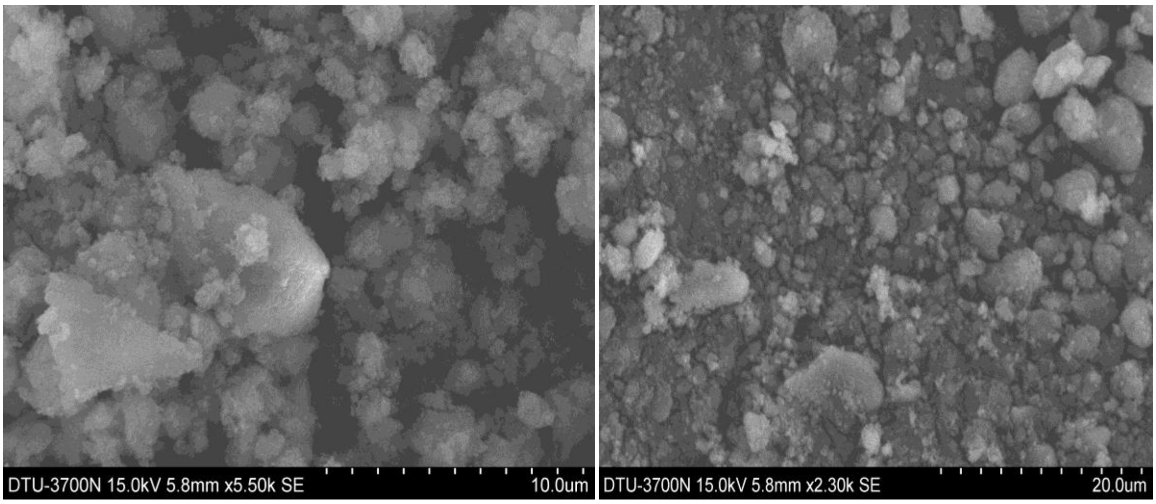
diffracted rays are collected, detected and then counted. Figure 5(a) & 5(b) shows XRD peaks for MWCNTs and Al_2O_3 nanoparticles.



3(a) 3(b)

Figure 3(a) & 3(b): SEM image of MWCNTs.
Source: Department of Nano Science Technology, Delhi Technological University



4(a) 4(b)

Figure 4(a) & 4(b): SEM image of Al_2O_3 nanoparticles
Source: Department of Nano Science Technology, Delhi Technological University

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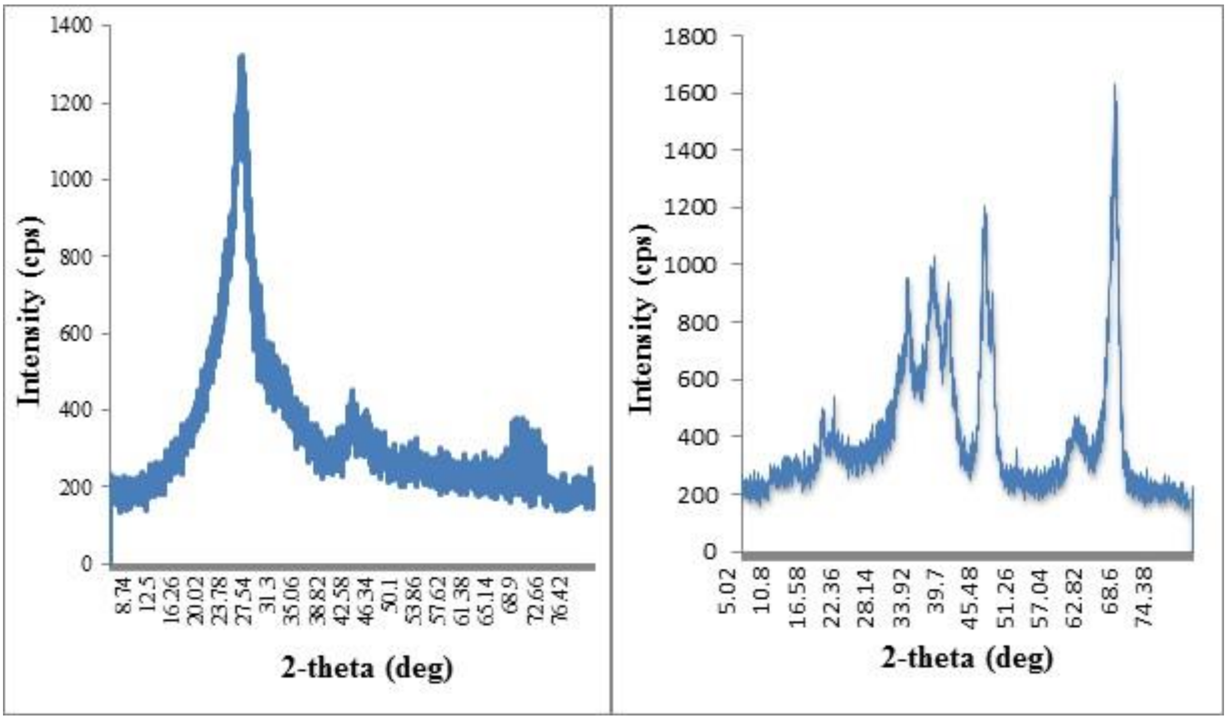

5(a) 5(b)

Figure 5(a) & 5(b): XRD pattern for MWCNTs and Al_2O_3 nanoparticles.

III. RESULTS AND DISCUSSIONS

This section includes the experimental evaluation of thermal conductivity of various fluids like distilled water, MWCNT and distilled water based nanofluid at different weight concentration 0.01% and 0.02%, mixture of distilled water and ethylene glycol ($C_2H_6O_2$), Al_2O_3 and distilled water based nanofluid at various weight concentration like 0.5%, 1%, 1.5% and 2% and a nanofluid mixture of Al_2O_3 nanoparticles and basefluid of distilled water and ethylene glycol ($C_2H_6O_2$) in the ratio of (60:40). KD2 Pro instrument was used to analyze the thermal conductivity of different conventional and nanofluids with change in temperature and weight concentration. It has been seen from experimental findings that thermal conductivity of distilled water decreases with increasing temperature and it has also been observed that thermal conductivity of MWCNT and distilled water based nanofluid with 0.01wt% and 0.02wt% increases with incremental change in temperature as shown in figure 6 and further more enhancement was observed in average thermal conductivity of MWCNT and distilled water based nanofluid at 0.02wt% as comparison to thermal conductivity of same nanofluid with 0.01wt%. So it has also been concluded that thermal conductivity increases with increasing weight concentration of nanotubes. From experimental observation it is clear that that thermal conductivity of mixture containing distilled water and ethylene glycol ($C_2H_6O_2$) in ratio of 60:40 increases with increasing temperature as shown in figure 6. Experimentally average thermal conductivity of distilled water and ethylene glycol was measured 0.617W/m-k and 0.410W/m-k. Apart from this thermal conductivity of Al_2O_3 and distilled water based nanofluid showed an incremental behavior with increasing weight concentration 0.5wt%, 1wt% and 1.5wt% except 2wt% as shown in figure 8. Maximum value of average thermal conductivity of Al_2O_3 and distilled water based nanofluid was measured 0.623W/m-k at 1.5wt%. Further it has also been seen that thermal conductivity of Al_2O_3 and distilled water based nanofluid decreases with increasing temperature value and showed the same behavior at different concentration

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of Al_2O_3 nanoparticles as shown in figure 7. It is clear from experimental observation that graph for thermal conductivity of Al_2O_3 and distilled water based nanofluid with 1wt% showed almost linear behavior or slightly decreases with increasing temperature as shown in figure 7. An enhancement in thermal conductivity of Al_2O_3-H_2O-$C_2H_6O_2$ based nanofluid was measured with increasing temperature at various weight concentrations like 0.5wt%, 1wt% and 2wt% as shown in figure 7. It has been observed experimentally that thermal conductivity of distilled water based nanofluid showed an opposite behavior as comparison to thermal conductivity of ethylene glycol and distilled water (H_2O-$C_2H_6O_2$) based nanofluid with change in temperature.

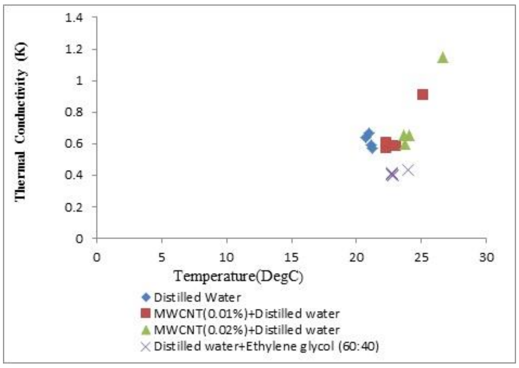

Figure 6: temperature between distilled water and ethylene glycol ($C_2H_6O_2$) thermal conductivity.

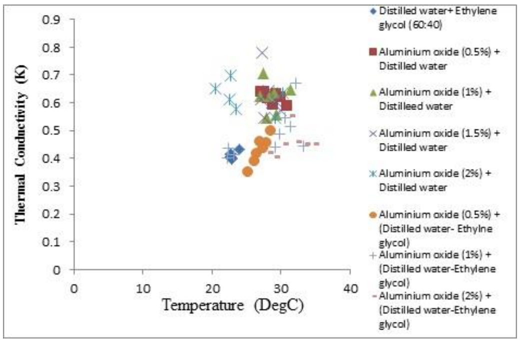

Figure 7: Concentration of Al_2O_3 nanoparticles.

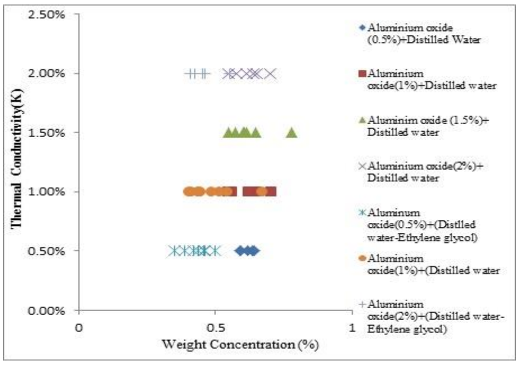

Figure 8: Concentration of thermal conductivity.

Further maximum value of average thermal conductivity of Al_2O_3-H_2O-$C_2H_6O_2$ based nanofluid was measured 0.482W/m-k with 1wt% and apart from this it has also been observed from experimentation data that thermal

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conductivity of Al_2O_3-H_2O-$C_2H_6O_2$ based nanofluid possess lower value always as comparison to Al_2O_3-H_2O based nanofluid, which can be due to lower value of thermal conductivity possessed by mixture of ethylene glycol and distilled water based mixture as compare to thermal conductivity of distilled water alone. Average thermal conductivity of Al2O3-H_2O-$C_2H_6O_2$ based nanofluid showed an incremental behavior with increasing weight concentration of nanoparticles 0.5wt% and 1wt% except 2wt%, because an decrement was observed in thermal conductivity value at this concentration as comparison to 1wt% , which is completely understood by figure 8.

IV. CONCLUSION

There are different results concluded by using KD2 Pro instrument for the experimental investigation of divergent nano fluids and are discussed below:

1. Thermal conductivity of MWCNT and distilled water based nanofluid with 0.01wt% and 0.02wt% increases with incremental change in temperature.
2. It has also been concluded that thermal conductivity increases with increasing weight concentration of nanotubes.
3. It has been found that average thermal conductivity of distilled water and ethylene glycol was measured 0.617W/m-k and 0.410W/m-k.
4. Maximum value of average thermal conductivity of Al_2O_3 and distilled water based nanofluid was measured 0.623W/m-k at 1.5wt%
5. Maximum value of average thermal conductivity of Al_2O_3-H_2O-$C_2H_6O_2$ based nanofluid was measured 0.482W/m-k at 1wt%
6. It has been found that thermal conductivity of Al_2O_3-H_2O-$C_2H_6O_2$ based nanofluid possesses lower value always as comparison to Al_2O_3-H_2O based nanofluid.

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