Estimation of Dynamic Viscosity for Cobalt Oxide/Glycol Nano Fluid

Sanaa Ahmed Abbashar Elhassan a* and Mohammed Sulieman Ali Eltoum b

a Department of Chemistry, International University of Africa, College of Science, Sudan. b Department of Chemistry, Sudan University of Science and Technology, College of Science, Sudan.

Authors’ contributions

This work was carried out in collaboration between both authors. Author SAAE designed the study, wrote the literature, did the laboratory part (preparation, testing) and wrote the first draft of the manuscript. Author MSAE supervised and reviewed of the study. Both authors read and approved the final manuscript.

ABSTRACT

In this study the effects due to temperature and shear rate on viscosity for Co₃O₄/glycol based Nano fluids at different concentration of metal oxide and different temperatures were experimentally investigated. The structure of the prepared Co₃O₄/glycol nanoparticles was confirmed using XRD (X-Ray Diffraction) technique. All viscosity measurements were conducted using a capillary viscometer, the viscosity experiment were carried out at wide temperatures ranging between 20°C and 80°C to determine their applicability in such range. The viscosity data were collected using a programmable rheometer. The result showed that the Co₃O₄ glycol exhibit increasing viscosity with increasing nanoparticle loading and decreasing viscosity with increasing temperature.

Keywords: Dynamic viscosity; cobalt oxide; glycol; nanofluid; nanoparticle.

1. INTRODUCTION

Nano fluids are a novel type of fluid created by dispersing nanometer-sized materials (nanoparticles, nanofibers, nanotubes, nanowires, Nano rods, Nano sheet, or droplets) in a base fluid. Nano fluids, in other terms, are nanoscale colloidal solutions that include condensed nanomaterial. They are two-phase systems in which one phase (solid phase) is contained within the other (liquid phase) [1]. Nano fluids have been discovered to have better

*Corresponding author: E-mail: sanaabbashar@gmail.com;
thermophysical properties than base fluids like oil or water, such as thermal conductivity, thermal diffusivity, viscosity, and convective heat transfer coefficients. It has shown to have a wide range of possible applications [2]. One of the significant characteristics that are highly practical in fluid mechanics and heat transfer systems is the dynamic viscosity which highly affects pressure drop and also has an influence on the heat transfer performance. Viscosity of Nano fluid is measured by Viscometer. A particular measuring device called Brookfield programmable viscometer was used for measuring viscosity of some particles Nano fluid, the viscometer drives a spindle immersed in test fluid [3]. When the spindle is rotated, the deflection of the calibrated spring measures the viscous drag of the fluid against the spindle. The viscosity of a liquid is a measurement of its resistance to flow. It is the shear stress to shear rate ratio. When the viscosity remains constant at different shear rates, the liquid is said to be Newtonian; when it varies as a function of shear rate, the liquid is said to be non-Newtonian [4]. Einstein [5] was the first to use the phenomenological hydrodynamic equations to compute the effective viscosity of a suspension of spherical solids, according to Garg, Poudel, Chiesa et al. [6] conducted an experiment to assess the viscosity of copper nanoparticles [7], and they found a significant increase in heat transmission, as well as the fact that friction plays a little role in the application process. Other researchers [8] have determined that the forced convection suffers from a systematic and obvious decrease of natural convective heat transfer, which is dependent on the solution concentration, particle density, and cylinder aspect ratio. Experimental investigation on Al2O3 nanofluids using water as base fluid has been studied by various research groups, and they concluded that the heat transfer coefficient in laminar flow [9–11] increases up to 12–15% and in the case of turbulent flow, it ranges up to 8% [12,13]. CNT, CuO, SiO, and TiO2 nanofluids using water have been investigated [14–16]. CNT nanofluid produced findings that were similar to those of Al2O3 nanofluid. Ding et al. [17] came to the conclusion that changing the flow condition and fluid concentration could improve heat transmission. CuO, on the other hand, has been studied for a variety of wall boundary circumstances and has yielded promising results [18].

The objectives of the present paper was to estimate the dynamic viscosity for cobalt oxide/glycol nanofluid, before measuring the dynamic viscosity the prepared nanofluid and its particles was subjected to different tests to confirm its preparation.

2. MATERIALS AND METHODS

The metal oxides nanoparticles was prepared using sol-gel method. Firstly, the sodium alkoxides were prepared and react with metal salt to give metal alkoxide, the second step involve the conversion of alkoxide to metal oxide by heating. Nano fluids was prepared using dispersion methods in which different loads(amount) g/L of the prepared metal oxides is dispersed in to ethylene glycol liquid such as 2, 4, 6, or 5,10 … etc

2.1 Preparation of Co3O4 Nanoparticle

2.1.1 Chemicals

Potassium hydroxide, Cobalt acetate, Ethylene glycol, Acetone and Ethanol.

2.1.2 Methods

The aquas solution was prepared by mixing the calculated amount of KOH (5.61gm 100mmole) and cobalt acetate (7, 08 gm. 4m mole) and stirred for 2 h followed by reflexing for 4 hours. After filtration the residue was washed with distilled water until the solution reach pH 7. The residue calcinated at 45°C for 4h in dry nitrogen, black powder was obtained with 58% yield.

2.2 Preparation of Co3O4/Glycol Nanofluid

Specific amount of Co3O4 glycol nanofluids (0.1gm) were dispersed in 40 ml of Glycol and subjected to ultrasonic vibration instrument for about 2h.

Four different concentration of nanofluids were prepared following the above method as shown in Table (1) below:

<table>
<thead>
<tr>
<th>Table 1. Four different concentration of nanofluids</th>
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<tbody>
<tr>
<td>Sample</td>
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<tr>
<td>Sample 1</td>
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<td>Sample 2</td>
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<td>Sample 3</td>
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<td>Sample 4</td>
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2.3 Viscosity of Co3O4/Glycol Nanofluid Measurement

The viscosity and rheological behaviour of nanofluids were obtained by conducting tests
under steady state conditions using a Haake RheoStress 1 rotational rheometer (Thermo Scientific). A cylinders system composed of two concentric cylinders was used. In the gap between the inner cylinder (diameter = 34 mm) and the outer cylinder (diameter = 36.88 mm) the sample was introduced. Before each test, a pre-treatment, in which the samples were submitted to a constant shear stress, was applied to the nanofluids for 30 seconds to ensure similar starting conditions for all the measurements. Used Brookfield DV-III+ Programmable Rheometer. The Brookfield DV-III+ Programmable Rheometer measures fluid parameters of Shear Stress and Viscosity at given Shear Rates. The viscosity of a fluid is a measurement of its resistance to flow. The principle of operation of the DV-III+ is to drive a spindle (which is immersed in the test fluid) through a calibrated spring. The spring deflection measures the fluid’s viscous drag against the spindle. A rotating transducer is used to measure spring deflection. The measuring range of a DV-III+ (in centipoise) is dictated by the spindle’s rotational speed, its size and form, the container in which the spindle is revolving, and the calibrated spring’s full scale torque. The CGS or SI systems are used to display all units of measurement.

- Viscosity appears in units of centipoise (shown as “cP”) or milliPascal-seconds (shown as mPa•s) on the DV-III Rheometer display.
- Shear Stress appears in units of dynes/square centimeter (“D/cm²”) or Newtons/square meter (“N/m²”).
- Shear Rate appears in units of reciprocal seconds (“1/S”).
- Torque appears in units of dyne-centimeters or Newton-meters (shown as percent “%” in both cases) on the DV-III Rheometer display.

3. RESULTS AND DISCUSSION

The Co₃O₄/glycol nanoparticles was characterized by using XRD Diffraction Pattern Graphic in Fig. 1.

The XDR (X-Ray Diffraction) measuring by using EXPLORER, GNR S.r.I, under the condition at room temperature, generator setting 30 mA and40 KV , Cu Kα radiation (K=0.154 nm weave length 1.540598 Å, angle range from 10° - 80° and the XRD(X-Ray Diffraction) peaks were recorded at 2θ in position (2θ= 18.89° , 31.29° , 36.93° , 38.52° , 44.93° , 59.31° and 65.12°). The XRD (X-Ray Diffraction) Fig. 1 is identical to prepared Co₃O₄ nanoparticles. The peak shape and intensity are agreed will with the reported literature.
Fig. 1. XRD Diffraction Pattern Graphic of Co$_3$O$_4$

Fig. 2. Viscosity of Co$_2$O$_3$/glycol in multi shear rate

In different condition where the shear rate 40 and heating range between 0 to 80 the Viscosity of Co$_3$O$_4$/glycol Nano fluid was also measured, the viscosity was decreased according to increase of temperature and take a value in range 3 to 15. It also showed the concentration effect in viscosity in which sample 1 the highest concentration achieves largest viscosity value and sample 4 the lowest concentration recorded less value of viscosity, but sample 3 and sample 4 record same value of viscosity.
Fig. 3. Viscosity of Co2O3/glycol at different temperature and high shear rate

4. CONCLUSION

The Co3O4 Nano fluid was prepared using sol gel method and dispersion of the Co3O4 Nano particles via ultrasonic vibration in glycol. The nanoparticle formed confirmed by XRD Diffraction Pattern Graphic and the obtained XRD data for 26 positions identifies the sample as Co3O4 Nano particles, the d-spacing values, lattice constant and cell volume, all confirm the sample to be Co3O4 Nano particles. The suitable shear rate to study viscosity behavior of Co3O4 Nano fluid was determine by tested the viscosity in wide range of shear rate from 1 to 45 which showed vibrated of viscosity in law shear rate and stabled at shear rate 25. In law shear rate the viscosity was not in harmony behavior, this may be related to the fact that no surfactant or chemical additives were used during Nano fluid preparation. It seems that the enhancement in viscosity does not only depend on the temperature, but also primarily on the volume concentration. The result of viscosity when measured at high shear rate40 and temperature range from 0°C to 80°C showed decreasing in viscosity by increasing of temperature and increases with increasing of nanoparticles concentration until reaches certain concentration.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES


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Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/79371