Proceedings of Malaysian International Tribology Conference 2015, pp. 209-210, November 2015

The feasibility study of $CaCO_3$ derived from cockleshell as nanoparticle in chemically modified lubricant

N.A. Zainal[1], N.W.M. Zulkifli[1,*], M. Yusoff[1], H.H. Masjuki[1], R. Yunus[2]

[1)] Department of Mechanical Engineering, University of Malaya, Kuala Lumpur 50603, Malaysia.
[2)] Institute of Advanced Technology, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia.

[*]Corresponding e-mail: nurinmz@um.edu.my

Keywords: nanoparticles; green lubricant; calcium carbonate

ABSTRACT – Calcium carbonate ($CaCO_3$) is one of the most abundant minerals in nature. $CaCO_3$ nanoparticles were synthesized from cockle shells. The tribological properties of the $CaCO_3$ nanoparticles as an additive in bio-based lubricant were evaluated with a four-ball tester. The bio-based lubricant is a mixture of PAO and 5% palm oil-based TMP ester. The results show that these $CaCO_3$ nanoparticles improved the tribological properties of bio-based lubricant. The optimum concentration of $CaCO_3$ nanoparticles is 8 wt.%. The results show that a boundary film mainly composed of $CaCO_3$, CaO, and iron oxide was formed on the worn surface during the friction process to protect the surface.

1. INTRODUCTION

In recent years, many studies related to automotive have been looked in the ways to improve the performance of engine and its efficiency. In tribology, nanoparticles can be categorized as a new low friction technology and a method to improve the anti-wear properties. These nanoparticles were added into the lubricating oil to improve friction-reduction and anti-wear properties and due to its nanometer size, it permits them to enter the contact area between surfaces easily [1].

Green additives have received more attention in recent years, especially calcium carbonate ($CaCO_3$) because it is not likely to give any potential threat to environment. Previous researchers have reported the addition of $CaCO_3$ nanoparticles as an oil additive in lithium grease [2] and polyalphaolefin (PAO) [3], which show a great performance in wear and friction reduction properties. Calcium carbonate nanoparticles can be prepared by carbonation method, which has been widely used in many studies to obtain $CaCO_3$ [2, 4]. Besides that, the solution route, via double decomposition reaction, also been practiced in some studies to obtain $CaCO_3$ nanoparticles [5]. However, in this paper, $CaCO_3$ nanoparticles were synthesized from its natural reservoirs such as cockle shells, which a simple, low-cost and environmental friendly method. This easy-to-perform method produces pure nanoparticles powder [6]. The blended bio-based lubricant consisted of 5% palm oil- based TMP ester in volume basis with PAO because this is the optimum percentage of TMP ester in PAO [7].

2. METHODOLOGY

2.1 *Material Preparation of $CaCO_3$ Nanoparticles*

Approximately 250 gm of cockle shells were washed and scrubbed to remove dirt, boiled for 10 minutes and then cooled at room temperature. This allows the shell and flesh to be separated easily. The shells were then washed thoroughly with the distilled water and dried for seven days at 50℃ in an oven. Small pieces of aggregate were finally grounded into powder form by using a blender machine. The powders were sieved using 45 µm using a stainless steel laboratory test sieve. To synthesis nanoparticles, 5 grams of micron-sized cockle shells powders were placed into a conical flask and 50 ml of distilled water were added to form slurry, also 2 ml of dodecyl dimethyl betaine (BS-12). The mixtures were stirred and the collected samples were separated from the mother liquid using a filter paper and the final products were dried for 1 day in an oven [6].

2.2 *Preparation of Bio-Based Nanolubricant*

The blended bio-based lubricant consisted of 5% palm oil- based TMP ester in volume basis with PAO was mixed with different concentrations of $CaCO_3$ nanoparticles. It is mixed by mechanical stirring.

2.3 *Four-Ball Test*

The effect of $CaCO_3$ nanoparticles as an additive on the tribological properties of bio-based lubricant were investigated through a series of four-ball friction tests. The four-ball wear tester consists of three balls held stationary in a ball pot plus a fourth ball held in a rotating spindle as shown in Figure 1. The test conditions were 40 kg for load, operating temperature is at room temperature, rotational speed of 1200 rpm and operation time is 60 minutes.

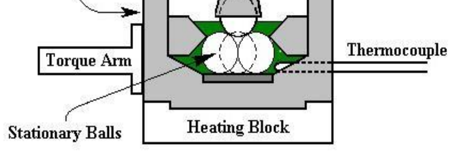


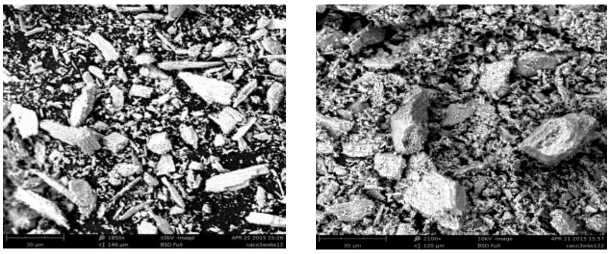
Figure 1 Schematic of four-ball test machine.

2.4 Surface Analysis

The worn surfaces of the lower steel balls were investigated by using scanning electron microscope (SEM) equipped with energy dispersive X-ray analyzer (EDX).

2 RESULTS AND DISCUSSION

From SEM analysis, the cockle shells powder has rod-like shaped, orthorhombic crystals. The presence of BS-12 probably catalyzed the breakdown of bigger particles into smaller ones through the improvement of inter particle adhesiveness [6].



(a) (b)

Figure 2 SEM images of cockle shells powders before (a) and after (b) the addition BS-12.

Based on Figure 3, bio-based lubricant added with $CaCO_3$ nanoparticles reduced coefficient of friction (CoF) and wear scar diameter (WSD) compared to bio-based lubricant alone. From the graph, the CoF of bio-based lubricant alone is 0.08813 and the lowest CoF can be achieved is 0.07088, with the addition of 8 wt.% $CaCO_3$ nanoparticles and it is reduced by 19.57%. On the other hand, WSD for bio-based lubricant alone is 547.99 μm while the lowest WSD achieved from this test is 447.21 μm. The addition of 8 wt.% $CaCO_3$ nanoparticles reduced the WSD by 18.39%. Thus, the optimum concentration of $CaCO_3$ nanoparticles is 8 wt.%. It can be highlighted that bio-based lubricant with the addition of $CaCO_3$ nanoparticles as an additive can be used as friction reducer and improve the anti-wear properties of bio-based lubricant.

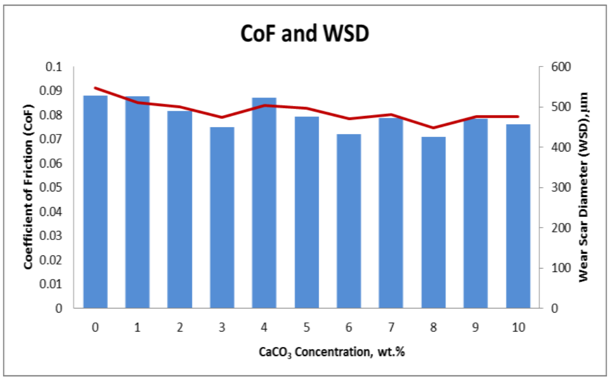


Figure 3 CoF and WSD with different $CaCO_3$ concentrations in bio-based lubricant.

During the friction process, $CaCO_3$ may be nanoparticles deposited on the surfaces, forming a boundary film. Based on SEM and EDX analyses of the worn surface, it can be seen that the boundary film was composed of $CaCO_3$ nanoparticles, CaO, and iron oxide [2]. The tribo-chemical reaction film is consisted of absorbed organic materials coming from additives or bio-based lubricant itself, CaO, and iron oxide, which acts as solid lubricants during the friction process. This results in good tribological behavior on the rubbing surface of the friction pair. Hence, the deposits of $CaCO_3$ nanoparticles and tribo-chemical reaction products on the worn surface improve the tribological properties of bio-based lubricant [2, 3].

3 CONCLUSIONS

In conclusion, the CoF and WSD for bio-based lubricant were higher than bio-based lubricant with $CaCO_3$ nanoparticles as an additive. It shows that lubricant with the addition of $CaCO_3$ nanoparticles can reduce the friction and improve anti-wear properties. It can be seen that the optimum concentration of $CaCO_3$ nanoparticles as an additive in bio-based lubricant is 8 wt.%, where it reduced the CoF and WSD by 19.67% and 18.39%, compared to bio-based lubricant alone. The boundary film was composed of CaCO3 nanoparticles, CaO, and iron oxide.

4 REFERENCES

[1] M. I. H. C. Abdullah, M. F. Abdollah, H. Amiruddin, N. Tamaldin, and N. R. M. Nuri, "Effect of hBN/Al_2O_3 Nanoparticle Additives on the Tribological Performance of Engine Oil," *Jurnal Teknologi,* vol. 66, pp. 1-6, 2014.

[2] X. Ji, Y. Chen, G. Zhao, X. Wang, and W. Liu, "Tribological Properties of CaCO3 Nanoparticles as an Additive in Lithium Grease," *Tribology Letters*, vol. 41, pp. 113-119, 2011/01/01 2011.

[3] M. Zhang, X. Wang, X. Fu, and Y. Xia, "Performance and anti-wear mechanism of CaCO3 nanoparticles as a green additive in poly-alpha-olefin," *Tribology International,* vol. 42, pp. 1029-1039, 7// 2009.

[4] C. Wang, J. Zhao, X. Zhao, H. Bala, and Z. Wang, "Synthesis of nanosized calcium carbonate (aragonite) via a polyacrylamide inducing process," *Powder Technology,* vol. 163, pp. 134-138, 4/28/ 2006.

[5] J. Chen and L. Xiang, "Controllable synthesis of calcium carbonate polymorphs at different temperatures," *Powder Technology,* vol. 189, pp. 64-69, 1/25/ 2009.

[6] K. N. Islam, A. B. Z. Zuki, M. E. Ali, M. Z. Bin Hussein, M. M. Noordin, M. Y. Loqman, *et al.*, "Facile Synthesis of Calcium Carbonate Nanoparticles from Cockle Shells," *Journal of Nanomaterials,* vol. 2012, p. 5, 2012.

[7] J. E. Fernández Rico, A. Hernández Battez, and D. García Cuervo, "Wear prevention characteristics of binary oil mixtures," *Wear,* vol. 253, pp. 827-831, 10// 2002.