Comparison on tribological properties of vegetable oil upon addition of carbon based nanoparticles

Citation for published version:
Kiu, SSK, Yusup, S, Chok, VS, Taufiq, A, Kamil, RNM, Syahrullail, S & Chin, BLF 2017, 'Comparison on tribological properties of vegetable oil upon addition of carbon based nanoparticles', *IOP Conference Series: Materials Science and Engineering*, vol. 206, no. 1, 012043. https://doi.org/10.1088/1757-899X/206/1/012043

Digital Object Identifier (DOI):
10.1088/1757-899X/206/1/012043

Published In:
IOP Conference Series: Materials Science and Engineering

IOP Conference Series: Materials Science and Engineering

PAPER • **OPEN ACCESS**

Comparison on tribological properties of vegetable oil upon addition of carbon based nanoparticles

To cite this article: S S K Kiu *et al* 2017 *IOP Conf. Ser.: Mater. Sci. Eng.* **206** 012043

IOP Conf. Series: Materials Science and Engineering **206** (2017) 012043 doi:10.1088/1757-899X/206/1/012043

Comparison on tribological properties of vegetable oil upon addition of carbon based nanoparticles

S S K Kiu[1], S Yusup[1], V S Chok[2], A Taufiq[3], R N M Kamil[4], S Syahrullail[5] and B L F Chin[6]

[1] Biomass Processing Laboratory, Center of Biomass and Biofuels Research, MOR Green Technology, Chemical Engineering Department, Universiti Teknologi PETRONAS, Seri Iskandar, 32160 Perak, Malaysia
[2] Chemical Engineering Department, Heriot-Watt University Malaysia, No. 1, Jalan Venna P5/2, Precinct 5, 62200 Putrajaya, Malaysia
[3] Scomi Platinum Sdn. Bhd., LOT15-19 & PT1409, Senawang Industrial Estate, Batu 4, Jalan Tampin, 70450 Seremban, Negeri Sembilan Darul Khusus, Malaysia, Malaysia
[4] Fundamental & Applied Science, Universiti Teknologi PETRONAS, Perak, Malaysia
[5] Faculty of Mechanical Engineering, Universiti Teknologi Malaysia, 81310 UTM Skudai, Johor, Malaysia
[6] Department of Chemical Engineering, Curtin University Sarawak Malaysia, CDT 250, 98009 Miri, Sarawak, Malaysia

E-mail: drsuzana_yusuf@utp.edu.my

Abstract. Carbon-based nanoparticles have gained much interest as lubricant additive due to their remarkable properties in mechanical, chemical and electrical field. In this research, graphene nanosheets (GN), carbon nanotubes (CNT), and graphene oxide (GO) were used as lubricant additives to investigate their effect on tribological properties. Friction coefficient and wear scar diameter were studied as parameters to determine the effectiveness of lubricant. In this study, vegetable oil (VO) was used as base fluid lubricant. GN, CNT and GO were added at 50ppm and 100ppm respectively to VO to study their optimum concentration when compared to pure VO. All nanoparticles were well dispersed by using a homogenizer. Results showed that addition of 50ppm GN has the most positive effect in improving the tribological properties of vegetable oil.

1. Introduction

In recent years, nanofluids have attracted more attention due to its wide range of applications. The main driving force for nanofluids research is cost effective. It is because by adding a relatively small

IOP Conf. Series: Materials Science and Engineering **206** (2017) 012043 doi:10.1088/1757-899X/206/1/012043

quantity of suitable nanoparticles, targeted properties of the base fluid can be improved remarkably. Specifically for lubricant with nano-additives, numerous researchers reported a reduction of coefficient of friction [1], increment in load carrying capacity [2] and reduction of wear [3]. Generally, there are three main differences which distinguish each research on nano-lubricants from one another. For instance, researchers often vary the type of nanoparticles used as additive, types of base fluid used as lubricant, and the homogenization mechanisms between nanoparticles with base fluid. In this study, vegetable oil was selected as lubricant to replace conventional lubricant which generally contains non environmental friendly compounds such as sulphur, phosphor, and chlorine [4]. Biolubricant production using vegetable oil is renewable, cheap, biodegradated and no adverse effects on nature [5].

In this study, graphene nanosheets (GN), carbon nanotubes (CNT), and graphene oxide (GO) were selected as additive in lubricant due to their outstanding performance in improving nanofluid properties [6-8]. A high speed homogenizer was chosen as homogenizing mechanism in this study. It utilized high shear force which promotes mixing between solid and liquid. 50ppm and 100ppm of GN, CNT and GO were added to vegetable oil (VO) to study the optimum concentration of the additives for lowest friction coefficient and wear scar diameter. The tribological properties of nanolubricants were tested using four-ball machine, following ASTM 4172.

2. Materials and Methods

2.1. Materials

GN, CNT, GO nanoparticles and vegetable oil (VO) were purchased from Scomi Sdn. Bhd, a local company which manufactures high performance chemical product. The properties of VO were shown in Table 1.

Table 1. Physical properties of VO

Flash Point	205^{o}C
Density	1100 kg/m^{3}
Iodine Value (Wijs)	56.7
Saponification Value	128.0 mg KOH/g
Kinematic viscosity	455.8 mm^{2}/s (25^{o}C)

2.2. Nanofluids preparation

Six nanofluid samples were prepared in this study. GN, CNT and GO were added to VO at 50ppm and 100ppm respectively. Each sample was homogenized using IKA homogenizer for an hour, at 8000 rpm for one hour. IKA T10 basic homogenizer are used as homogenizing apparatus in this study. It consists of a rotor-stator design with an outerstationary tube and an innerturning rotor which is connected to a motor. The high shearing force was used to provide an intensive mixing between solid and liquid phases. The schematic diagram of IKA T10 homogenizer is as shown in Fig. 1.

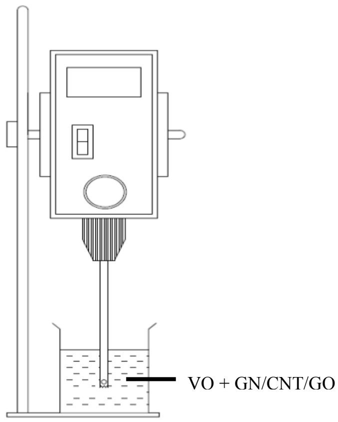

Figure 1. Schematic set-up of high speed homogenizer.

2.3. Four ball test

Pure VO and six prepared nanofluids were tested under ASTM D4172, Wear Preventive Characteristics of Lubricating Fluid (Four-Ball Method) using DUCOM fourball tribotester. Three 12.7 mm diameter steel balls were clamped together and covered with the lubricant to be evaluated as shown in Fig. 2 by following the setup procedure which was discussed by Chiong and his team [9]. By rotating the top ball against three bottom ball at operating condition of 1200 rpm, 75^{o}C, 392N for one hour, wear scar is produced on the contact surfaces of the balls, and the average friction coefficient between the contact surfaces was recorded using Winducom 2010.

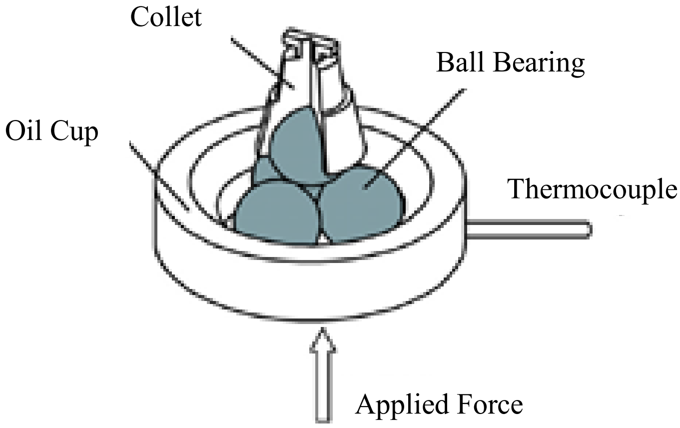

Figure. 2. Schematic diagram of four ball setup in experiment [10]

2.4. Wear Scar Diameter

The wear scar diameter was observed by optical microscope attached to a computer. The measurement of wear scar diameter was carried out with the aid of dimension software. The image and diameter of the wear scar was captured and measured as shown in Fig. 3. The average reading of wear scar diameters for three balls was recorded.

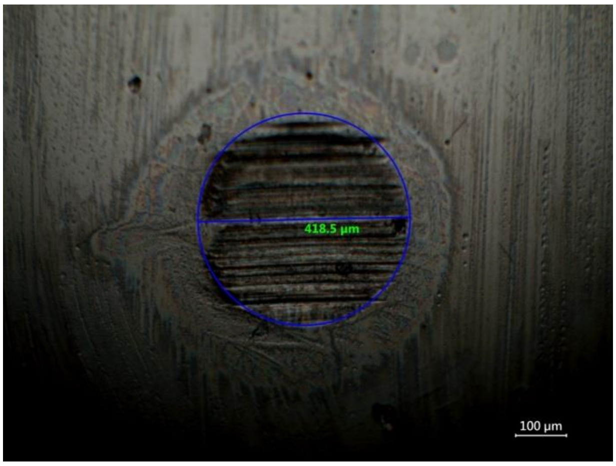

Figure. 3. Wear scar diameter measured on one of the sample ball

3. Results and Discussion

3.1. Nanofluid Dispersion
Fig. 4 showed the dispersion of GN, CNT and GO nanofluid by using high speed homogenizer. There were no observation of sediments of nanoparticles at the bottom of the measuring cylinder after 45 days of observations.

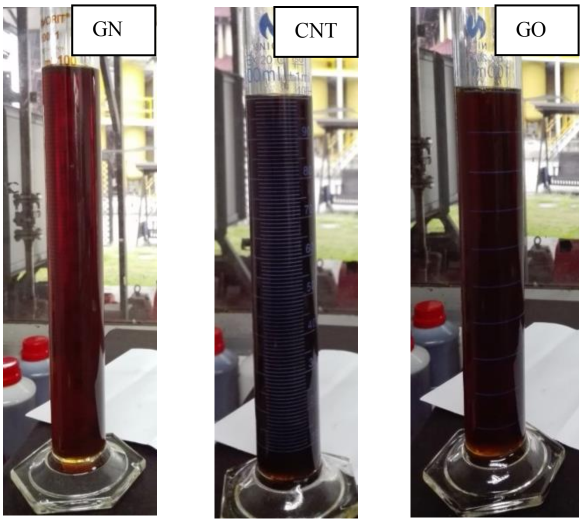

Figure. 4. Samples containing GN (left), CNT (middle) and GO (right) respectively

3.2. Friction Coefficient and Wear Scar Diameter
From Fig. 5 and Fig 6, the addition of GN, CNT and GO recorded unique trend of coefficient of friction and wear scar diameter against increasing concentration of nanoparticles. For GN, friction coefficient and wear scar diameter initially decreased at 50ppm. However, 100ppm concentration showed increment in both friction coefficient and wear scar diameter. Similarly, Eswariah et.al found that friction coefficient initially decreases with increase GN concentration but further increases with higher GN concentration [11]. They concluded that initial decrement in frictional coefficient can be

IOP Conf. Series: Materials Science and Engineering **206** (2017) 012043 doi:10.1088/1757-899X/206/1/012043

attributed to the layered structure of GN and the optimum concentration is 0.025 mg/mL. Since GN are made up of planar structure, it is possible that 100 ppm of GN caused stacking and agglomerations which indirectly caused more wear and friction.

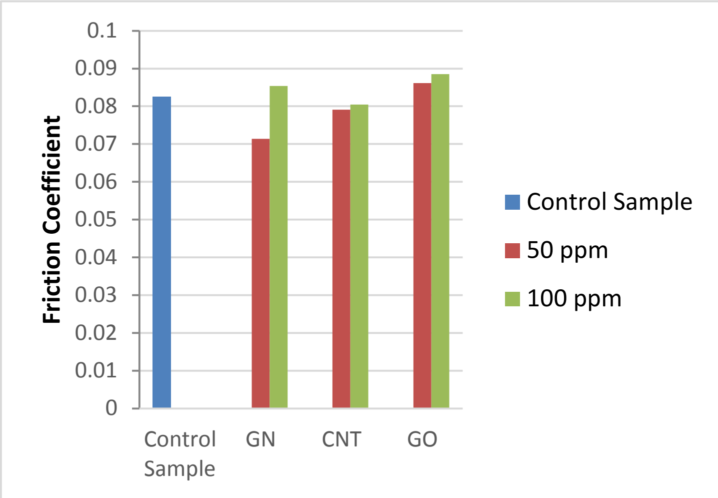

Figure. 5. Friction coefficient against 50ppm and 100ppm GN, CNT, and GO

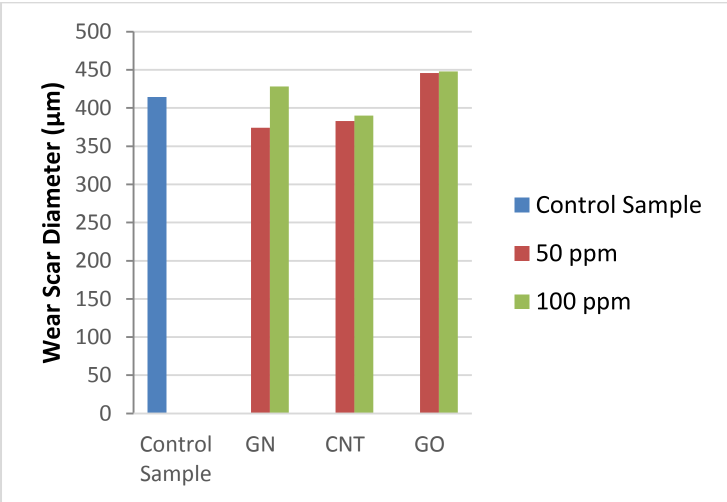

Figure. 6. Wear scar diameter against 50ppm and 100ppm GN, CNT and GO

For CNT, both 50ppm and 100ppm CNT samples showed greater reduced friction coefficient and wear scar diameter as compared to pure VO, which signifies the positive impact of addition of CNT into VO. However, both 50ppm and 100ppm CNT samples showed similar intensity in reducing the friction coefficient and wear value, which signifies the ineffectiveness of increasing concentration from 50ppm to 100ppm. Similarly, Antonio and his colleagues found that by increasing CNT concentration from 0.01 to 0.05 %, the COF value varied from 0.063 to 0.066, which is insignificant as well [9].

Meanwhile, both 50ppm and 100ppm of GO addition recorded higher friction and wear scar diameter than pure VO. It was probably due to the immiscibility of GO with the base fluid. GO have higher tendency to disperse in polar organic solvents due to their functional group on surface such as hydroxyl and carboxyl group [12]. However, VO which made up of long carbon group is non-polar in nature. The difference in polarity causes immiscibility and GO tends to form agglomerates. Hence, more friction and wear were produced. Generally, GO was used as water based lubricant additive [13]. Besides that, other researchers carried out surface modification [14] or mix GO within composite to improve the miscibility of nanoparticles into their base fluid [15] before carrying out tribological studies.

In comparison among six prepared nanofluids and pure VO, 50ppm of GN addition showed the lowest COF and WSD. Therefore, the optimum concentration and most effective nanoparticle type in this study is 50ppm GN.

4. Conclusion

In conclusion, 50ppm of GN addition showed the lowest coefficient of friction and lowest wear scar diameter among all seven samples tested including pure VO. Furthermore, 50ppm of GN showed reduced friction coefficient and wear but further addition up to 100ppm caused higher friction and wear due to stacking of GN. Addition of CNT at both 50ppm and 100ppm demonstrated reduction in friction coefficient and wear, but there are small difference between the two concentrations. On contrary, addition of GO at both 50ppm and 100ppm caused more wear and friction as compared to VO, which is detrimental towards tribological properties of VO. In future, more experiments involving nanoparticles concentration at smaller stepwise increment are needed to understand better the trend for each graphene, graphene oxide and carbon nanotube.

Acknowledgement

The authors wish to thank Universiti Teknologi Petronas, Scomi Sdn. Bhd and Universiti Teknologi Malaysia Mechanical Department for their support during this study. The authors would also like to thank BIOMASS Grant (0153AB-F02) for their financial support to carry out this study.

References

[1] Antonio J, Cornelio C, Andrea P, Hoyos-palacio L M, Lara-romero J & Toro A 2015. Tribological properties of carbon nanotubes as lubricant additive in oil and water for a wheel – rail system ☆. *Integrative Med. Res.* **5** 68–76

[2] Arbain N H & Salimon J 2010. Synthesis And Characterization Of Ester Trimethylolpropane Based Jatropha Curcas Oil As Biolubrificant Base Stocks. *J. of Sci. and Techno.* 47–58.

[3] Chiong I T, Rafiq A K M, Azli Y & Syahrullail S 2012. Tribological behaviour of refined bleached and deodorized palm olein in different loads using a four-ball tribotester. *Scientia Iranica*, **19** 1487–1492

[4] Elomaa O, Singh V K, Iyer A, Hakala T J & Koskinen J 2015. Graphene oxide in water lubrication on diamond-like carbon vs. stainless steel high-load contacts. *Diamond and Related Mat.*, **52** 43–48

[5] Eswaraiah V, Sankaranarayanan V & Ramaprabhu S 2011. Graphene-based engine oil nanofluids for tribological applications. *ACS App. Mat. and Interfaces*, **3** 4221–4227

[6] Ilie F & Covaliu C 2016. Tribological Properties of the Lubricant Containing Titanium Dioxide Nanoparticles as an Additive. *Lubricants*, **4** 1–13

[7] Ing T C, Rafiq M & Kadir A 2011. Experimental Evaluation on Lubricity of RBD Palm Olein Using Fourball Tribotester. *Tribology - Lubricants and Lubrication*, *2011*, 175–185

[8] Jia Z, Pang X, Li H, Ni J & Shao X 2015. Synthesis and wear behavior of oleic acid capped calcium borate/graphene oxide composites. *Tribology Int.* **90** 240–247

[9] Kinoshita H, Nishina Y, Alias A A & Fujii M 2014. Tribological properties of monolayer graphene oxide sheets as water-based lubricant additives. *Carbon*, **66** 720–723

[10] Meng Y, Su F & Chen Y 2015. Synthesis of nano-Cu/graphene oxide composites by supercritical CO2-assisted deposition as a novel material for reducing friction and wear. *Chem. Eng. J.*, **281** 11–19

[11] Peng D X, Kang Y, Hwang R M, Shyr S S & Chang Y P 2009. Tribological properties of diamond and SiO2 nanoparticles added in paraffin. *Tribology Int.*, **42** 911–917
[12] Taha-Tijerina J, Venkataramani D, Aichele C P, Tiwary C S, Smay J E, Mathkar A & Ajayan P M 2015. Quantification of the particle size and stability of graphene oxide in a variety of solvents. *Particle and Particle Systems Characterization*, **32** 334–339
[13] Yang G B, Chai S T, Xiong X J, Zhang S M, Yu L G, & Zhang P Y 2012. Preparation and tribological properties of surface modified Cu nanoparticles. *Trans. of Nonferrous Metals Society of China (English Ed.)*, **22** 366–372
[14] Zhang C, Zhang S, Yu L, Zhang P, Zhang Z & Wu Z 2012. Tribological behavior of 1-methyl-3-hexadecylimidazolium tetrafluoroborate ionic liquid crystal as a neat lubricant and as an additive of liquid paraffin. *Tribology Let.*, **46** 49–54
[15] Zhang W, Zhou M, Zhu H, Tian Y, Wang K, Wei J & Wu D 2011. Tribological properties of oleic acid-modified graphene as lubricant oil additives. *J of Phy. D: App. Phy.* **44** 1–4