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An Investigation of Hard-on-Soft Sliding Contact Using Palm Fatty Acid Distillate

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Abstract – *This research investigated the effect of surface modification on a soft curvature cup made of acrylonitrile butadiene styrene (ABS) against hard metal ball bearing. The experiment was conducted using different ABS surfaces (flattened and embedded with pits). Different pits embedded on the curvature cup have shown the potential for improving the tribology of hard-on-soft (HoS) sliding contact. The data included the evaluation of anti-wear and anti-friction properties for the lubrication with palm oil. A modified four-ball machine as a hard-on-soft screening machine has been used to evaluate the friction on ABS sample. The results showed that undertreated curvature cup with pits and lubricated by palm oil had a better frictional rate and allowed for a stable of hard-on-soft sliding contact.*

Keywords: Hard-on-soft, Curvature cup, Pit, Palm oil

1.0 INTRODUCTION

Ball and socket tribology in the application of hip implants still remains a broad study and needs experimental findings, especially for hard-on-soft model (HoS). Generally, it is assumed that the socket wear is localized in the hip prosthesis, which is softer than the steel of femoral head [1]. Moreover, the surfaces are considered in dry contact, thus the lubrication effect has been taken into account in the wear factor. In addition, several HoS wear mechanisms can affect the curvature implant during the experimental and running time of sliding contact [2].

Incessant contact between HoS material causes sliding impact failure. For example, in hip prosthesis, soft material tears leads to loosening. Much research has shown that implants of curvature cup still remains as experimental findings. The most important aspect is the surface modification with embedded pits on soft curvature cup in order to reduce friction and tear that can reduce the life span of equipment or implant. Surface modification on soft metal is one of the approaches for avoiding direct soft material on metal contact from rubbing surfaces, such as by introducing lubricants trap between the two surfaces [3-5].

The study by Yee showed that oil reservoir acts as a cushion to avoid sticky condition [6]. The trapped liquid lubricants form a very thin film between the moving surfaces and thus avoid direct contact of the two surfaces and reduces friction. The chemical composition and mechanical properties are able to identify the performance of oil in sliding contact. Indeed, palm oil is an alternative lubricant based on the good performances, and non-toxic based lubricant received attention from many researchers [7-10].

The use of acrylonitrile butadiene styrene (ABS) in thermoplastic technology has a broad range of performance characteristics. This experiment was set up with a CSS model created using the technology of fused deposition modelling (FDM). Lee showed that a rapid prototyping is able to fabricate ABS as the part required compared to metal [11].

The main aim of the paper is to compare the effect of treated and untreated surfaces on a curvature cup made of acrylonitrile butadiene styrene (ABS) against metal ball bearing. The experiment of hard-on-soft contact prosthesis model lubricated in PFAD compared the physical properties of mineral lubricant. Also, the effect of palm oil as a lubricator for improving the lubrication between hard-on-soft contact sliding was discussed.

2.0 EXPERIMENTAL CONDITION

Two types of palm-oil based (PFAD and kernel) were used as lubricants. Palm kernel (PK) is the base of palm containing protein, moisture, carbohydrate and is yellow in color. Meanwhile, palm fatty acid distillate (PFAD) PFAD is a by-product of physical refining of crude palm oil and is normally composed of free fatty acids, and the rest is composed of triglycerides, diglycerides (DG), monoglycerides (MG) and traces of impurities.

Before the experiment was started, all parts of a single modified tribometer ball were cleaned, especially at the ball cup and the ball bearing assembly ballot using acetone, and then blotted with a fresh lint-free industrial wipe. This is to ensure to the absence of persist solvent effect when placing oils.

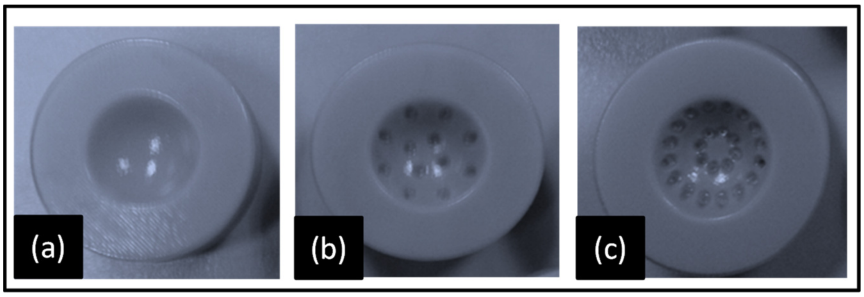

Figure 1: Surface of the sample prior to experiment a) Untreated soft surface cup, b) Treated surface cup embedded with 12 pits, and c) Treated surface cup embedded with 24 pits.

The tests were carried out for a duration of 10 min for each sample of HoS with and without lubricants. The soft cup samples in the wear test were observed. All soft cup samples were made of ABS with the diameter of 12.8mm and were manufactured using a rapid prototyping process. The treated cups were embedded 12 and 24 pits, where the pits were placed in a circular arrangement (see Fig 1).

3.0 EXPERIMENTAL PROCEDURES

A modified four-ball tester was developed to identify the tribology characteristic of hard-on-soft surface contact using various types of lubricant. In order to evaluate the effect of curved surface in wear and friction, the researchers designed new ball cap to replace three-ball bearing locking ring as shown in Fig. 3. The workpiece (cup model) had an approximately 3.47 mm depth of curvature surface. The purpose of this experiment is generally to measure or study the effect of pits on the soft cup with palm oil as a lubricant in HoS tribology with the variable parameters (load and speed) in terms of friction.

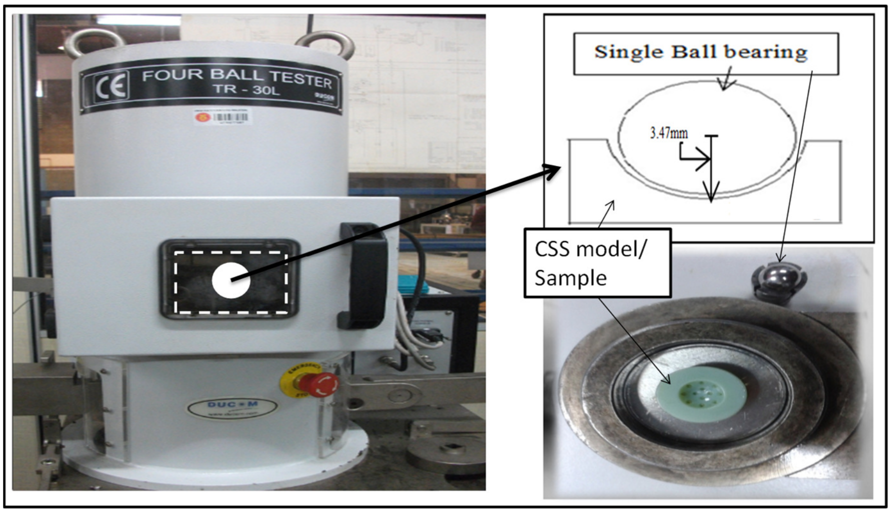

Figure 2: Apparatus (a) Four-ball tribotester, and (b) Schematic modified single ball (in upper side) and soft cup model or CSS ABS sample with treated surface embedded with pits.

The modified four-ball tribometer involved a ball bearing (chrome alloy steel made of AISI E-52100) on the top side with the diameter approximately 6.35 mm, and three bottom-ball bearings were replaced by different sample of untreated (flatten) and treated (embedded with pits) soft workpieces. ABS as the soft workpieces for untreated and treated (circular cup) were clamped together and immersed with two types of palm-based lubricant.

The soft cup was placed into the ballpoint assembly and tightened using a torque wrench in order to prevent the sample from moving during the experiment. The top spinning hard ball was locked inside the collect and tightened into the spindle. Lastly, the test lubricant was introduced into the ballpot assembly. Apart from that, the authors observed that the oil level filled all the voids in the test cup assembly. The ballpot assembly component was installed on the non-friction disc in the four-ball machine. The load was slowly applied to the machine to avoid shock loading that could affect the result.

After that, the lubricant was heated up to 40°C. When the desired temperature was reached, the drive motor was started where it had been set to drive the top ball at the desired speed. After 10 min, the heater was switched off, and the oil cup assembly was removed from the machine. The wear scars on the bottom side (CSS) were captured on a special base of a microscope that had been designed for the purpose. Besides that, the lubricating ability of PFAD and PK was evaluated based on the friction torque produced and compared with the HOS sliding speed of 100 rpm load of 40 kg.

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4.0 RESULTS AND DISCUSSION

Fig. 2 shows the modified four-ball tester used to conduct the experiments of hard-on-soft curvature cup. The ABS cup of the materials was evaluated with microscopic image analysis (MIA). A quantitative observation was made based on the roughness of the figures (see Fig. 3). The frictional tests involved hard single ball bearing on the soft curvature surfaces with free- lubricant (dry) and with lubricants (PK and PFAD) on the samples.

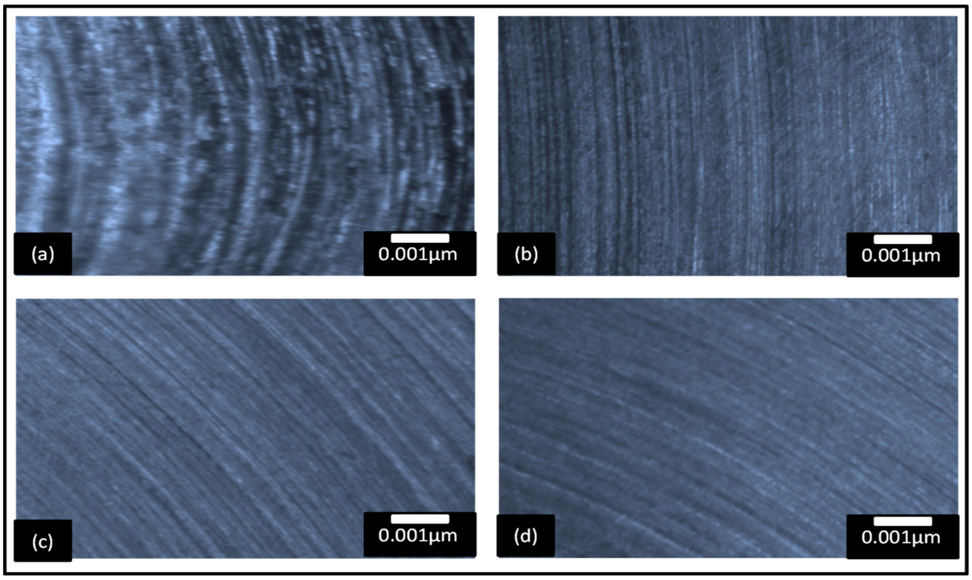

Figure 3: The surface of the samples after experiment a) Untreated cup without lubricant, b) Untreated cup with lubricant, c) Treated cup with 12 pits under lubricant condition, and d) Treated cup with 24 pits under lubricant condition.

In this experiment, an investigation on the HoS without lubricant showed a damaged and wear surface for sample without lubricant as shown in Fig 3 (a). The absence of lubricant may affect the change of surface roughness. Different results for HoS were obtained when lubricants used tested. Samples of soft cup with free wear were observed for PK and PFAD lubricants. Palm oil has a potential as an anti-corrosion substance that reduces wear [12]. Because of that, the surfaces of the ABS samples showed no difference before and after the experiment, and approximately no severe wear was recorded. Hence, it is accepted that the result is a fair surface for all samples with lubricant. For the surface without pit and lubricant, the sample in Fig .3 (b) was a bit rough but better than Fig 3. (a). Previous studies have shown that dimples and micro-hole work as the oil reservoir and also will assist osseointegration on the biomaterial [13,14]. In detail, it was determined that there was almost no physical damage to the surface of the cup embedded with pits (Fig.3 (c) and Fig. 3 (d)). The analysis of the treated and untreated cup in this experiment determined that the occurrence of wear depends on the presence of lubricant and pits. As the surfaces observed using MIA only determined the surface topography of the samples, detailed explanation of the effects of pits and lubricant in reducing friction torque is shown in Fig. 4.

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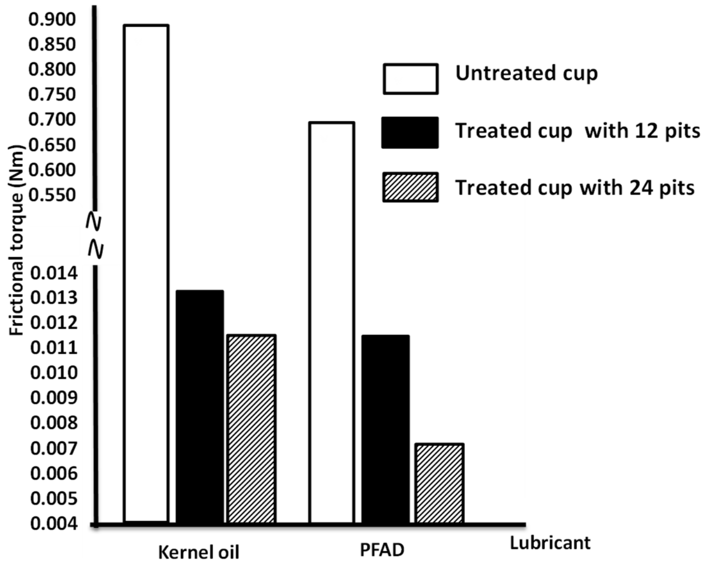

Figure 4: Frictional torques for untreated and treated samples

From Fig. 4, there was an improvement as lubricants were applied during the experiment of soft cup on the sliding contact. In this experiment, PK showed poorer performance compared to PFAD. The soft sample embedded with 24 pits performed better compared to the sampled embedded with 12 pits based on the frictional measurement. It can be seen for each sample that there was a slight difference of frictional torque recorded for the untreated cup compared to treated surface. The qualitative analysis from MIA showed that both lubricants (PK and PFAD) surface had good conditions. The average of frictional torque against PK and PFAD were 0.884 Nm and 0.709 Nm, respectively. The mean frictional torque for soft cup embedded with 12 pits using PFAD and PK were 0.011 Nm and 0.013 Nm, respectively. In addition, the more pits added on the cup, the higher the reduction of friction for both lubricants used. The PK and PFAD layers on the contact are the main factor that affects the reduction of wear and frictional rates. In addition, PFAD recorded low friction because of the solid condition in room temperature. A previous study about PFAD viscosity showed that lubricant oils with high viscosity have a much superior characteristic [15]. The friction and surface observation results on the soft surface appearance will prolong the lifespan of soft curvature cup, depending on the amount of pits and the characteristics of lubricant.

5.0 CONCLUSION

The friction torque obtained for curvature cup lubricated with PFAD is better compared to PK. The results of this study revealed that the treated curvature cup with more pits and lubricated by palm oil improves the frictional rate and allows for a stable of hard-on soft-sliding contact. The factor of high fatty acid in PFAD oil can reduce the coefficients of friction and wear. Finally, the palm oil used as the lubricant in the tribology studied between HoS cab be summarized as a great lubricating oil because it possesses natural fat resources without additive.

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