Proceedings of Mechanical Engineering Research Day 2018, pp. 111-112, May 2018

Optimization of tribological performance for filtration waste cooking oil enhance by ZrO_2 and graphite nanoparticle

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Keywords: Bio-lubricant; optimization; friction

ABSTRACT – Nowadays, nanoparticles have an important role as a friction reducer and wear behaviour due to their ability to be replaced as new additives. The aim of this study is to optimize the tribological performance of the new develop bio-lubricant from waste cooking oil (vegetable oil) by adding the additives of nanoparticles (ZrO_2 and graphite) with surfactant agent (oleic agent). A set of nano-oil was prepared according to L_9 Taguchi array by using ultrasonic homogenizer. A tribological test was conducted using a four-ball tester. The results show that the lowest coefficient of friction (COF), 0.0507 and the wear scar diameter obtained was 0.576 µm.

1. INTRODUCTION

The increase of ecological concern inspires current researcher to go for renewable sources as a new raw material in lubricant industry. Waste cooking oil is one of the raw materials that can be produced as a new renewable source due to huge quantities of this oils available throughout the world. The main issues for waste cooking oil are that the disposal problem due to slow degradation, and possibly contamination occur on water and land resources. According to Biresaw [1], some refinery and modification process on waste cooking oil can be used as a multi-purpose lubricant. Currently, vegetable oil gains popularity in lubricant industry because it has a potential to be used as a lubricant.

Furthermore, vegetable oil obtains high lubricity, high flash point, good viscosity index, bio-degradability, low toxicity and low evaporative loss. By adding nanoparticles agent as an additive, it is believed that the vegetable oil can be improved as a new lubricant. Nanoparticles agents that normally used are zirconia, ZrO_2 and graphite, while the surfactant agent is oleic acid. Nanoparticles currently are among the most demanded and promising additives, where low concentration between 0.2 vol.% and 3 vol.% are added into lubricating oil that can improve the tribological performance [2].

Therefore, in this study, it is importance to investigate the effect of the different composition of nanoparticles and surfactant towards friction properties on the waste cooking oil.

2. METHODOLOGY

2.1 Design of Experiment (DOE) Taguchi L_9

Taguchi method which consisting of L_9 orthogonal arrays was used in this study. Table 1 shows the DOE with L_9 orthogonal arrays using Minitab statistical software.

Table 1 DOE with L_9 (3^3) orthogonal arrays.

Test	ZrO_2 (vol.%)	Graphite (vol.%)	Surfactant (vol.%)
1	0.1	0.1	0
2	0.1	0.3	0.1
3	0.1	0.5	0.3
4	0.3	0.1	0.1
5	0.3	0.3	0.3
6	0.3	0.5	0
7	0.5	0.1	0.3
8	0.5	0.3	0
9	0.5	0.5	0.1

2.2 Sample preparation

The filtration process was conducted by using paper filter apparatus. For this experiment, the filtration process for the waste cooking oil sample was conducted according to ASTM D7317. Based on the DOE shown in Table 1, the nine sample of nano-oil were mixed by using ultrasonic homogenizer for 30 minutes with 50% amplitude and 0.5 active time interval for 30 minutes as shown in Figure 1.

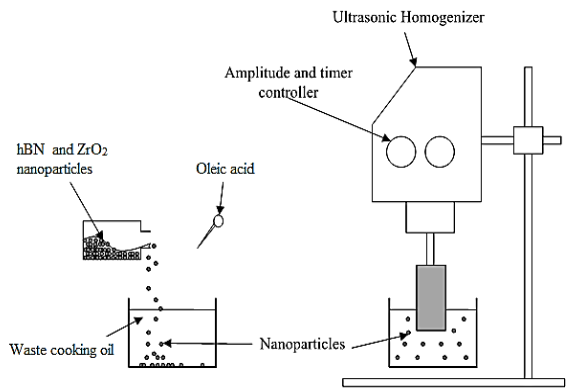

Figure 1 Schematic diagram sample preparation by using ultrasonic method [3].

2.3 Sample testing

The tribological testing was carried out to determine the coefficient of friction (COF) using four-ball tribo-tester. The testing was followed according to ASTM D4172 procedures. The worn image was capture by using SEM.

3. RESULTS AND DISCUSSION

According to Mat Tahir [4] response variation by using signal-to-noise (SN) ratio is important due to uncontrollable parameters, and it can result in the minimization of quality characteristic variation. Figure 2 shows a greater SN ratio value corresponds to a better performance (i.e. low COF) where the optimum parameter obtained is 2 1 1. The optimum parameter for ZrO_2 was obtained by level 2, graphite level 1 and the surfactant agent at level 1, which are equivalent to ZrO_2 (0.3 vol%), graphite (0.1 vol%) and oleic acid (0 vol%).

Figure 3 shows the graph of COF for optimization results compared with the lowest and highest average COF from the nine nano-oil samples. The optimized value approaching the lowest value obtained from the nine samples. According to the Abdullah [5], most of any 4-ball testing, in the early stage the COF will be higher due to frictional force impact between both surfaces but the main reason of COF value still higher (sample 4) maybe due to lubricant film breakage.

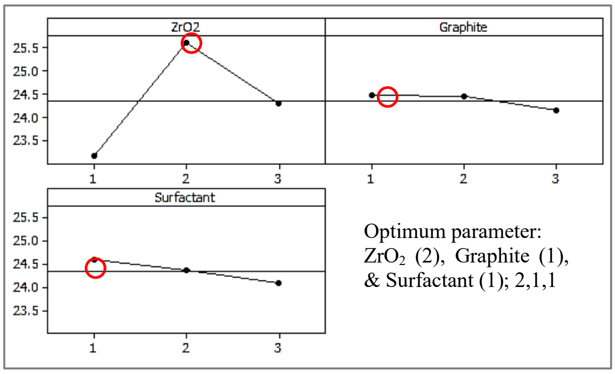

Figure 2 Main effects plot for S/N ratio.

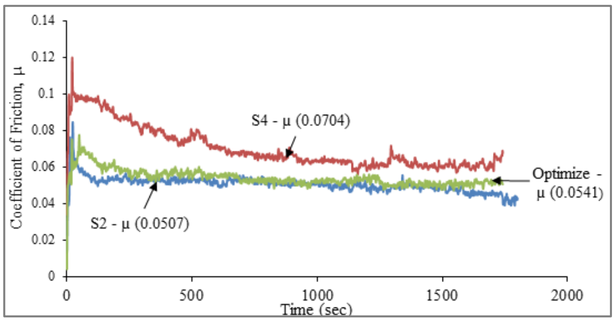

Figure 3 CoF for optimized sample.

Figure 4 shows the highest average of wear scar diameter obtained was by sample 4 with the value of 859.5µm. The lowest average of wear scar diameter obtained by sample 2 with the value of 576.0 µm, meanwhile, the optimum average is 596.4 µm. The patent was like friction behavior where normally friction and wear are directly proportional.

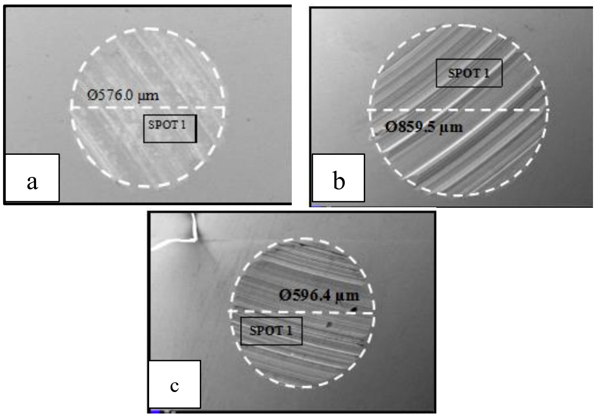

Figure 4 SEM micrograph of worn surfaces on a ball bearing under lubricated conditions of (a) sample 2, (b) Sample 4 and (c) optimized sample.

4. CONCLUSION

In conclusion, Sample 2 shows the lowest average of COF (0.0507µ) indicated that the composition ZrO_2 (0.1 vol.%), graphite (0.3 vol.%) and surfactant agent (0.1 vol.%) much better compare to optimized value. The newly found results would encourage further studies on green bio-lubricants.

ACKNOWLEDGEMENT

The author would like to thank Universiti Teknikal Malaysia Melaka for funding this research under Short Grant Scheme PJP/2015/FTK(13A)/S01418.

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