Proceedings of Malaysian International Tribology Conference 2015, pp. 205-206, November 2015

Graphene nanoplatelets in bio-based lubricant

S.S.N. Azman*, N.W.M. Zulkifli, H.H. Masjuki

Department of Mechanical Engineering, Faculty of Engineering, University of Malaya, 50603 Kuala Lumpur, Malaysia.

*Corresponding e-mail: safiyahazman@um.edu.my

Keywords: Graphene nanoplatelets; biolubricant; additives

ABSTRACT – This paper investigated the effects of graphene nanoplatelets (GNP) as additives in trimethylolpropane (TMP) ester blended in polyalphaolefin (PAO), where different concentrations of GNP were used and tested on fourball tribotester. Addition of 0.05wt% GNP in PAO resulted in the lowest COF and WSD, thus selected as the optimum concentration of GNP in lubricant to be added in blended lubricants consisting of 85% PAO and 15% TMP. The tribological behaviors of GNP in blended lubricants were studied and frictions were reduced by 4.16% at RT and 3.22% at 75˚C. However, GNP does not behave as wear reducer to the lubricants.

1. INTRODUCTION

Lubricants are widely used in applications such as machining industries, automotive and others. The main characteristics of lubricants are its lubricity, the ability of lubricant to reduce friction that exist between surfaces when they are in relative motion [1]. Due to the increasing awareness of environmental issues, lubricant industry tends to produce more biodegradable and environmental friendly products that can performed as good as commercial lubricants in the market.

The main specialties of bio-based lubricant are its broad availability and renewable resources, make it is easy to be found worldwide. It is also known as environmentally lubricant [2] where the lubricant is capable in reducing the emission of carbon monoxide and hydrocarbon to the surrounding when being used as engine oil [3].

To improve bio-based lubricants performance, additives can be added to the lubricants in order to create more environmentally products with no toxicity labels [1]. Masjuki and Maleque [4] discovered the usage of Palm Oil Methyl Esters (POME) as lubricating oil additives in a two-stroke engine.

The usage of nanoparticles as additive in lubricating oils is emerging in the 21st century due to its unique properties such as the effects of quantum-size, effects of small-size, effects of surface and interface and others [5]. The nanoparticles behave as anti-friction and anti-wear additives since they acted as the spacer between two frictional surfaces [6].

This paper will discuss on the effects of GNP as an additives in biolubricants on the physical and tribological properties. The optimum amount of GNP need to be added in bio-based lubricants also will be determined at the end of this study.

2. METHODOLOGY

2.1 *Samples Preparation and Test Procedures*

Lubricants used in this study were polyalphaolefin (PAO), synthetic mineral-based oil and palm oil trimethylolpropane (TMP) ester, a bio-based lubricant. The additive used was graphene nanoplatelets (GNP) with ≈5nm thickness and 120m^2/g surface area.

GNP were added to PAO at 0.01wt%, 0.03wt%, 0.05wt%, 0.1wt%, 0.2wt%, 1wt%, 3wt% and 5wt% and mixed ultrasonically for 1 hour. The concentrations were selected to illustrate low, medium and high concentration of nanoparticles in lubricants.

The nanofluids were then tested for 1 hour on fourball tribotester at 392N load, room temperature (RT) and 1200rpm speed to investigate their tribological behavior and to select the optimum GNP concentration in lubricants.

85% of PAO was blended with 15% TMP ester before mixed with GNP at the optimum concentration. The bio-based nanolubricant was then tested on fourball tribotester for 1 hour using 392N load and 1200rpm speed at RT and at 75˚C. The friction coefficients (COF) and wear scar diameters (WSD) were evaluated and further surface characterizations were done using SEM and EDX on the steel balls to analyze the wear behaviours.

3. RESULTS AND DISCUSSION

Figure 1 shows the COF and WSD of GNP added into PAO at different concentrations. Addition of 0.05wt% GNP showed the greatest COF and WSD reduction compared to other concentrations. This result was consistent with studies conducted by Kheireddin, et al. [7] and Zen and W. [8]. Even though 5wt% GNP shows the least COF, but WSD does not showed any improvement. This might be due to the GNP acted as ball bearing but in the same time, agglomerations which caused by high concentration of GNP resulted in abrasive-like wear to happen [7]. This also proved that addition of nanoparticles might cause deleterious effects in some cases either by increasing COF or WSD [9].

As in Figure 2, 0.05wt% GNP added into 85PAO15TMP showed reductions in COF but no obvious improvement can be seen at WSD values for both temperatures. Thus, it can be said that GNP can act as a friction reducer in bio-based lubricants but not as anti-wear additives.

Figure 3 presented the SEM and EDX analysis on the steel balls. Balls b) and c) showed more visible groove as compared to ball a). This proved that GNP as additives does not improve anti-wear ability of the biolubricants.

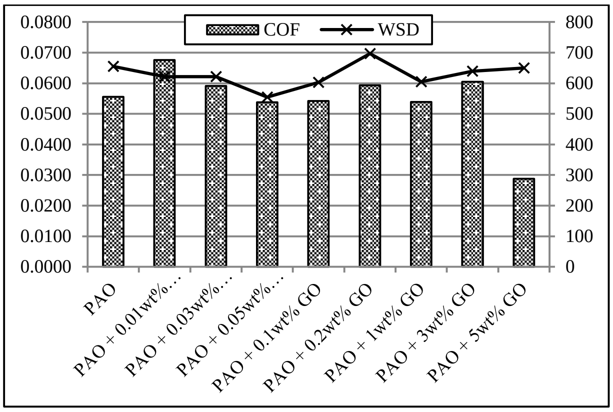

Figure 1 COF and WSD of GNP added into PAO at different concentrations.

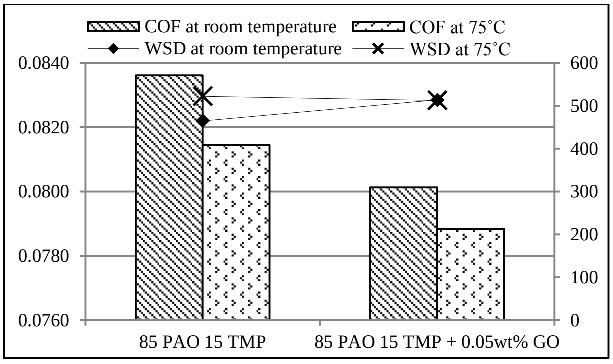

Figure 2 COF and WSD of 85PAO15TMP with and without GNP at RT and 75˚C.

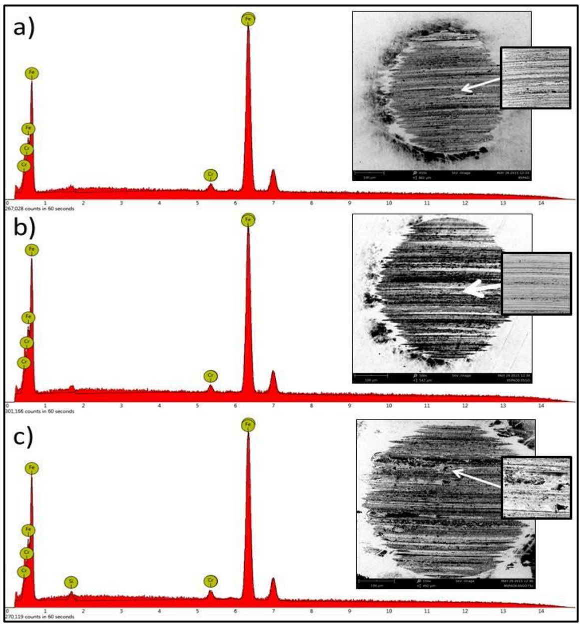

Figure 3: SEM and EDX analysis of scars from a) 85PAO15TMP at RT, b) 85PAO15TMP + 0.05wt% GO at RT and c) 85PAO15TMP + 0.05wt% GO at 75˚C.

4. CONCLUSIONS

0.05wt% of GNP in lubricant resulted in the smallest COF and WSD and addition of the optimum amount of GNP into blended lubricants exhibit better friction reduction ability but does not behave as an anti-wear reducer. Further researches need to be done to investigate the mechanisms of film forming, load carrying capacity and etc. of the GNP as additive in biolubricants.

5. ACKNOWLEDGEMENT

The financial support provided by FP032-2013A, high impact research grant UM.C/HIR/MOHE/ENG/60 and BK062-2014 is gratefully acknowledged.

6. REFERENCES

[1] H. S. Abdalla and S. Patel, "The performance and oxidation stability of sustainable metalworking fluid derived from vegetable extracts," *Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture,* vol. 220, pp. 2027-2040, December 1, 2006 2006.

[2] H. H. Masjuki, M. A. Kalam, M. F. Nurul, M. H. Jayed, A. M. Liaquat, and M. Varman, "Environmentally friendly bio-lubricant lubricity testing," in *Clean Energy and Technology (CET), 2011 IEEE First Conference on*, 2011, pp. 140-144.

[3] H. H. Masjuki, M. A. Maleque, A. Kubo, and T. Nonaka, "Palm oil and mineral oil based lubricants—their tribological and emission performance," *Tribology International,* vol. 32, pp. 305-314, 6// 1999.

[4] H. H. Masjuki and M. A. Maleque, "Wear, Performance and Emissions of a Two-Stroke Engine Running on Palm Oil Methyl Ester Blended Lubricant," *Proceedings of the Institution of Mechanical Engineers, Part J: Journal of Engineering Tribology,* vol. 210, pp. 213-219, December 1, 1996 1996.

[5] Q. Xue, W. Liu, and Z. Zhang, "Friction and wear properties of a surface-modified TiO2 nanoparticle as an additive in liquid paraffin," *Wear,* vol. 213, pp. 29-32, 12/30/ 1997.

[6] T. Xu, J. Zhao, and K. Xu, "The ball-bearing effect of diamond nanoparticles as an oil additive," *Journal of Physics D: Applied Physics,* vol. 29, p. 2932, 1996.

[7] B. A. Kheireddin, W. Lu, I. C. Chen, and M. Akbulut, "Inorganic nanoparticle-based ionic liquid lubricants," *Wear,* vol. 303, pp. 185-190, 6/15/ 2013.

[8] A. G. Zen and R. G. W., "Tribological Evaluation of Nano Graphene Platelets as an Additive to Biolubricant Base Fluid," presented at the Engineering Undergraduate Research Catalyst Conference 2013, Malaysia, 2013.

[9] J. E. Fernandez, J. L. Viesca, and A. Hernandez Battez, "Tribological behaviour of copper oxide nanoparticle suspension," in *Lubrication Management and Technology Conference & Exhibition*, San Sebastian, Spain, 2008.