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Effects of nanoparticles volume fractions on the viscosity of nanofluids prepared from palm kernel shell nanoparticles

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ABSTRACT

In this research, palm kernel shell nanoparticles were produced for nanofluid application and the viscosity of the produced nanofluids was measured. The size of the nanoparticles fabricated is 100nm diameter. This paper presents results on the synthesis of palm kernel shell bio-material to obtain nanoparticles and subsequently produced nanofluids. Nanofluids were prepared using two-step method by dispersing or pouring palm kernel shell- nanoparticles into the base fluid (a binary mixture of Ethylene Glycol (EG) and deionised water (base fluid) in a ratio of 50:50) .An ultrasonic sonicator was used to ensure proper mixtures of different volume fractions (0.3%, 0.6 %, 0.9 % 1.2 % and 1.5%) of palm kernel shell nanoparticles into base fluid (a binary mixture of Ethylene Glycol (EG) and deionised water). A Vibro Viscometer machine (SV-10) was used to measure the viscosity of the prepared nanofluids more easily. For minimum and maximum volume fractions of palm kernel shell nanoparticles (0.3% and 1.5%) in the base fluid, the viscosity was found to be 26 mPa.s and 43 mPa.s, which increases slightly with an increase of particle volume fraction and decreases as the temperature increases. The experimental results show a maximum of 23% increasing of viscosity for 1.5% volume fraction of nanofluids as compared with the base fluid. From the experimental study on prepared nanofluids conducted, results show that all the values of viscosities at different volume fractions of the prepared nanofluids were found to be higher than the values of the base fluids (a binary mixture of Ethylene Glycol (EG) and deionised water). The experiments were conducted at varying temperature range (300C through 700C).

1 Introduction

The Nanofluids are liquid suspensions containing nanometer sized particles, typically solid nanoparticles dispersed in a base fluid like water or oil. These nanoparticles enhance the thermal conductivity and other properties of the fluid, making nanofluids useful in various applications such as cooling systems and heat transfer devices [1], [2]. Viscosity is one of the very important properties of nanofluids which is necessary for the evaluation of heat transfer coefficient. This varies with volume fraction and size of the nanoparticles and temperature of the nanofluid [3]. Many investigations [4-5] have been carried out for obtaining and measuring the viscosity of nanofluids made from metallic or non-metallic nanometers-size particles. However, there is little research on the viscosity of nanofluids made from natural materials and from the literature survey conducted; there is no research on the viscosity of nanofluid made from palm kernel shell nanoparticles.

The need for the use of bio-based nanoparticles and bio-based nanofluids is important to mitigate over-dependence on toxic synthetic nanoparticles. This idea is also in line with renewable and sustainable developmental goals. Moreover, bio-based materials like palm kernel shell constitute environmental waste in some quarters and its conversion to useful products for engineering application will go a long way in solving environmental issues and health hazards. Hence, the need to investigate the viscosity of nanofluids made from bio-materials (palm kernel shell nanoparticles) becomes a paramount importance. In this paper we prepared palm kernel shell nanoparticles to develope nanofluids and subsequently measure the viscosity. Many of the researchers on nanofluids [2, 3, 6, 7, and 8] used different methods to synthesize nanofluids and they underestimate the effective

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viscosity of the nanofluids. It was stated in the literature [9], that nanofluid viscosity significantly increases when particle volume fraction is increased and decreases when temperature increases.

2 Materials and Methods

The materials used for the laboratory experiment are Palm kernel, Powdered Sodium Hydroxide (NaOH), Ethylene Glycol and Deionized water, RADWAG AS 220-R2 Sensitive weighing scale (10mg – 500g, with a precision of 0.01g), ball mill, GAUTRACK POTCH Oven, GAUSTING GT225 Impact Grinder (ball miller), a programmable constant temperature thermal bath (LAUDA ECO RE1225). 24 kHz Hielscher ultrasonic processor (UP200S).

2.1. Preparation of nanoparticles from palm kernel

Palm kernel shells were placed into bucket filled with water to a level such that it will be completely submerged. The bucket was covered to prevent air from entering it; the soaking lasted for two weeks. After the two weeks, the palm kernel shells were removed from the water and washed with fresh water and sundry for two weeks to remove the absorbed water at constant temperature. The sun-dried palm kernel shells were oven-dried at a temperature of 50^0C for 24 hours to ensure that the residual moisture will be completely removed. The dried palm kernel shells were feed into a ball-milling machine and allowed to run steady for two days to obtain palm kernel shell nanoparticles.

The palm kernel shells were crushed thoroughly into very fine particles. 400g of the crushed bio materials shells particles was measured and passed through a thick cotton fabric with a pore size of about 100 nm, of which the nanoparticles were separated from other particles of palm kernel shells larger than 100nm. During the separation process, the nanoparticles pass into a container while particles larger than the cotton fabric's pore size are trapped on the fabric. The separation process was carefully done to ensure that particles obtained after separation are within the size range (<100nm).

The obtained palm kernel shell nanoparticles were characterized using scanning electron microscope (SEM) to show the particle size and morphology of the nanoparticles. and X-ray diffraction (XRD) to determine crystal structure (Anthony et al. 2022). Nanoparticles obtained were washed using caustic alkali (NaOH) of 0.5M to remove impurities such as oil, which would affect the nanofluid mixture. After washing with NaOH, the nanoparticles became basic. Hence, it was neutralized using Sulphur acid of 0.2M. pH indicator papers were used to test for the pH value of the nanoparticle during neutralization until the nanoparticles became neutral.

2.2 Preparation of various volume fractions of nanofluids

A ‘two-step’ method was used in the preparation of nanofluid from the fabricated bio-material nanoparticles since it is better method out of the two common methods in use [10], [11] A known mass of the palm kernel shell nanoparticles corresponding to a predetermined volume concentration were measured and mixed with a binary mixture of Ethylene Glycol (EG) and deionised water(base fluid) in a ratio of 50:50 .Volume fractions of nanofluid obtained ranged from 0.3%-1.5%, with five (5) samples of nanofluid formed for each bio materual nanoparticle. This was achieved using a mathematical model equation to calculate the weight of base fluid (ethylene glycol/ de-ionized water) and nanoparticles required to achieve various volume fractions.

$$Volumetric\ \ fraction, \varphi\ \times 100\ = \frac{\frac{M_P}{\rho_P}}{\frac{M_P}{\rho_P} + \frac{M_f}{\rho_f}} \qquad (1)$$

Where Mp the mass of the nanoparticle is, ρ is the density of the nanoparticle, W_f, is the mass of base fluid and ρf is the density of the base fluid.

The density of the nanoparticles (ρ) was determined by measuring the weight of the nanoparticle for a given volume 1.78 grams of the nanoparticle was determined using a weighing balance as the weight of the nanoparticle for 5 ml. of the nanoparticle, of which the density of the nanoparticle was calculated using equation 2.

$$\rho_p = \frac{\text{mass}}{\text{volume}} \qquad (2)$$

After mixing the various weighed samples of nanoparticles with a measured volume of base fluid to achieve different volume fractions from 0.3-1.5, magnetic stirrer containing a magnetic stirring bar is used to stabilize the nanofluid mixtures for about 90 minutes for each volume fraction. This is to ensure proper mixing of the two phases of the mixture. All samples of the nanofluid were stored in a test tube. The bio-materials nanofluids were prepared by dispersing or pouring different volume fractions (0.3%, 0.6 %, 0.9 % 1.2 % and 1.5%) of palm kernel shell nanoparticles into the base fluid. The nanofluids samples were homogenized by using an ultrasonic sonicator continuously for 40 minutes and the samples were observed for dispersion and stability. The flow chart for bio-material nanofluids preparation is shown in figure 1.

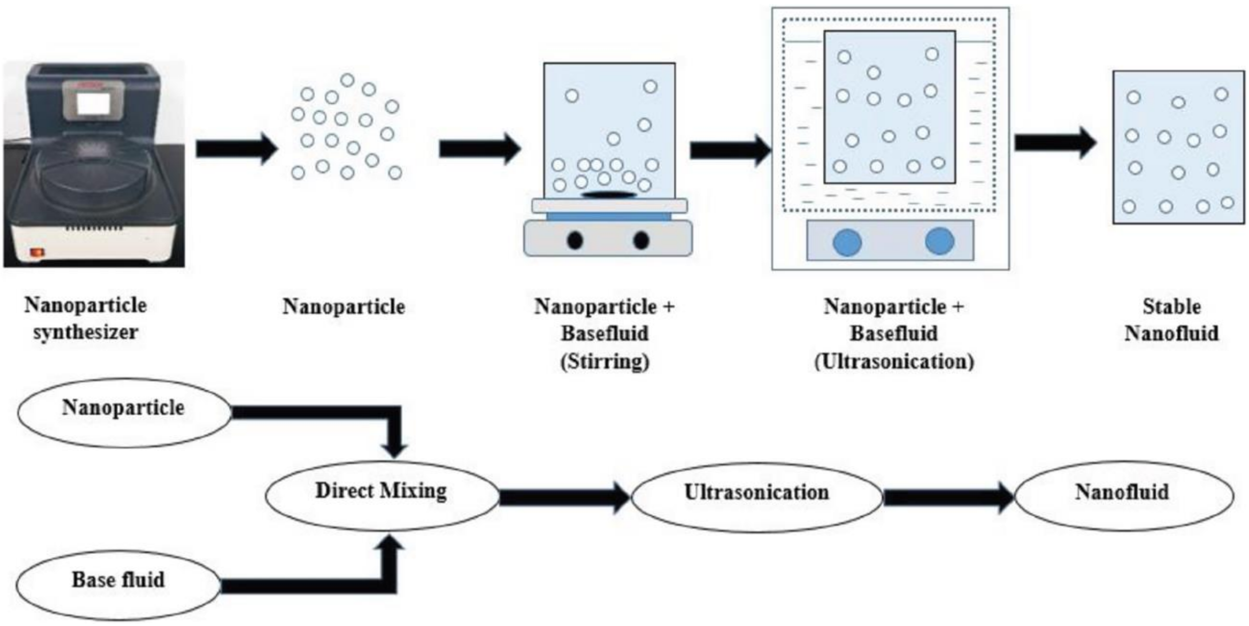

Figure 1: Two-step method of preparation of nanofluids

3. Measurement of viscosity

Viscosity is a measure of a fluids resistance to flow. It is an essential property for various industrial and scientific applications. There are several methods to measure viscosity, each suitable for different types of fluids and precision requirements. In this work the viscosity of the base fluid and the bio-material nanofluids at different volume fractions and at different temperature range were measured using vibro- viscometer. Viscometers are specialized instruments designed to measure viscosity directly.

The viscosity of the base fluid and the palm kernel shell nanofluids at different volume fractions (0.3%, 0.6%, 0.9%, 1.2% 1.5%) and at different temperature (30^{0}C through 70^{0}C) were measured, the results of these experiments are showed in figure 6.

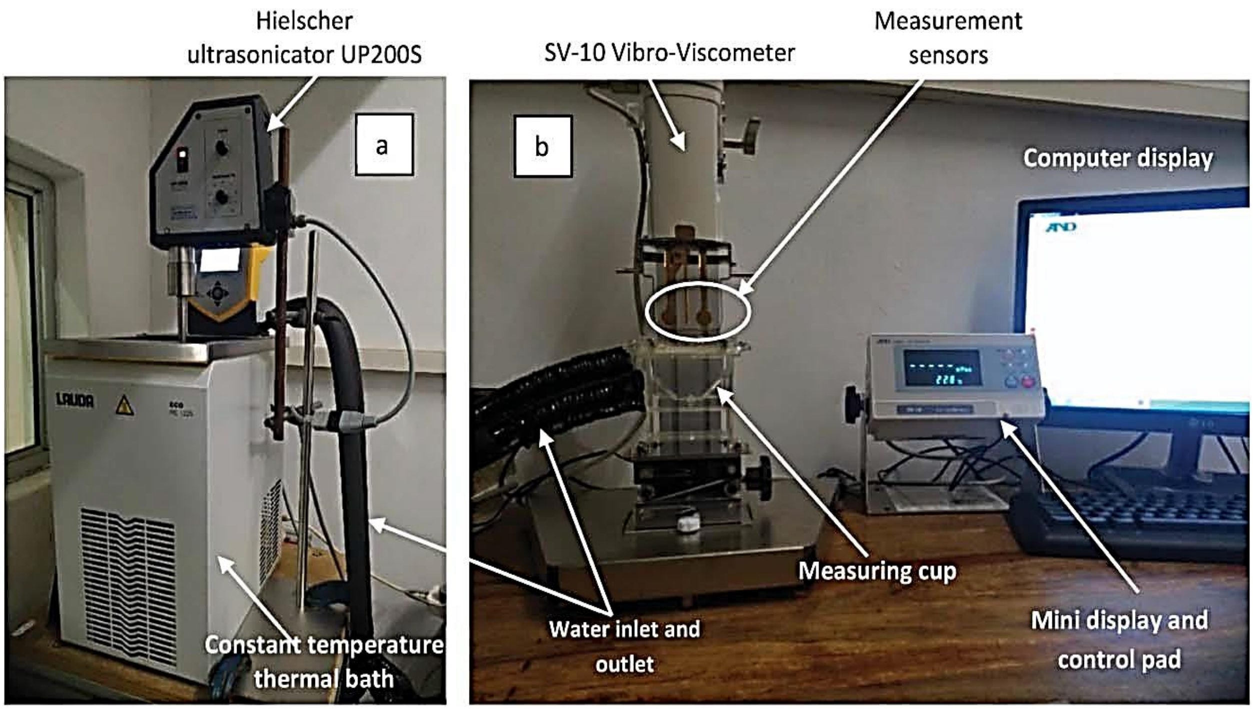

Figure 2: Experimental set up for measurement of viscosity

4. Results and Discussion

The viscosity, which is considered as one of the thermo physical propertied that affect the heat transfer rate was measured in this study, the measurement was carried out at different volume fractions (0.3% 0,6%, 0.9%,1.2%,and 1.5%). For minimum and maximum volume fractions of palm kernel shell nanoparticles (0.3% and 1.5%) in the base fluid, the viscosity was found to be 26 mPa.s and 43 mPa.s, which increases slightly with an increase of particle volume fraction and decreases as the temperature increases.

The experimental results show a maximum of 23% increasing of viscosity for 1.5% volume fraction of nanofluids as compared with the base fluid. The viscosity results of the base fluid obtained in this present study at different temperature(30 through 70^{0}C) are compared with the viscosity of the experimental work at different volume fractions (0.3 %, 0.6%, 0.9%, 1.2 % and 1.5 %). Results showed that the viscosities of the different volume fractions of prepared nanofluids are higher than the viscosity of base fluid as showed in figure 3.

The measured viscosity of the palm kernel shell nanofluids was observed to be decreasing exponentially with an increase in the nanofluid temperature and increases slightly with the increased in the volume fraction. It can also be observed from the results that the trends in the change of viscosity with temperature for all the volume fractions of palm kernel shell nanofluids are similar.

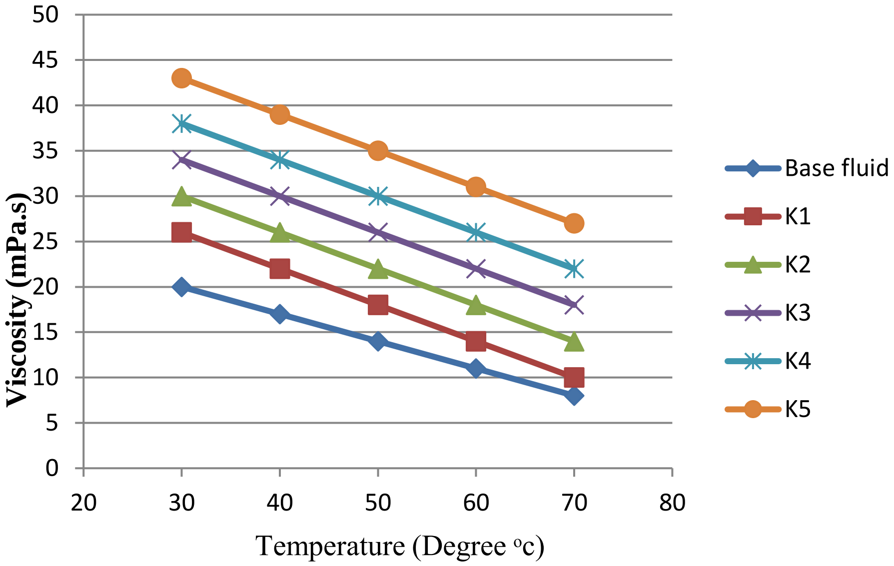

Figure 3: Effects of Temperature and volume fraction on Viscosity of 0.3 - 1.5 % volume fractions concentrations of palm kernel shell nanofluid with Di ionize water/EG (50:50) Base Fluid

K_1 = 0.3% volume fraction of Palm kernel shell nanoparticle
K_2 = 0.6% volume fraction of palm kernel shell nanoparticle
K_3 = 0.9% volume fraction of Palm kernel shell nanoparticle
K_4 = 1.2% volume fraction of Palm kernel shell nanoparticle
K_5 = 1.5% volume fraction of Palm kernel shell nanoparticle

5. Conclusions

In this study, experimental investigations had been carried out to determine the effects of volume fractions and temperature on viscosity of palm kernel shell nanofluids. The study was accomplished by using viscometry machine considering the following parameters: volume fraction and temperature. From the results the viscosity of the prepared palm kernel shell nanofluids was noticed to increase with increase in volume fractions of nanoparticles and exponential decrease with increase in temperature. For maximum volume fraction (1.5%), the increase in the viscosity was found to be 22%.

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