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The effect of titanium dioxide nanoparticles on bio-lubricant film thickness using ultrasonic reflection

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ABSTRACT – The ability to separate the bearing surfaces from being contact is required in order to avoid from collapsed. Ultrasound has been developed as a technique to determine the thickness of lubricant films. Using quasi-static theoretical model, reflection response from an oil film are determined. In this study, the effect of TiO_2 nanoparticles on bio-lubricant film-thickness were investigated. The ultrasonic equipment was used to determine reflection coefficient and subsequently investigate the corresponding film thickness. Based on the results, it was found that corn oil have better film thickness compared to the canola oil. A difference of 13.7% reduction in the film thickness between corn oil and canola oil was recorded.

1. INTRODUCTION

Fluid film lubrication is necessary in order to separate the bearing surfaces from being contact. The consequence of film failure is due to insufficient thickness of fluid film to provide smooth moving surfaces that may lead to friction and wear process. In the industry application, monitoring and inspection have achieved by the measurement of operating temperature, signals from vibration or acoustic emission. However, this method only measured the effect of an already partially ruined bearing. The common failure phenomena of bearing during elevated temperature caused by contact between bearing surfaces, followed by fluid film no longer entrained as effectively, surface cracks, machine vibrate and finally the bearing no longer prolonged [1].

The measurement of film- thickness of lubricant provides a quantitative technique on prediction of the performance of bearing, before actual bearing is collapsed [1]. There are some typical methods accessible for the lubricant film-thickness measurement such as resistance [2] and capacitance methods [3, 4]. In comparison with the method mentioned above, the ultrasound method [5, 6] is used to determine the film thickness in this experiment.

Some researchers have used reflection coefficient measurement from ultrasonic pulse to characterize the properties of lubricant films in journal bearing and pad-thrust bearing [7 – 8].

There are some approaches to calculate lubricant-film thickness using reflected signals: time of flight (TOF), the resonant-layer model and spring- layer model. Assuming that the media have identical acoustic properties and the wave is normally incident, the film thickness can be measure using quasistatic spring model [8, 9]. This assumptions leads to following equations relating film thickness to the amplitude of the reflection coefficient as a function of frequency, $|R(f|$:

$$h = \frac{\rho c^2}{\pi f z}\sqrt{\frac{R(f)^2}{1-R(f)^2}} \qquad (1)$$

where ρ is the density of the lubricant, and z is the acoustic impedance of the media surrounding the lubricant film. It is not possible to measure the reflection coefficient directly as the input amplitude. Hence, the measurement proceeds by comparing signal reflected from the interface to a known reference interface:

$$R(f) = \frac{A_m(f)}{A_{ref}(f)} R_{ref} \qquad (2)$$

where $A_m(f)$ is the amplitude of the signal reflected from the layer, $A_{ref}(f)$ is the amplitude of the reference signal and R_{ref} is the reflection coefficient of the reference interface. The reflection coefficient from equation (2) could be used in equation (1) to determine the lubricant film thickness assuming all material constants and acoustic properties are known.

2. BIOLUBRICANT WITH NANOPARTICLE ADDITIVE

The conventional lubricants nowadays are related to environmental and toxicity problem. Numerous researches have been done on development of environmental friendly lubricants due to their high cost and poor biodegradability. Besides that, environmental legislation discourages the use of mineral-oil based lubricant and environmental-harmful additives. Hence, there has been increasing demand for green lubricants and lubricant additive in recent years.

Vegetable oils are good alternative resources because of their environmental friendly and non- toxic such as rapeseed oil, canola oil and palm oil. In order to enhance the performance of vegetable oils, additive plays a major contribution to the performance of lubricants especially nanoparticles additives. Several studies show that nanoparticles deposited at contact area and improve the tribological properties of the base oil. It also known that nanoparticles exhibit good characteristics even at less than 2 wt% of concentrations [10].

3. APPARATUS AND MEASUREMENT

Figure 1 shows the ultrasound equipment deployed and the corresponding schematic diagram. A static oil film was created by sandwiching a drop of oil between two sheets of float perspex of 1cm in thickness each (as shown in figure 1). The oil drop was pressed into a circle between the two plates. In this experiment, two types of oils are used which is canola oil and corn oil. Each oil is added with titanium dioxide (TiO_2) with different concentration from 0.1 wt% to 1.0 wt%.

Figure 1

Figure 2

Figure 3

Figure 1 Types of bio-lubricant: canola oil and corn oil.
Figure 2 Oil drop sandwiched between two sheets of Perspex.
Figure 3 Titanium dioxide (TiO_2) nanoparticles.

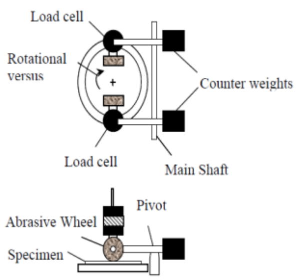

Figure 1 Abrasion Resistance Tester and the schematic diagram

4. RESULT AND DISCUSSION

The time-domain signals were converted to the frequency domain using an FFT to obtain the amplitude (shown in figure 4 and 5). The equation (2) was then used to calculate reflection coefficient for each percentage of concentration of titanium dioxide for different bio-lubricant. The results for reflection coefficient at different concentration of titanium dioxide for different types of bio-lubricant are shown in Figure 6 and 7 respectively.

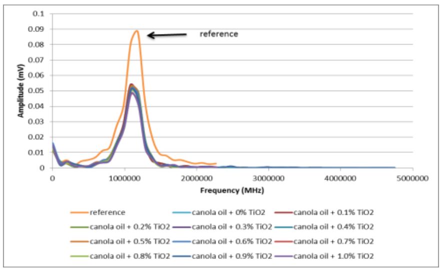

Figure 4 Amplitude spectra of reflected pulses from series of static canola oil with TiO_2 nanoparticles and the reference pulse (incident signal).

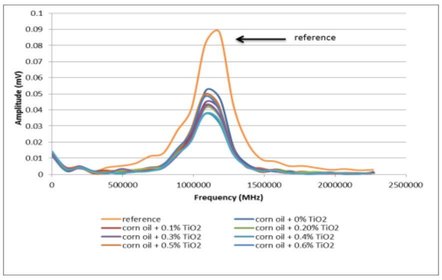

Figure 5 Amplitude spectra of reflected pulses from series of static corn oil with TiO_2 nanoparticles and the reference pulse (incident signal).

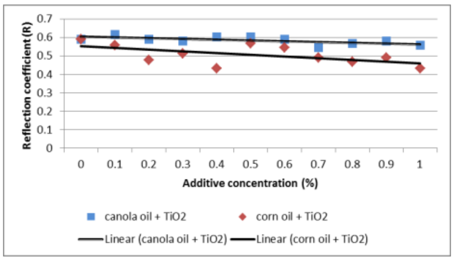

Figure 6 Reflection coefficient at different concentration of titanium dioxide of different bio-lubricant.

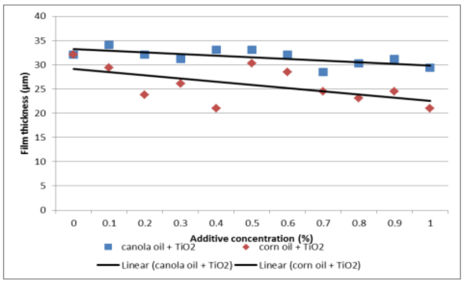

Figure 7 Film thickness at different concentration of titanium dioxide of different bio-lubricant.

In Figure 4 and 5, the amplitude of corn oil is much smaller than canola oil. Based on the results, it shows that increasing of concentration of additives may affect the amplitude. The amplitude of corn oil is smaller than canola oil by 9.30%.

Besides that, in Figure 6 and 7, as the concentration of TiO_2 additive increases, the reflection coefficient become reduces. It shows that clearly the reflection coefficient will affect the film thickness. In comparison, corn oil has much smaller film thickness than canola oil.

The film thickness of corn oil is 13.7% reduction than canola oil.

5. CONCLUSION

The fluid-film thickness using ultrasound method tests have been conducted to investigate the effect titanium dioxide (TiO2) nanoparticles on bio-lubricant. The results indicate that the reflection coefficient and film thickness for corn oil with TiO2 are lower compared to canola oil as concentration of TiO2 additives increases. The highest difference of reflection coefficient between corn oil and canola oil is 13.7% reduction. This preliminary study indicates that TiO2 additives has potential in reducing film thickness.

6. REFERENCES

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