International Journal of Mathematics and Physical Sciences Research ISSN 2348-5736 (Online)
Vol. 4, Issue 1, pp: (96-103), Month: April 2016 - September 2016, Available at: www.researchpublish.com

The viscosity Study of CuO nanofluid based on Propylene Glycol

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Abstract: **Nanofluids have heat transfer more than typical fluids that causes they used in cooling systems and performance their efficiency. They usually supplied by dispersing metallic and oxide nanoparticles in fluids. Heat transfer performance of nanofluid depends on viscosity, thermal conductivity, specific heat and density. Viscosity affects the pressure and the pumping power of fluids. When nanofluids are circulated in a closed loop for transfer of heat in cooling systems, they can affect the thermal conductivity due to the phenomenon of convection. In the present research, an empirical viscosity assessment of nanofluids comprising CuO nanoparticles (NPs) Propylene Glycol-based in different concentrations and various temperatures of nanofluids has been carried out in this paper. For viscosity investigation of nanofluid, CuO NPs dispersed within propylene glycol (PG). CuO nanoparticles suspended in PG with volume fractions ranging from 0.3, 0.7, 1.1, 1.5, 1.9 and 2.3 % were prepared. So viscosity measured by stabinger viscometer (SVM3000) in various temperatures such as 77^{0}F=25^{0}C, 40^{0}C and 50^{0}C. It seems that the sample with 0.3 % and temperature of 25^{0}C has maximum viscosity and 1.9 % with temperature of 50^{0}C shown minimum viscosity. It shows that there is an almost decrease in viscosity of propylene glycol-based nanofluids with increase in CuO nanoparticles concentration. The viscosity results thus obtained are compared with the Einstein's model.**

Keywords: **nanofluids, propylene glycol, viscosity.**

I. INTRODUCTION

A Nanofluid is a fluid containing nanometer-sized particles, called nanoparticles (NPs). These fluids are engineered colloidal suspensions of nanoparticles in a base fluid.[1][2] The nanoparticles used in nanofluids are typically made of metals, oxides, carbides, or carbon nanotubes. Common base fluids include water, ethylene glycol [3] and oil.

Nanofluids have novel properties that make them potentially useful in many applications in heat transfer,[4] including microelectronics, fuel cells, pharmaceutical processes, and hybrid-powered engines,[5] engine cooling/vehicle thermal management, domestic refrigerator, chiller, heat exchanger,in grinding, machining and in boiler flue gas temperature reduction. They exhibit enhanced thermal conductivity and the convective heat transfer coefficient compared to the base fluid.[6] Knowledge of the rheological behaviour of nanofluids is found to be very critical in deciding their suitability for convective heat transfer applications.[7][8]

In analysis such as computational fluid dynamics (CFD), nanofluids can be assumed to be single phase fluids. However, almost all of new academic paper use two-phase assumption. Classical theory of single phase fluids can be applied, where physical properties of nanofluid is taken as a function of properties of both constituents and their concentrations.[9] An alternative approach simulates nanofluids using a two-component model.[10] Nanofluids are supplied by two methods called the one-step and two-step methods.

II. DEFINITION

The viscosity of a fluid is a measure of its resistance to gradual deformation by shear stress or tensile stress [11]. For liquids, it corresponds to the informal concept of "thickness". For example, honey has a much higher viscosity than water [12]. Viscosity is a property arising from collisions between neighboring particles in a fluid that are moving at different velocities. When the fluid is forced through a tube, the particles which comprise the fluid generally move more quickly near the tube's axis and more slowly near its walls. Use of the Greek letter mu (μ) for the dynamic stress viscosity is common among mechanical and chemical engineers, as well as physicists.[13][14][15] However, the Greek letter eta (η) is also used by chemists, physicists, and the IUPAC.[16]

The cgs physical unit for dynamic viscosity is the poise (P), is also named after Jean Poiseulle. It is more commonly expressed, particularly in ASTM[1] standards, as centipoise (cP) since the latter is equal to the SI multiple milliPascal seconds (mPa·s).

1 cP = 1 mPa·s = 0.001 Pa·s

III. TOOLS

By modifying the classic Couette type rotational viscometer, it is possible to combine the accuracy of kinematic viscosity determination with a wide measuring range. The outer cylinder of the Stabinger Viscometer is a tube that rotates at constant speed in a temperature-controlled copper housing. The hollow internal cylinder – shaped as a conical rotor – is specifically lighter than the filled samples and therefore floats freely within them, centered by centrifugal forces. In this way all bearing friction, an inevitable factor in most rotational devices, is fully avoided. The rotating fluid's shear forces drive the rotor, while a magnet inside the rotor forms an eddy current brake with the surrounding copper housing. An equilibrium rotor speed is established between driving and retarding forces, which is an unambiguous measure of the dynamic viscosity. The speed and torque measurement is implemented without direct contact by a Hall effect sensor counting the frequency of the rotating magnetic field. This allows for a highly precise torque resolution of 50 pN.m and a wide measuring range from 0.2 to 20000 mPa.s with a single measuring system. A built-in density measurement based on the oscillating U-tube principle allows the determination of kinematic viscosity from the measured dynamic viscosity employing the relation $\vartheta = \frac{\eta}{\rho}$ where; ϑ is the kinematic viscosity (mm^2/s), η is the dynamic viscosity (mPa.s), ρ is the density (g/cm^3). In this research, The Stabinger Viscometer^{TM} SVM 3000 measured the dynamic viscosity and density of nanofluid according to ASTM D7042[2].

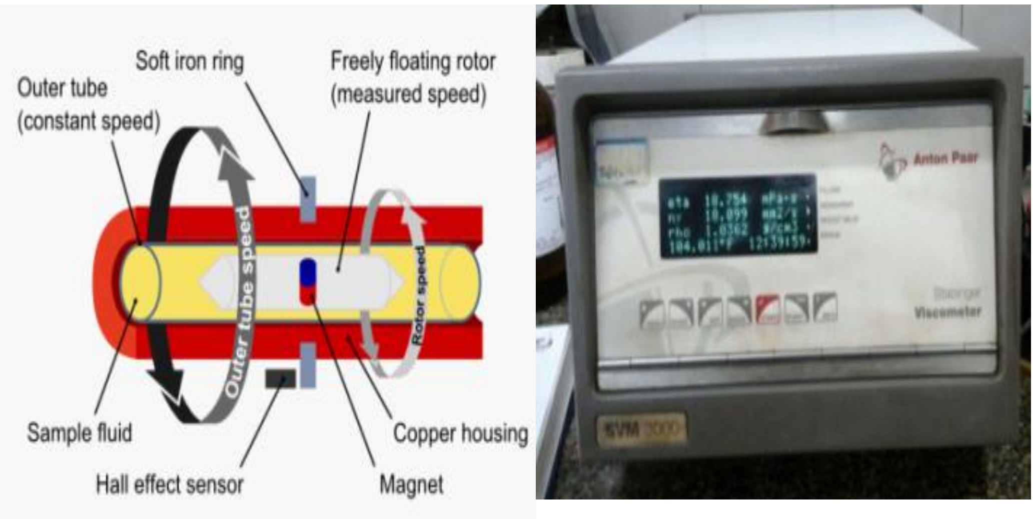

Figure 1. Stabinger Viscometer SVM 3000

IV. EXPERIMENT

A. Characteristics of materials

CuO Nanoparticles and propylene glycol 99.0% bought from US Research Nanomaterials,Inc. and SAMCHUN of korea companies respectively. Analyses SEM, TEM and XRD supplied. SEM and TEM analyses (Fig. 2) of the nanoparticles show that CuO nanoparticles shape are spherically and their diameters size was estimated as 40nm. XRD analysis Confirmed purity of CuO Nanoparticles too.

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[1] American Society for Testing and Materials
[2] Standard Test Method for Dynamic Viscosity and Density of Liquids by Stabinger Viscometer

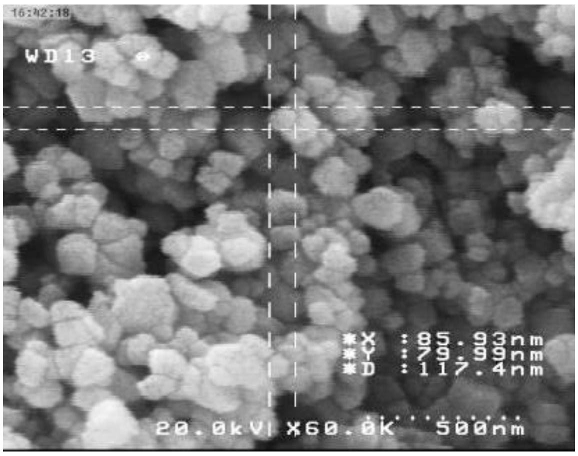

Fig. 2. SEM image suplied by US NANO company

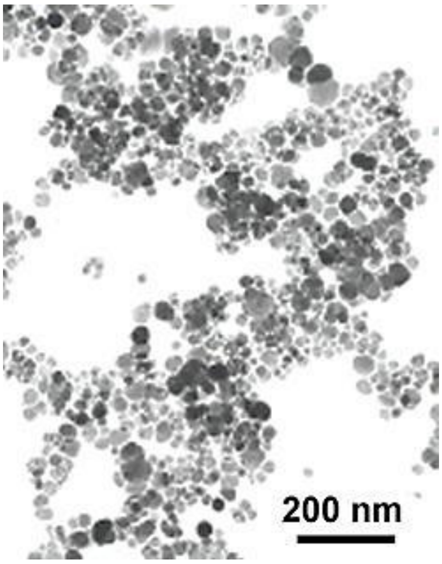

Fig. 3. TEM image suplied by US NANO company

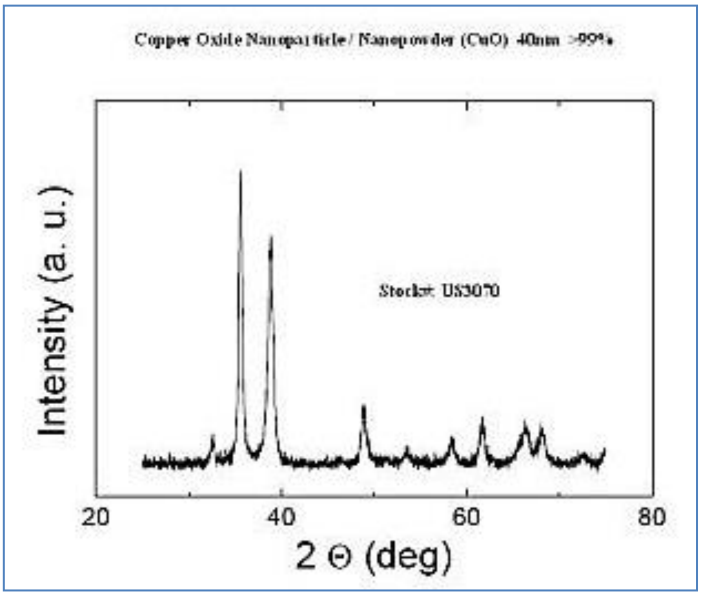

Fig. 4. XRD patern suplied by US NANO company

In addition, Propylene glycol is a colorless viscosity liquid, its molecular formula is $CH_3CH(OH)CH_2OH$ and soluble in water.

B. Preparation of nanofluid and viscosity investigation

In this work Cuo nanoparticles with average particle diameter 40 nm sized and particle density of 6.4g/cm^3 has been used. The Cuo nanoparticles are prepared by US Research Nanomaterials,Inc. The amount of CuO nanoparticles used for a volume concentration in the test sample of base fluid is calculated using the principle of mixtures in terms percentage of volume fraction, Here volume percentage of particles in base fluid called (φ). Density of propylene glycol base fluid and density of CuO NPs using the following relationship of particles volume percentage in base fluid is equal:

$$\varphi = \frac{\frac{mass\ of\ CuO\ NPs}{density\ of\ CuO\ NPs}}{\frac{mass\ of\ CuO\ NPs}{density\ of\ CuO\ NPs} + \frac{mass\ of\ propylene\ glycol}{density\ of\ propylene\ glycol}} \quad (1)$$

Note, density of propylene glycol in various temperatures is different so volume percentage will be function of temperature if materials mixed in various temperatures, but we mixed them on room temperature then heating them.

CuO nanoparticles mass was measured by a sensitive balance of $10^{-4}g$ resolution. Then CuO nanoparticles suspended in propylene glycol in volume fractions ranging from 0.3, 0.7, 1.1, 1.5, 1.9 and 2.3 %.

For viscosity investigation of nanofluid, CuO NPs dispersed within propylene glycol. Samples with various concentrations such as $\frac{0.5\ \mathrm{g}}{20\ \mathrm{ml}} = \frac{25\ \mathrm{g}}{\mathrm{l}}, \frac{50\ \mathrm{g}}{\mathrm{l}}, \frac{75\ \mathrm{g}}{\mathrm{l}}, \frac{100\ \mathrm{g}}{\mathrm{l}}, \frac{150\ \mathrm{g}}{\mathrm{l}}$ were prepared so their viscosity measured by stabinger viscometer (SVM3000) in various temperatures such as 77^{0}F=25^{0}C, 40^{0}C and 50^{0}C.

Table I. Density of propylene glycol

Temperature	25^{0}C	40^{0}C	50^{0}C
Density of propylene glycol (g/lit) [17]	1032.3	1019.7	1006.9

Different masses of CuO NPs (0.5, 1, 1.5, 2, 2.5, 3g) dispersed in 20 ml of propylene glycol (PG) for making various concentration of nanofluid. Volume percentage of particles in base fluid called (φ) was calculated for samples. These data have shown in table 2.

Table II. Mass, concentration of CuO NPS and volume percentage of particles in base fluid

Mass of CuO (g)	**Concentration of CuO NPS in fluid (g/lit)**	**φ in 25^{0}C**
0.5	25	0.003891051
1	50	0.007751938
1.5	75	0.011583012
2	100	0.015384615
2.5	125	0.019157088
3	150	0.022900763

V. RESULTS

The experimental setup for measurement of viscosity of the CuO nanofluid based on propylene glycol consists of a Stabinger programmable viscometer. A computer controls the temperature of this nanofluid that is used to lock in the temperature of the test sample. The results after measuring the viscosity of nanofluids at different temperatures and concentrations were determined shown in Table 3.

Table III. Result of CuO nanofluids viscosity with various concentrations and temperatures

Temperature *Concentration of CuO NPS in fluid*	25 ^{0}C	40 ^{0}C	50 ^{0}C
0 g/l (pure PG)	39.43 mpa.s	15.13 mpa.s	10.69 mpa.s
25 g/l	40.43 mpa.s	18.74 mpa.s	11.78 mpa.s
50 g/l	38.32 mpa.s	17.9 mpa.s	11.03 mpa.s
75 g/l	38.04 mpa.s	16.4 mpa.s	11.51 mpa.s
100 g/l	38.48 mpa.s	16.01 mpa.s	11.08 mpa.s
125 g/l	38.78 mpa.s	15.97 mpa.s	10.51 mpa.s
150 g/l	39.01 mpa.s	14.01 mpa.s	10.81 mpa.s

According to this table, the sample with Concentration of 25g/l (0.3 %) and temperature of 25^{0}C has maximum viscosity (approximately 40.5 mpa.s) and Concentration of 125g/l (1.9 %) with temperature of 50^{0}C and approximately 10.5 mpa.s, shown minimum viscosity. Variation of viscosity depending on the concentration in different and fixed temperature shown in fig. 5. At the first of curves, It was found that supplied suspension made an increase in viscosity but after, with increase in CuO concentration cause decreasing in chart although the chart has little fluctuations.

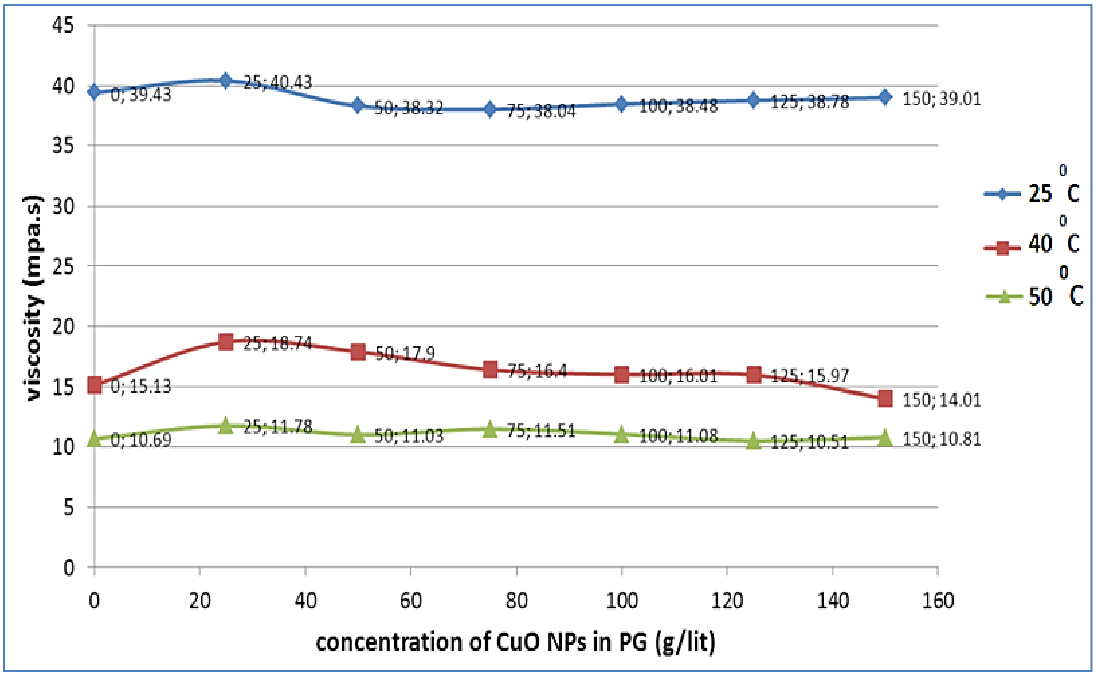

Fig. 5. Variation of viscosity depending on the concentration in 25 ^{0}C, 40 ^{0}C and 50 ^{0}C

Variation of viscosity with constant temperature in 25 ^{0}C show that increases in concentration associated initially reduction (after concentration of 50 g/lit) and then partial increase in viscosity (after concentration of 100 g/lit) but in 40^{0}C, increasing in concentration cause decreasing the viscosity generally. In the Lowest curve there are fluctuations of viscosity but their Changes is little.

Below, to evaluate the effect of temperature on fixed concentration the diagrams of various concentration of CuO NPs dispersed in PG were drawn. These curves shown in fig.6, and represent that each temperature raise, cause a decrease in viscosity of CuO nanofluids based on PG.

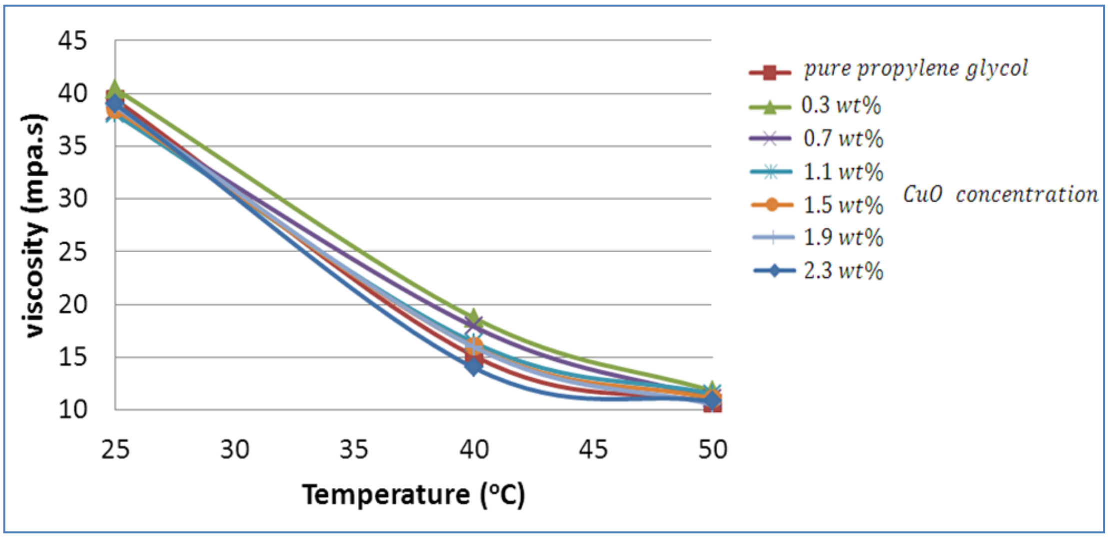

Fig. 6. Variation of viscosity depending on the temperature in constant concentration

Slope of curve for 2.3 % of CuO NPs is rather than other curves. All of curves are approximately up the pure propylene glycol curve but it is not for 2.3 %.

Einstein offered a viscosity relation for suspension of particles in base fluid when the volume concentration is lower than 5%.

$$\mu_s = \mu_f(1 + 2.5\varphi) \qquad (2)$$

Here, μ_s= suspension viscosity, μ_f= viscosity of base fluid, and φ is volume percentage of particles in base fluid [18]. We compared our experimental data with Einstein prediction.

We measured viscosity of pure propylene glycol without any NPs (μ_f) in various temperatures and volume percentage of particles(φ) in room temperature shown in tables 2 and 3 so replaced in Einstein's equation. The theoretical result obtained in table 4.

Table IV. calculated of CuO nanofluids viscosity with various concentrations and temperatures by Einstein equation

Viscosity **Concentration** of CuO NPS in fluid (**g/lit**)	μ_s (mpa.s) in 25^0C	μ_s (mpa.s) in 40^0C	μ_s (mpa.s) in 50^0C
25	39.81	15.27	10.79
50	40.19	19.10	10.89
75	40.57	18.41	10.99
100	40.94	17.03	11.10
125	41.31	16.77	11.20
150	41.68	16.88	11.30

A Comparing between our experiment work and the result of Einstein's model with our initial dada has done that shown in fig.7. Variations in viscosity in both theoretical and experimental works because of variation in concentration of CuO, are similar approximately.

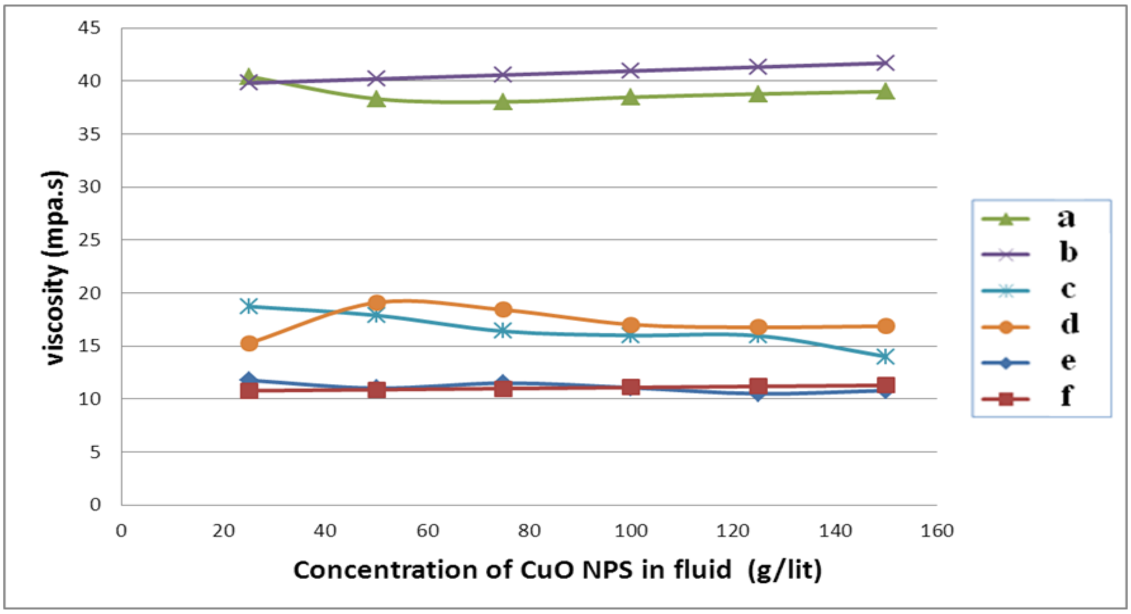

Fig. 7. Comparing between our experiment work and the result of Einstein's model with our initial dada. a,c and e) Calculation's viscosity (μ_s) of CuO nanofluid in 25^{0}C, 40^{0}C and 50^{0}C respectively. b,d and f) experimental viscosity of CuO nanofluid in 25^{0}C, 40^{0}C and 50^{0}C respectively.

There is relatively good agreement between the experimental data and Einstein's equation prediction results. Although a little fluctuation in results is seen. We think, the Einstein's model of viscosity is appropriate to predict the viscosity of CuO NPs based on propylene glycol.

VI. CONCLUSION

In this paper CuO nanofluid based on PG is prepared. Its viscosity is measured; the viscosity results thus obtained are compared with the Einstein's model. nanofluids concentration and temperatures change effects have been assessment. It shows that there is an almost decrease in viscosity of propylene glycol-based nanofluids with increase in CuO nanoparticles concentration. However in this way inharmonic fluctuation has been seen. On the other amount of these fluctuation is very little so we can attribution them to measurement system perturbation. CuO NPs entrance into base-fluid decreased molecular adhesion and makes it easy to move on both the molecular layer and reduction the viscosity of propylene glycol base nanofluid. Viscosity of nanofluids is a function of nanoparticles volume percentage and temperature. Einstein's model could predict viscosity of CuO NPs based on propylene glycol too.

VII. ACKNOWLEDGMENT

The authors are thankful to consul of research and technology Islamic Azad University, Masjedsoleyman branch for supporting this work.

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