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Enhancement of properties of vegetable oil with γFe_2O_3 nanoparticles

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ABSTRACT – Lubricants are used to reduce friction between contacting surfaces especially involving mechanical parts. In metal cutting processes, there have been considerable effort to develop a lubricant that will aid sustainable machining. The research findings reveal that thermal and oxidative stability of vegetable oil improved significantly and the tribological results that the developed nanolubricants is efficient at reducing friction and wear between contacting surfaces.

1. INTRODUCTION

The The past decades have witnessed tremendous effort towards development of coolants and lubricants that will support sustainable metal cutting process thereby achieving desired product with significant reduction in environmental hazard, energy consumption, waste disposal, manufacturing cost etc. Vegetable oils are considered suitable alternative to petroleum-based lubricants due to their biodegradability, less toxic, environmental friendly and excellent boundary lubricants which enhance efficient interaction between lubricated contacting surfaces [1-3]. The challenges with low oxidative and thermal stability of vegetable oils which affect their efficient performance are improved with modification of base stocks through inclusion of additives, chemical modification [4,5]. Nanoparticles inclusion in base oils is one of the ways with which the properties of the base oils are improved [6, 7] to enhance their performance in lubrication and cooling of manufacturing processes. Base oils have had their properties improved with the dispersion of nanoparticles. The tribological properties and load carrying capacity of lubricating engine oil was substantially enhanced with dispersion of a 70nm hexagonal boron nitride (hBN) at 0.5 vol fraction [7,8]. However, there have been less report on the thermal conductivity enhancement of vegetable oil based nanolubricants. Moreover, there are less report on the investigation of vegetable oil based nanolubricants in comparison to other base fluids and even mineral oils [9]. The current work is aimed at evaluating the thermophysical and tribological properties of an enhanced coconut oil with dispersion of maghemite nanoparticles of less than 10nm in size at three level of concentrations.

2. METHODOLOGY

The maghemite nanoparticle (γ-Fe_2O_3) a member of the iron oxides family was dispersed in coconut oil at three level volume concentrations (0.35, 0.70 and 1.05) weight percent to produce nanolubricants. The mixture was stirred using stirrer before subjecting to homogenous mixing using the silverson L5 series homogenizer. The thermal conductivity, viscosity and tribological properties of the prepared nanolubricants were evaluated using KD2 pro thermal analyser, LVDV-III (low viscosity digital viscometer) ultra-programmable rheometer and four ball (friction) tester respectively.

$$k_{r}=\frac{k_{NL}}{k_{bf}} \quad (1)$$

3. RESULTS AND DISCUSSION

The research focused on the evaluation of the thermo-physical and tribological properties of the nanolubricants in comparison with the pure coconut oil. thermal conductivity, viscosity and wear scar diameter in addition to coefficient of friction were evaluated for the lubricants.

3.1 Thermal conductivity

Thermal conductivity of the coconut oil and the nanolubricants were evaluated with the aid of KD2 pro thermal analyser. For each sample, the measurement is repeated 5 times and an average value is recorded as the thermal conductivity of the lubricant at a temperature under consideration. It was conducted for a temperature range of 30°C to 70°C as presented in Figure 1. The thermal conductivity of nanolubricants are affected by temperature and concentration as the increase of temperature decreases thermal conductivity while increase of concentration increases thermal conductivity. Increase of concentration can improve thermal and oxidative stability of the base fluid**.**

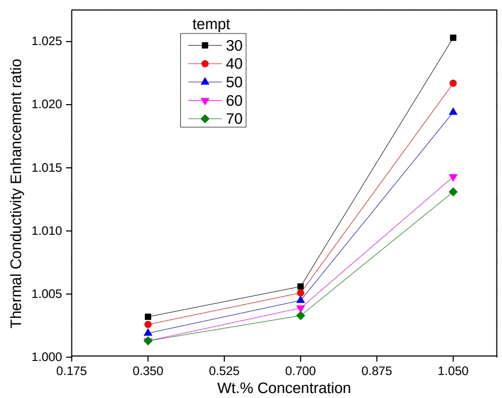

Figure 1 thermal conductivity enhancement ratio for all concentrations under varying temperature.

3.2 Tribological properties

Efficient tribological performance of lubricants is related directly to lubricity when wear and frictions are evaluated. Increase of lubricants viscosity enhanced formation of thicker lubricant film which significantly reduce friction and wear scar diameter. From Figure 2 and Figure 3 shows the effect of temperature and concentration on viscosity and wear scar diameter and coefficient of friction respectively. The increase of concentration improves the viscosity of lubricant that resist free flow which impact positively in reduction of friction and wear scar diameter as seen in Figure 3.

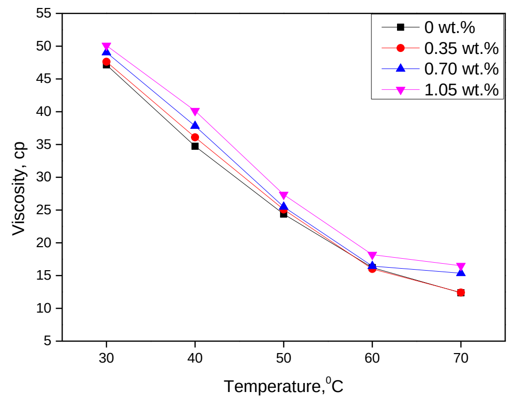

Figure 2 Viscosity of lubricants under varying concentrations and temperature.

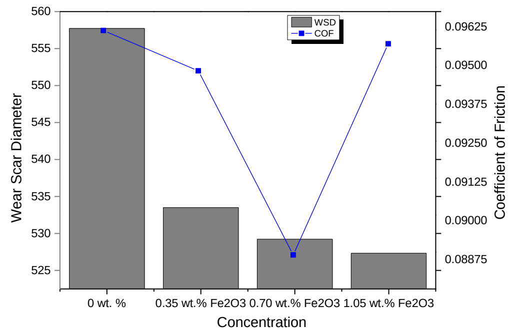

Figure 3 Wear scar diameter (WSD) and coefficient of friction (COF) for different concentrations.

4. CONCLUSION

The properties of an enhanced vegetable oil with nanoparticle have been evaluated in terms of thermal conductivity and tribological properties. From the analysis, the following can conclusions can be reached.

(a) The thermal conductivity of nanolubricants increased with nanoparticle addition which will aid thermal and oxidative stability of the nanolubricants.

(b) The nanolubricants indicated good tribological properties as it shows a reduced wear scar diameter and coefficient of friction. The nanolubricants indicated lower friction coefficient and wear scar diameter compared to the pure base fluid of coconut oil. However, the coefficient of friction increases at highest concentration but lower than the pure vegetable oil.

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