TRIBOLOGICAL PERFORMANCES OF JOURNAL BEARING USING PALM OIL BASED LUBRICANT

ZULHANAFI BIN PAIMAN

A thesis submitted in fulfilment of the
requirement for the award of the degree of
Doctor of Philosophy

School of Mechanical Engineering
Faculty of Engineering
Universiti Teknologi Malaysia

JANUARY 2021

ACKNOWLEDGEMENT

In the name of Allah, the Most Benevolent and Most Merciful, praise to Allah SW.T. Thanks to Allah for giving me His blessing to complete this research on time.

I would like to express my deepest gratitude to my supervisor, Professor Ir. Dr. Syahrullail bin Samion, for his invaluable guidance, consistent advice, sharing his valuable time, encouragement, and patience upon the completion of this research. Not forgetting to all my co-supervisors which keep giving encouragement and sharing their knowledge, Dr. William Chong Woei Fong and Dr. Mohd Kameil bin Abdul Hamid from UTM as well as Ir. Ts. Dr. Mohamad Ali bin Ahmad from Centre of Tribology, UiTM Shah Alam.

Special thanks to all technicians and staff at Tribology Lab, Universiti Teknologi Malaysia, Mr. Shahlan, and Mrs. Jannah for giving me permission to run the experiment there, giving their useful opinions, sharing their knowledge and skills especially in getting the results of the experiment.

Not forgotten to my beloved family, especially my dearest wife Mrs. Norhaslinda Binti A.Rahman, fellow friends, course mates, and each individual who has contributed either directly or indirectly throughout the progression of this research.

ABSTRACT

The green technology policy and strict environmental legislation have driven researchers to focus their attention to bio-based lubricants. Bio-based lubricants are known to have excellent biodegradability characteristics, but low oxidative stability and limited viscosity range. The purpose of this research was to analyze the tribological performances of journal bearing using palm oil-based lubricants. In this study, few types of palm oil-based lubricants went through a tribological test using a four-ball tribotester by following ASTM D4172B and D2783 standards accordingly. Results revealed that Palm Mid Olein (PMO) exhibited excellent performance in terms of friction coefficient and wear scar diameter (WSD) compared with other palm oil-based lubricants. The addition of 0.045 % tertiary-butyl hydroquinone (TBHQ) and 1.3 % ethylene vinyl acetate (EVA) resulted in a 4.5-fold increase in oxidative stability and 19.16 % increase in viscosity index, respectively. PMO+TBHQ+EVA also showed a 16.05 % decrease in friction coefficient and 8.89 % decrease in WSD compared with raw PMO. Furthermore, the performance of PMO+TBHQ+EVA was evaluated by using a journal bearing test rig and compared with that of raw PMO. Results revealed that PMO+TBHQ+EVA showed 72.1 % higher maximum oil film pressure, 47.5 % lower friction coefficient, and 51.2 % higher load carrying capacity when compared to PMO alone. In addition, it was observed that dimples with a spherical shape showed 6.8 % higher maximum oil film pressure, 21.5 % lower friction coefficient, 5.26 % higher load carrying capacity, and 39.6 % higher minimum oil film thickness than dimples with a conical shape. The combination of PMO+TBHQ+EVA co-acting with a spherical shape profile also resulted in optimum performance in journal bearing operation. It is suggested that the addition of TBHQ and EVA successfully improves the characteristics of base stock palm oil (PMO) and the combination of PMO+TBHQ+EVA with the spherical shape of dimple's bottom profile offers comparable performance in journal bearing operation.

ABSTRAK

Dasar teknologi hijau dan undang-undang alam sekitar yang ketat telah mendorong para penyelidik untuk memfokuskan perhatian mereka kepada pelincir berasaskan bio. Pelincir berasaskan bio diketahui mempunyai ciri bio-degradasi yang sangat baik, tetapi mempunyai kestabilan oksidatif yang rendah dan julat kelikatan yang terhad. Tujuan penyelidikan ini adalah untuk menganalisis keupayaan tribologi galas jurnal menggunakan pelincir berasaskan minyak sawit. Dalam kajian ini, beberapa jenis pelincir berasaskan minyak sawit menjalani ujian tribologi menggunakan penguji tribo empat bola dengan mengikuti piawaian ASTM D4172B dan D2783. Keputusan menunjukkan bahawa *Palm Mid Olein* (PMO) menunjukkan prestasi yang sangat baik dari segi pekali geseran dan diameter parut haus (WSD) berbanding dengan pelincir berasaskan minyak sawit yang lain. Penambahan 0.045 % *Tertiery Butyl Hydroquinone* (TBHQ) dan 1.3 % *Ethyylene Vinyl-Acetate* (EVA) menghasilkan 4.5 kali peningkatan dalam kestabilan oksidatif dan 19.16 % peningkatan dalam indeks kelikatan. PMO+TBHQ+EVA juga menunjukkan 16.05 % penurunan pekali geseran dan 8.89 % penurunan dalam WSD berbanding PMO mentah. Seterusnya, prestasi PMO+TBHQ+EVA dinilai dengan menggunakan penguji galas jurnal dan dibandingkan dengan PMO asli. Keputusan menunjukkan bahawa PMO+TBHQ+EVA mempamerkan keputusan 72.1 % lebih tinggi tekanan maksimum minyak, 47.5 % lebih rendah pekali geseran, dan 51.2 % lebih tinggi kapasiti membawa muatan jika dibandingkan dengan PMO asli. Selain itu, didapati bahawa lompang tekstur berbentuk sfera menunjukkan 6.8 % lebih tinggi tekanan maksimum minyak, 21.5 % lebih rendah pekali geseran, 5.26 % lebih tinggi kapasiti membawa muatan, dan 39.6 % lebih tinggi ketebalan minimum filem minyak jika dibandingkan dengan bentuk kerucut. Kombinasi PMO+TBHQ+EVA dan bentuk sfera juga memberikan prestasi yang optimum dalam operasi galas jurnal. Disarankan bahawa penambahan TBHQ and EVA berjaya meningkatkan ciri-ciri minyak sawit stok asas (PMO) dan kombinasi PMO+TBHQ+EVA dengan lompang yang bertekstur sfera menawarkan prestasi yang setanding dalam operasi galas jurnal.

TABLE OF CONTENT

LIST OF TABLE

LIST OF FIGURES

LIST OF ABBREVIATIONS

AISI	-	American Iron and Steel Institute
AOCS	-	American Oil Chemist Society
ASTM	-	American Society for Testing and Materials
AWS	-	Anti-wear
BHA	-	Butyl Hydroxy-Anisole
BHT	-	Butyl - Hydroxytoloune
CFD	-	Computational Fluid Dynamic
CNC	-	Computer Numerical Control
CPO	-	Crude palm oil
DC	-	Direct current
DSC	-	Differential Scanning Calorimetric
EC	-	Ethyl Cellulose
EP	-	Extreme pressure
EVA	-	Ethylene Vinyl Acetate
FAC	-	Fatty acid composition
FFA	-	Free fatty acid
GLC	-	Gas Liquid Chromatography
ISO	-	International Organization for Standardization
IV	-	Iodine value
LDPE	-	Low Density Poly-Ethylene
MPOB	-	Malaysian Palm Oil Board

NPT	-	National Pipe Thread
OIT	-	Oxidative induction time
PE	-	Pentaerythritol ester
PFAD	-	Palm fatty acid distillate
PMF	-	Palm Mid Fraction
PMO	-	Palm mid Olein
POME	-	Palm Oil Methyl Ester
ppm	-	Part per million
PV	-	Peroxide value
RBDPO	-	Refined Bleached and Deodorized Palm Oil
RBDPL	-	Refined Bleached and Deodorized Palm Olein
RBDST	-	Refined Bleached and Deodorized Palm Stearin
RBO	-	Rice Bran Oil
rpm	-	Revolution per minute
SAE	-	Society of Automotive Engineers
SFC	-	Solid fat content
SPL	-	Double Fractionated Palm Olein
TBHQ	-	Tertiery-Butyl Hydroquinone
TMP	-	Trimethylolpropane
USA	-	United States of America
UTM	-	Universiti Teknologi Malaysia
VG	-	Viscosity grade
VI	-	Viscosity Index

WSD	-	Wear scar diameter
ZDTP	-	Zinc dialkyldithiophospate

LIST OF SYMBOLS

η_0	-	Absolute viscosity in Pa.s
h	-	Film thickness
$h_{\min}$	-	Minimum oil film thickness
h_{avg}	-	Average dimple depth
h_0	-	Local oil film thickness
e	-	Eccentricity
ε	-	Eccentricity ratio
c	-	Radial clearance
D	-	Bearing diameter
d	-	Journal diameter
b	-	Bearing width (length)
ω_b	-	Shaft speed
y	-	Bearing width respect to y-axis $\left(\pm\frac{b}{2}\right)$
W_r	-	Resultant load carrying capacity
p	-	Oil film pressure
p_m	-	Maximum pressure
θ_m	-	Angle of maximum pressure
r_b	-	Bearing radius
r_a	-	Journal radius
ϕ	-	Circumferential direction
π	-	Pi (3.142)
φ	-	Attitude angle
T	-	Torque

F	-	Load measured by load cell
L	-	Length of lever arm
μ	-	Friction coefficient
F_f	-	Frictional force
N	-	Applied load
$V_{cylindrical}$	-	Cylindrical volume
$V_{spherical}$	-	Spherical volume
$V_{conical}$	-	Conical volume
r_d	-	Dimple's radius
h_d	-	Dimple's height
ρ	-	Density
$u_{a/b}$	-	Velocity component respect to x-axis (fixed/moving) surface
$v_{a/b}$	-	Velocity component respect to y-axis (fixed/moving) surface
$w_{a/b}$	-	Velocity component respect to z-axis (fixed/moving) surface
q_x	-	Volume flow rate in x-direction
q_y	-	Volume flow rate in y-direction
q_z	-	Volume flow rate in z-direction
q_θ	-	Volume flow rate in circumferential direction
$w_{x/y/z}$	-	Load component respect to x,y and z axis
τ	-	Shear stress
P	-	Pressure acted on projected area
S	-	Sommerfeld number

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Research background

The global market size for lubricants is expected to reach USD 182.6 billion in 2025, approximately a 15% increase compared to the year 2020. This is contributed by the rapid growth of industrialization in the Asia Pacific, the Middle East, and Africa, increasing demand in automotive industries, and process automation in most of the industries (*Lubricants market*, 2020). It shows that the demand for lubricant oil is grown exponentially with the technology revolution. Lubricant oil is largely consumed as engine oil, followed by hydraulic oil, metalworking fluid, gear oil, turbine oil, and many more. Meanwhile, mineral-based resources remain the largest base stock that produces most of the lubricant oil in the world, followed by synthetic based and bio-based oil.

Basically, lubricant is used to ease the motion between two surfaces by reducing the friction and minimize the wear occurrence. On top of that, lubricant is also functioned to reduce the operating temperature and simultaneously remove the wear debris and particles. The good lubricant led to less friction, minimum power losses, prolong the shelf life of the material and wear reduction (Panchal et al., 2017). It might come either in solid or liquid form with different properties. Few justifications need to be considered during selecting the lubricant. The different working conditions requires different properties of the lubricant. Usually, the lubricant viscosity, oxidative stability, cold flow properties, and fluidity behavior are some of the main criteria in selecting the lubricant. The established lubricant oil in the market is commonly based on mineral resources which are derived from petroleum-based oil (Kucera et al., 2013). Mineral oil-based lubricant was having excellent characteristics in any application. Moreover, nowadays the lubricant technologies are enhanced and improved with the addition of nanotechnologies that makes mineral oil-based lubricant become more reliable especially in industrial application.

Other approaches were also introduced such as adding the anti-friction and anti-wear additives to improve the lubricant capability. These additives were commonly originated from in-organic based. Even though the mineral-based oil has promising excellent performance, but it has also raised concerns on the environmental issues as the oil is toxic to the environment and not readily bio-degradable (Panchal et al., 2017; Omrani et al., 2016). This is a grounded statement as, over the years, the total oil consumption in the world keeps increasing tremendously. On top of that, the remaining mineral-based oil resources are also concerned as it takes million years to recover the stock naturally. This situation urges the researchers to improve the bio-degrade ability of mineral-based oil. Simultaneously, researchers also working on finding alternative resources including plants, animal and even chemically formulated like synthetic oil. Out of these alternative resources, bio-based oil which is derived from the plant is gaining high popularity as it is readily bio-degradable, easily harvested, and needless processing cost compared to synthetic oil. Bio-based lubricant shows big potential as most of the study revealed that their long polar fatty acid chain and molecules are able to provide protection on the contact surface, thus resulted in less wear and friction (Jain and Suhane, 2012). Even bio-based lubricant is showing good adaptability to the environment, but in technical point of view, it has few weaknesses that need to be addressed to perform as perfect lubricant as mineral-based oil. Bio-based lubricant has poor low temperature characteristics, poor hydrolytic stability, low oxidative stability and exhibit poor resistance to foaming (Panchal et al., 2014). Since bio-based lubricant possess the long polar of saturated and unsaturated fatty acid chain, thereby the chemical structure modification can be executed in order to improve their performances.

Journal bearing is one of the applications that uses lubricant as a main element on its operation. Journal bearing consists of two major parts known as shaft or journal and bearing or bushing. As a fundamental, the shaft is freely moving inside the bearing and transmits the power to the other machines in the system for various purposes. Commonly journal bearing is operated in the hydrodynamic lubrication regime. This is the condition where the load-carrying surface of the bearing is separated by the thick film lubricant to avoid metal to metal contact thus reduce the friction. Generally, the pressure profile distribution of the fluid film is one of the main criteria to evaluate the bearing performance. A lot of research was also conducted to improve the bearing performance in order to achieve optimum output, less friction, longer material shelf life, minimum wear and tear, less power consumption and minimum handling mechanism. There were a lot of bearing geometry design developed and introduced (Muzakkir et al., 2015). Some researchers studied various operating conditions that impacted the bearing performances such as the fed lubricant oil pressure (Ahmad et al., 2013a), the location of fed oil (Ahmad et al., 2014), the lubricant oil temperature (Singla et al., 2014), the design of oil groove (Adatepe et al., 2011; Asral et al., 2013) and so on. On top of that, surface texturing on the bearing or shaft surface also has gaining its popularity since this approach tends to provide positive impact to the journal bearing performances to some extent.

1.2 Problem statement

A good lubricant is not about simply providing excellent tribological performances, but it has to be environmentally friendly. The usage of mineral-based lubricant oil arises an environmental issue as it is known to have a high level of toxicity and hardly dissolved to the environment naturally (Luther, 2000). Vegetable oil has a big potential as it is highly bio-degradable, non-toxic, and the resources are renewable. In recent years, there are lots of researches were conducted in utilizing vegetable-based oil as a lubricant. Even there is still no major application that used vegetable oil as the main lubricant, but some of the established mineral-based oil lubricants use vegetable oil as additives to improve friction and wear behaviors

(Aiman et al., 2017). In fact, it has been commercially used in certain countries as hydraulic fluid, gear oil, refrigeration oil, chainsaw oil, metalworking fluid, and many more.

Palm oil is one of the most consumed vegetable oil in the world. It is commonly consumed in the form of cooking oil or known as palm olein. From a lubrication point of view, palm oil has a long polar fatty acid chain that provided better boundary lubrication. However, palm oil has low oxidative stability (Zainal et al., 2018) and a limited range of viscosity (Quincha et al., 2010). The oxidative stability of palm oil is mainly influenced by its fatty acid molecules. Palm oil has a double bond on its ninth and tenth molecules chain that is unstable and actively reacted with oxygen molecules to form primary and secondary oxidation products. These compounds are corrosive and affected the wear behaviors and viscosity of the oil. Besides, the viscosity of the palm oil is also influenced by the length of the fatty acid chain as well as the degree of unsaturation fatty acid. This resulted in poor lubricity performance as some palm oil shows good lubricity at low temperatures and some might be not. These issues are affecting the lubricant performances and limiting their range of application. There are many studies conducted to improve the palm oil capabilities, but most of the research was limited to the oil that is produced up to a single fractionation process like palm olein and palm stearin. There are many types of palm oil being produced at a higher degree of fractionation including Super olein (SPL), palm mid olein (PMO), and palm mid fraction (PMF). Indeed, the tribological performance data of these oil is extremely limited. In this study, the tribological investigations covered all common palm oil products up to third-degree of fractionation.

As mentioned in the research background, the aim of this study is to improve the capability of palm oil to be used as a lubricant in journal bearing applications. In the journal bearing operation, the main function of a lubricant is to create hydrodynamic pressure and provide load-carrying capacity. Thus, the sufficient supply of lubricant and the capability to sustain their properties is crucial to ensure the efficacy. During the operation, there is a possibility to experience a shortage of lubricant supply. This led to the destruction of journal bearing and caused severe damage. One of the methods used by researchers to overcome this problem is by introducing textures on the contact surfaces. The surface irregularities help in maintaining a certain amount of lubricant oil in the event of a shortage. On top of that, the presence of a textured surface is able to improve the journal bearing capability to some extent. But it totally depended on various factors including its geometry design. Most of the research was conducted numerically and fewer studies were carried out experimentally. This is due to the complex design of the dimples that lead to difficulties in fabrication and machining. Simultaneously, most of the dimples were fabricated on the stationary part (bearing) either fully or partially textured rather than the rotating part (journal). Apparently, the experimental study of using palm oil-based lubricants in journal bearing was also rarely conducted and resulted in limited data and findings.

In this study, a few types of palm oil-based were used as a lubricant at the beginning stage. Each type was undergoing basic tribological testing. After a few consideration, the one that has shown the most excellent lubricant behavior was further improved by adding some additives and the impact was investigated. This 'treated' palm oil was further applied in journal bearing and the performance was observed. Furthermore, the surface texturing was also introduced to improve the journal bearing capability in this study. The performance of 'treated' palm oil-based lubricant co-acting with a textured surface in journal bearing was also investigated.

1.3 Objectives

Based on the problems and aims that has been described in Chapter 1.2, it can be achieved through the following objectives:

i. To investigate the most suitable palm oil based lubricant in term of their physical, chemical, and tribological characteristics for journal bearing applications..

ii. To optimize the effect of adding antioxidant and viscosity improver on improving the oxidative stability and viscosity behaviors of palm oil-based lubricant.

iii. To establish the tribological performances of palm oil-based lubricant in journal bearing application in comparison to the established mineral based oil lubricant.

1.4 Scope of work

This study covers the following scopes:

1. Selection of bio-based lubricant

   The bio-based lubricant that is being used in this study is from a palm oil-based group. The main reason is because of the availability of the resources. Here in Southeast Asia, Malaysia is the second-largest palm oil producer in the world behind Indonesia. In addition, palm oil has a wide range of products that started from its crude oil until downstream products in the oleo-chemical plant. On top of that, most of the products derived from palm oil have significant physico-chemical characteristics to be developed as lubricant oil. Since the downstream process of palm oil required higher cost and not much produced, the selection of palm oil types to be used at the beginning of this study is within the common refining and fractionation practices only.

2. Experimental condition for each experiment

a) For the basic tribological testing using a four-ball tribotester, the experimental condition is basically following the ASTM standard and on some occasion, the temperature, speed, and load are varied to observe the behaviors of the lubricant in that particular conditions. All parameters are considered to be static and there is no dynamic mechanism involved.

b) Similarly to the test conducted in a pin-on-disc machine, the rotational speed and applied load are considered as fixed for every experiment and no dynamic motion involved. The material for pin and disc is made of Stainless steel SS 304 and similar material was applied to the journal and bearing test rig.

c) In journal bearing test rig, short journal bearing made of SS304 with length to diameter ratio of 0.5 was used. The test was conducted at a rotational speed range of 200 rpm to 1000 rpm and a radial load of 10 N to 100 N. This condition is considered as steadily low load and medium speed journal bearing. This is well suited as the intention of this study is to enhance the palm oil-based lubricant to be used in that condition. The bearing is statically loaded and no dynamic load involved.

d) For the surface texturing, the dimples are fabricated on the shaft surface by the drilling process. There are two types of dimple’s bottom shape being studied which is conical and spherical. Both dimple shapes have similar dimple density, arrangement and aspect ratio. A similar experimental condition is applied as conducted on a smooth shaft surface.

3. Results and analysis of each experiment

a) For the tribological test using a four-ball tribotester, the analysis is focusing on friction, surface roughness, wear scar diameter and physical wear observation. Wear scar diameter (WSD) measurement and wear observation was carried out by using high and low definition optical microscope equipped with I-Lite Solution software.

b) Similarly, for the experiment conducted in a pin-on-disc machine, the analysis is involving friction coefficient and wear scar diameter (WSD) behavior.

c) In the journal bearing test rig, there are two main parameters value that is directly obtained from the experiment which is pressure distribution as well as the friction coefficient. The other parameters including eccentricity ratio, maximum pressure, attitude angle, load-carrying capacity, and minimum oil film thickness were determined by using an analytical solution. The analytical solution is derived from standard reduced form of Reynolds Equation in tangential motion by Dubois and Ocvirk (1953) for short journal bearing with the following assumptions:

   i. Fluid properties does not vary significantly throughout the bearing and considered constant

   ii. The motion is pure sliding

   iii. Side leakages is taken into consideration

   iv. The pressure-induced flow in circumferential direction is very small relative to Coutte flow term. Then it is neglected

   v. There is no misalignment

   vi. Film thickness is varied in the circumferential direction only

   vii. Half Sommerfeld assumptions is applied

   viii. Oil viscosity is constant

Experiment used low radial load and lead to minimum effect to the temperature and vicosity. Maximum speed of journal bearing during experiment was 1000 rpm while maximum speed of the machine was 1500 rpm. This lead to less potential of vibration. Furthermore, the rig used rubber coupling that suggested the system is self-aligned. Meanwhile, in the experiment that involving textured surface, similar journal bearing parameters were analyzed but the concern was on the performance of each type of dimple's bottom shape co-acting with different lubricant oil.

4. Targeted application

The development of palm oil based lubricant in this study is basically designed for the journal bearing operating in turbocharge, small pump or any machine element which has operating condition in the following range:

Shaft speed : 200 rpm to 1500 rpm

Radial load: 10 N to 100 N

Operating temperature: 35°C to 40°C

1.5 Research significance

In bigger perspectives, the main intention of this research is providing alternative lubricants that can perform better or at least equivalent to the mineral oil-based. This surely benefits our environment especially in supporting green technology development. Simultaneously the dependency on the mineral-based oil is reduced. From the economic point of view, since Malaysia is one of the biggest palm oil producers in the world, the success of this research could contribute to the Malaysian economy directly. If previously Malaysia was known as one of the biggest palm oil exporters in the world, it is not possible Malaysia could be the biggest bio-lubricant exporter. It has big potential and Malaysian should take these advantages to be a giant market leader in the bio-lubricant industry. In addition, it could be the most cost-effective product as Malaysia is dominating the resources. In another point of view, the findings in this research can also be applied in other engineering applications extensively, not only for journal bearing. It could be the starting point to achieve a more beneficial and significant impact in the future.

Meanwhile, for surface texturing, it opens a new conception that texturing was not only applicable on the stationary surface, but it does in moving surface. Moreover, having a different type of bottom dimple profile incorporated with bio-based lubricant give more option to engineers and offer variety in designing the journal bearing to achieve optimum performances.

1.6 Thesis layout

In Chapter 1, some research background was presented which consists of the elements involved in this research including bio-based lubricant, additives, journal bearing as well as surface texturing on the contact surface. The problem statement was highlighted and the current development of the research area was clarified. To overcome the issues, three (3) objectives have been identified to execute the solution. All scopes that covered this study were extensively verified and the targeted application was mentioned. In Chapter 2, the related literature from the previous study was reviewed and the knowledge gap was identified. It included the study of palm oil-based lubricant, journal bearing design, operating condition, surface texturing, oxidative stability, additives, journal bearing parameters, and many more. This chapter also illustrated the derivation of the analytical solution for journal bearings.

In Chapter 3, all related research methods were explained in detail. It began with the selection of palm oil-based lubricants based on their physical and chemical properties. The machine and specification that was used in this study including four-ball tribotester, pin on disc machine, and journal bearing test rig was also elaborated in detail. The chemical composition of additives was also tabulated and the method of blending was clearly explained. Furthermore, the detail of dimple geometry was illustrated and justified accordingly. In Chapter 4, all results, findings and discussions were presented according to the objectives being set in Chapter 1. The palm oil type that showed excellent tribological characteristics was selected to be further enhanced by adding additives and applied in journal bearing application. The most beneficial combination of palm oil-based lubricant and dimple shape was also identified. The performance of palm oil-based lubricant was compared to established mineral-based oil mutually.

In Chapter 5, the findings were summarized and some concluding remarks were given. Few recommendations were also proposed that created research interest for future works.

REFERENCES

Adatepe, H., Bıyıklıoglu, A., & Sofuoglu, H. (2011) 'An experimental investigation on frictional behavior of statically loaded micro-grooved journal bearing', *Tribology International*, *44*(12), 1942-1948.

Adhvaryu, A., Biresaw, G., Sharma, B. K., & Erhan, S. Z. (2006) 'Friction behavior of some seed oils: biobased lubricant applications', *Industrial & engineering chemistry research*, *45*(10), 3735-3740.

Aiman, Y., & Syahrullail, S. (2017) 'Development of palm oil blended with semi synthetic oil as a lubricant using four-ball tribotester', *Jurnal Tribologi*, *13*(unknown), 1-20.

Ahmad, M. A., Kasolang, S., Dwyer-Joyce, R., & Abdullah, N. R. (2013a) 'The effect of oil supply pressure on the circumferential pressure profile in hydrodynamic journal bearing', *Applied Mechanics and Materials* (Vol. 315, pp. 809-814). Trans Tech Publications.

Ahmad, M. A., Kasolang, S., & Dwyer-Joyce, R. (2013b) 'The effects of oil supply pressure at different groove position on frictional force and torque in journal bearing lubrication', *Procedia Engineering*, *68*, 70-76.

Ahmad, M. A., Kasolang, S., & Dwyer-Joyce, R. S. (2014) 'Experimental study on the effects of oil groove location on temperature and pressure profiles in journal bearing lubrication. *Tribology International*, *74*, 79-86.

Ahn, H. J. (2006) 'A cylindrical capacitive sensor (CCS) for both radial and axial motion measurements', *Measurement Science and Technology*, *17*(7), 2027.

Al-Araji, N., & Sarhan, H. (2011). 'Effect of temperature on sliding wear mechanism under lubrication conditions'. *International Journal of Engineering*, *5*, 176-184.

Alexander Slocum (2008). Fundamentals of Design. Chapter 10: Design. Massachusetts. MIT Precision Engineering Research Group.

Alias, N. H., Yunus, R., & Idris, A. (2011). Effect of additives on lubrication properties of palm oil-based trimethylolpropane ester for hydraulic fluid application. In *Sustainable Energy & Environment (ISESEE), 2011 3rd International Symposium & Exhibition in* (pp. 88-93). IEEE.

Alias, M. A. M., Abdollah, M. F. B., & Amiruddin, H. (2019). 'Lubricant and tribological properties of zinc compound in palm oil'. *Industrial Lubrication and Tribology*. Vol 71(10): 1177-1185.

Aluyor, E. O., & Ori-Jesu, M. (2008). 'The use of antioxidants in vegetable oils–A review'. *African Journal of Biotechnology*, *7*(25).

Anand Kalani, Rita Jani, (2015). 'Comparative Study of Full Journal Bearing With Bio Lubricants – Jatropha Oil, Castor Oil, Neem Oil and Mineral Oil (SAE20W50)'. *International Journal of Mechanical Engineering (IAEME)*, Vol.6 Issue 6. Pp 127-131.

Asadauskas, S., Perez, J. H., & Duda, J. L. (1997). 'Lubrication properties of castor oil--potential basestock for biodegradable lubricants'. *Tribology & Lubrication Technology*, *53*(12), 35.

Asadauskas, S., & Erhan, S. Z. (1999). 'Depression of pour points of vegetable oils by blending with diluents used for biodegradable lubricants'. *Journal of the American Oil Chemists' Society*, *76*(3), 313-316.

Asral, A., Md Sheriff, J., & Osman, K. (2013). 'The Effect of Wavy Groove Liner on Pressure Distribution of Journal Bearing'. *Applied Mechanics and Materials* (Vol. 315, pp. 889-893).

Asral, Dodi Sofyan Arief, Jamaluddin Md Sherif, Abd Khair Junaidi. (2014). 'Computational Analysis of the influence of Two Circumferential Grooves on Performance of Journal Bearing with Palm Oil as Lubricant'. *Journal of Ocean, Mechanical and Aerospace – Science and Engineering*. Vol.14.

Aziz, N. A. M., Yunus, R., Rashid, U., & Zulkifli, N. W. M. (2016). 'Temperature effect on tribological properties of polyol ester-based environmentally adapted lubricant'. *Tribology International*, *93*, 43-49.

Babu, D., Gurumurthy, P., Borra, S. K., & Cherian, K. M. (2013). 'Antioxidant and free radical scavenging activity of triphala determined by using different in vitro models'. *J Med Plant Res*, *7*(39), 2898-2905.

Bandyopadhyay, A. K., Mazumder, S. K., & Majumdar, M. C. (2017). 'Steady State Characteristics of Finite Oil Journal Bearings considering Fluid Inertia effect and Influence of pressure dependent variable viscosity'. *International Journal of Engineering Trends and Technology (IJETT), 46(7),* 372-378.

Baskar, S., & Sriram, G. (2012, March). Experimental analysis of hydrodynamic journal bearing under different biolubricants. In *Advances in Engineering, Science and Management (ICAESM), 2012 International Conference on* (pp. 132-135). IEEE.

Baskar, S., & Sriram, G. (2014a). 'Tribological Behavior of Journal Bearing Material under Different Lubricants'. *Tribology in Industry*, *36*(2).

Baskar.S, Sriram.G, (2014b). 'Pressure Distribution Analysis of a Hydrodynamic Journal Bearing Using Vegetable oil Based Nano Lubricants'. *Technology Letters,* Vol.1(5). Pp 22-25.

Basu, S. K., Sengupta, S. N., & Ahuja, B. B. (2005). *Fundamentals of Tribiology*. PHI Learning Pvt. Ltd.

Bergmann, P., & Grün, F. (2016) Modeling Wear of Journal Bearings. *Proceeding of the 2016 COMSOL* Conference in Munich.

Berg, M. (1996). *Untersuchungen zum Schmierstoffdurchsatz und zur Reibungsleistung dynamisch belasteter Radialgleitlager.* PhD Thesis. Technische Universitat Kaiserslautern.

Bhushan, B. (2009). 'Biomimetics: lessons from nature–an overview'. *Philosophical Transactions of Royal Society A Mathematical Physical and Engineering Sciences* 367 (1893): 1445-86.

Binu, K. G., Shenoy, B. S., Rao, D. S., & Pai, R. (2014). 'A variable viscosity approach for the evaluation of load carrying capacity of oil lubricated journal bearing with TiO2 nanoparticles as lubricant additives'. *Procedia Materials Science*, *6*, 1051-1067.

Binu, K. G., Yathish, K., Mallya, R., Shenoy, B. S., Rao, D. S., & Pai, R. (2015). 'Experimental study of hydrodynamic pressure distribution in oil lubricated two-axial groove journal bearing'. *Materials Today: Proceedings*, *2*(4-5), 3453-3462.

Boopathi, D., Parthiban, P., Palanivendhan, M., & Devanand, S. (2016). 'Experimental Investigation on Effect of Vegetable Oil based Lubricant for Diesel Engine'. *Indian Journal of Science and Technology*, *9*(29).

Bouyer, J., & Fillon, M. (2002). 'An experimental analysis of misalignment effects on hydrodynamic plain journal bearing performances'. *Journal of Tribology*, *124*(2), 313-319.

Bouyer, J., & Fillon, M. (2007). Behaviour of a hydrodynamic journal bearing: torque measurement during start-up. In *10th International Conference of Tribology, Bucharest, Romania* (Vol. 810).

Bouyer, J., & Fillon, M. (2011). 'Experimental measurement of the friction torque on hydrodynamic plain journal bearings during start-up'. *Tribology International*, *44*(7-8), 772-781.

Brito, F. P., Bouyer, J., Fillon, M., & Miranda, A. S. (2006a). Thermal behavior and performance characteristics of a twin axial groove journal bearing as a function of applied load and rotational speed. In *Fifth International Congress on Mechanics and Materials in Design, July, Porto, Portugal* (pp. 24-26).

Brito, F. P., Bouyer, J., Fillon, M., & Miranda, A. S. (2006b). 'Thermal behaviour and performance characteristics of a twin axial groove journal bearing as a function of applied load and oil supply temperature'. *Tribologia Finnish Journal of Tribology,* 3 Volume 25.

Brito, F. P., Miranda, A. S., Bouyer, J., & Fillon, M. (2006c). Experimental investigation of the influence of supply temperature and supply pressure on the performance of a two-axial groove hydrodynamic journal bearing. *In: Proceedings of the IJTC2006: STLE/ASME International Joint Tribology Conference.* October 23-25, 2006, San Antonio, Texas, USA.. IJTC06-12042. 9p.

Brito, F. P., Miranda, A. S., Pimenta Claro, J. C., & Fillon, M. (2008). Experimental study of the influence of groove flow rate on the performance of a single and a twin groove journal bearing. In *Proceedings of the STLE Annual Meeting, Cleveland Convention Center,* May, *Ohio* (pp. 18-22).

Brito, F. P., Miranda, A. S., Claro, J. C. P., & Fillon, M. (2012). 'Experimental comparison of the performance of a journal bearing with a single and a twin axial groove configuration'. *Tribology international*, *54*, 1-8.

Brizmer, V., & Kligerman, Y. (2012). 'A laser surface textured journal bearing'. *Journal of Tribology*, *134*(3).

Budynass, R. G., Nisbett, J.K. (2011). Mechanical Engineering Design, 10th Edition. New York: Mc Graw-Hill.

Cabrera, D. L., Woolley, N. H., Allanson, D. R., & Tridimas, Y. D. (2005). 'Film pressure distribution in water-lubricated rubber journal bearings'. *Proceedings of the Institution of Mechanical Engineers, Part J: Journal of Engineering Tribology*, *219*(2), 125-132.

Campen, S., Green, J. H., Lamb, G. D., & Spikes, H. A. (2015). 'In situ study of model organic friction modifiers using liquid cell AFM; saturated and mono-unsaturated carboxylic acids'. *Tribology Letters*, *57*(2), 18.

Chan, C. H., Tang, S. W., Mohd, N. K., Lim, W. H., Yeong, S. K., & Idris, Z. (2018). 'Tribological behavior of biolubricant base stocks and additives'. *Renewable and Sustainable Energy Reviews*, *93*, 145-157.

Chatterton, S., Dang, P. V., Pennacchi, P., De Luca, A., & Flumian, F. (2017). 'Experimental evidence of a two-axial groove hydrodynamic journal bearing under severe operation conditions'. *Tribology International*, *109*, 416-427.

Cho, I. S., & Jung, J. Y. (2014). 'The friction characteristics of the journal bearing in a reciprocating compressor for refrigeration and air conditioning systems'. *Journal of Mechanical Science and Technology*, *28*(4), 1473-1480.

Costa, L., Miranda, A. S., Claro, J. C. P., & Fillon, M. (2003). 'Temperature, flow, and eccentricity measurements in a journal bearing with a single axial groove at 90 to the load line'. *Lubrication Science*, *15*(2), 147-161.

Covitch, M. J., & Trickett, K. J. (2015). 'How polymers behave as viscosity index improvers in lubricating oils'. *Advances in Chemical Engineering and Science*, *5*(02), 134.

Crespo, A., Morgado, N., Mazuyer, D., & Cayer-Barrioz, J. (2018). 'Effect of Unsaturation on the Adsorption and the Mechanical Behavior of Fatty Acid Layers'. *Langmuir*, *34*(15), 4560-4567.

Cristea, A. F., Bouyer, J., Fillon, M., & Pascovici, M. D. (2011). 'Pressure and Temperature Field Measurements of a Lightly Loaded Circumferential Groove Journal Bearing'. *Tribology Transactions*, *54*(5), 806-823.

Cupillard, S., Cervantes, M. J., & Glavatskih, S. (2008). 'Pressure buildup mechanism in a textured inlet of a hydrodynamic contact'. *Journal of Tribology*, *130*(2).

Dadouche, A., & Conlon, M. J. (2016). 'Operational performance of textured journal bearings lubricated with a contaminated fluid'. *Tribology International*, *93*, 377-389.

Daniel, R. V., Siddhappa, S. A., Gajanan, S. B., Philip, S. V., & Paul, P. S. (2017). Effect of Bearings on Vibration in Rotating Machinery. In *IOP Conference Series: Materials Science and Engineering* (Vol. 225, No. 1, p. 012264). IOP Publishing.

Dayou, S., Liew, W. Y. H., Ismail, M. A. B., & Dayou, J. (2011). 'Evaluation of palm oil methyl ester as lubricant additive using milling and four-ball tests'. *Int J Mech Mater Eng*, *6*(3), 374-379.

Dean, B., & Bhushan, B. (2010). ‘Shark-skin surfaces for fluid-drag reduction in turbulent flow: a review’. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, *368*(1929), 4775-4806.

De Graef, V., Goderis, B., Van Puyvelde, P., Foubert, I., & Dewettinck, K. (2008). ‘Development of a rheological method to characterize palm oil crystallizing under shear’. *European journal of lipid science and technology*, *110*(6), 521-529.

Del Din, M., & Kassfeldt, E. (1999). ‘Wear characteristics with mixed lubrication conditions in a full scale journal bearing’. *Wear*, *232*(2), 192-198.

Dhande, D. Y., & Pande, D. W. (2016). ‘Multiphase flow analysis of hydrodynamic journal bearing using CFD coupled Fluid Structure Interaction considering cavitation’. *Journal of King Saud University-Engineering Sciences,* Vol 30(4): 345-354.

Dmitri Kopeliovich (2017). Oil Clearance And Engine Bearings. *Engine Professional*, Page (54-60).

Dobrica, M. B., Fillon, M., Pascovici, M. D., & Cicone, T. (2010). ‘Optimizing surface texture for hydrodynamic lubricated contacts using a mass-conserving numerical approach’. *Proceedings of the Institution of Mechanical Engineers, Part J: Journal of Engineering Tribology*, *224*(8), 737-750.

Doig, M., Warrens, C. P., & Camp, P. J. (2014). ‘Structure and friction of stearic acid and oleic acid films adsorbed on iron oxide surfaces in squalane’. *Langmuir*, *30*(1), 186-195.

DuBois, G. B., & Ocvirk, F. W. (1953). Analytical derivation and experimental evaluation of short-bearing approximation for full journal bearing. University of North Texas Libraries, UNT Digital Library.

Dwyer-Joyce, R. S., Reddyhoff, T., & Zhu, J. (2011). ‘Ultrasonic measurement for film thickness and solid contact in elastohydrodynamic lubrication’. *Journal of Tribology*, *133*(3), 031501.

Eastman Chemical Company (2007): High Performance Additives. Retrieved on 15th July 2018 from www.eastman.com Eastman Chemical Company, Kingsport, TN, USA.

Erhan, S. Z., Sharma, B. K., & Perez, J. M. (2006). 'Oxidation and low temperature stability of vegetable oil-based lubricants'. *Industrial Crops and Products*, *24*(3), 292-299.

Erhunmwun, I., & Akpobi, J. (2019). 'Viscosity Change and its Effect on Pressure Distribution in Hydrodynamically Lubricated Journal Bearing'. *International Journal of Computational and Experimental Science and Engineering*, *5*(2), 56-60.

Etsion, I. (2005). 'State of the art in laser surface texturing'. *J. Trib.*, *127*(1), 248-253.

Farhanah, A. N., & Syahrullail, S. (2016). 'Evaluation of lubrication performance of RBD palm stearin and its formulation under different applied loads'. *Jurnal Tribologi*, *10*, 1-15.

Fazal, M. A., Haseeb, A. S. M. A., & Masjuki, H. H. (2013). 'Investigation of friction and wear characteristics of palm biodiesel'. *Energy conversion and management*, *67*, 251-256.

Filipović, I., & Bibić, D. (2010). 'Impact of Oil Viscosity on Functional Parameters of Journal Bearings in Internal Combustion Engines'. *Goriva i maziva: časopis za tribologiju, tehniku podmazivanja i primjenu tekućih i plinovitih goriva i inžinjerstvo izgaranja*, *49*(4), 343-351.

Fowell, M., Olver, A. V., Gosman, A. D., Spikes, H. A., & Pegg, I. (2007). 'Entrainment and inlet suction: two mechanisms of hydrodynamic lubrication in textured bearings'. *J. Trib* 129(2): 336-347.

Fowell, M. T., Medina, S., Olver, A. V., Spikes, H. A., & Pegg, I. G. (2012). 'Parametric study of texturing in convergent bearings'. *Tribology International*, *52*, 7-16.

Fox, N. J., Tyrer, B., & Stachowiak, G. W. (2004). 'Boundary lubrication performance of free fatty acids in sunflower oil'. *Tribology letters*, *16*(4), 275-281.

Fox, N. J., & Stachowiak, G. W. (2007). 'Vegetable oil-based lubricants—a review of oxidation'. *Tribology international*, *40*(7), 1035-1046.

Galda, L., Sep, J., & Prucnal, S. (2016). 'The effect of dimples geometry in the sliding surface on the tribological properties under starved lubrication conditions'. *Tribology International*, *99*, 77-84.

Galda, L., Sep, J., Olszewski, A., & Zochowski, T. (2019). 'Experimental investigation into surface texture effect on journal bearings performance'. *Tribology International*, *136*, 372-384.

Gao, G., Yin, Z., Jiang, D., & Zhang, X. (2014). 'Numerical analysis of plain journal bearing under hydrodynamic lubrication by water'. *Tribology International*, *75*, 31-38.

Gitay, M. M., & Narwade, P. (2017). 'Pressure distribution and load carrying capacity of journal bearing by using bio oil'. *International Research Journal of Engineering and Technology (IRJET)*. Vol. 4 Issue 7.

Golshokouh, I., Golshokouh, M., Ani, F.N., Kianpour, E. and Syahrullail, S. (2013a) 'Investigation of physical properties for jatropha oil in different temperature as lubricant oil'. *Life Science Journal,* 10(8s), pp 110-119.

Golshokouh, I., Syahrullail, S., Ani, F.N. and Masjuki, H.H. (2013b) 'Investigation of Palm Fatty Acid Distillate as an Alternative Lubricant of Petrochemical Based Lubricants, Tested at Various Speeds'. *International Review of Mechanical Engineering (IREME)*; 7(1), 72 – 80.

Gopinath. K and Mayuram. M.M. Machine Design 2. Module 5 – Sliding Contact Bearing, Lecture 1: Sliding Contact Bearing – *Introduction. Indian Institute of Technology*. Retrieved on Jan 15 2018.

Gregory F. Simmons (2013). *Journal Bearing Design, Lubrication and Operation for Enhanced Performance*. PhD Thesis, Lulea University of Technology, Sweden.

Gropper, D., Wang, L., & Harvey, T. J. (2016). 'Hydrodynamic lubrication of textured surfaces: A review of modeling techniques and key findings'. *Tribology International*, *94*, 509-529.

Gryglewicz, S., Piechocki, W., & Gryglewicz, G. (2003). 'Preparation of polyol esters based on vegetable and animal fats'. *Bioresource Technology*, *87*(1), 35-39.

Guillén, M. D., & Cabo, N. (2002). 'Fourier transform infrared spectra data versus peroxide and anisidine values to determine oxidative stability of edible oils'. *Food Chemistry*, *77*(4), 503-510.

Gundarneeya, T., & Vakharia, D. (2017). 'Evaluation of Load Carrying Capacity of Hydrodynamic Journal Bearing with Nanolubricants'. *Kalpa Publications in Engineering*, *1*, 609-617.

Gunsel, S., Smeeth, M., & Spikes, H. (1996). 'Friction and wear reduction by boundary film-forming viscosity index improvers'. *SAE transactions*, 1831-1855.

Guo, B. (2017). 'Optimal surface texture design of journal bearing with axial grooves'. *International Journal of Heat and Technology*, *35*(2), 267-272.

Habibullah, M., Masjuki, H. H., Kalam, M. A., Ashraful, A. M., Habib, M. A., & Mobarak, H. M. (2014). 'Effect of bio-lubricant on tribological characteristics of steel'. *Procedia Engineering*, *90*, 740-745.

Hamdavi, S., Ya, H. H., & Rao, N. (2016). 'Effect of surface texturing on hydrodynamic performance of journal bearing'. *ARPN Journal of Engineering and Applied Sciences*, *11*(1), 172-176.

Hamrock, B. J. (1991). *Fundamentals of fluid lubrication.* Mc Graw Hill.

Hargreaves, D., & Sharma, S. C. (2001). 'Effects of solid contaminants on journal bearing performance'. *Tribology. Wien, Austria: The Austrian Tribology Society*, 237-240.

Haseeb, A. S. M. A., Sia, S. Y., Fazal, M. A., & Masjuki, H. H. (2010). 'Effect of temperature on tribological properties of palm biodiesel'. *Energy*, *35*(3), 1460-1464.

Harper, P., Hollingsworth, B., Dwyer-Joyce, R., & Drinkwater, B. (2003). 'Journal bearing oil film measurement using ultrasonic reflection'. *Tribology Series* (Vol. 41, pp. 469-476). Elsevier.

Huey, S. M., Let, C. C., & Chee, Y. (2015). 'New developments in palm oil fractionation'. *Palm Oil Developments*, *62*, 4-14.

Hutton, J. F., Jackson, K. P., & Williamson, B. P. (1986). 'The effects of lubricant rheology on the performance of journal bearings'. *ASLE transactions*, *29*(1), 52-60.

Ing, T. C., Rafiq, A. K. M., Azli, Y., & Syahrullail, S. (2012). 'Tribological behaviour of refined bleached and deodorized palm olein in different loads using a four-ball tribotester'. *Scientia Iranica*, *19*(6), 1487-1492.

Irani, K., Pekkari, M., & Ångström, H. E. (1997). 'Oil film thickness measurement in the middle main bearing of a six-cylinder supercharged 9 litre diesel engine using capacitive transducers'. *Wear*, *207*(1-2), 29-33.

Jain, A. K., & Suhane, A. (2012). 'Research approach & prospects of non edible vegetable oil as a potential resource for biolubricant - a review'. *Advanced Engineering and Applied Sciences: An International Journal*, *1*(1), 23-32.

Jayadas, N. H., & Nair, K. P. (2006). 'Coconut oil as base oil for industrial lubricants—evaluation and modification of thermal, oxidative and low temperature properties'. *Tribology international*, *39*(9), 873-878.

Jayadas, N. H., Nair, K. P., & Ajithkumar, G. (2007). 'Tribological evaluation of coconut oil as an environment-friendly lubricant'. *Tribology International*, *40*(2), 350-354.

Jearl, W. (1979). ‘More on boomerangs, including their connection with the dimpled golf ball’. *Scientific American*, 180.

Jim Clark. (2016, July). *Gas Liquid Chromatography*. Retrived June 15, 2019 from https://www.chemguide.co.uk/analysis/chromatography/gas.html.

Jin, Z., & Fisher, J. (2014). Tribology in joint replacement. In *Joint replacement technology*. Woodhead Publishing 31-61.

Jumaah M.A, Yusuff M.F.M, Salimon .J, & Bahadi .M. (2019). ‘Physical Characteristics of Palm Fatty Acid Distillate’. *Journal of Chemical and Pharmaceutical Science*, 12(1), ISSN (Print 0974 - 2115).

Kalam, M. A., Masjuki, H. H., Shahabuddin, M., & Mofijur, M. (2012). ‘Tribological characteristics of amine phosphate and octylated/butylated diphenylamine additives infused bio-lubricant’. *Energy Education Science and Technology Part A: Energy Science and Research*, *30*(1), 123-136.

Kango, S., Sharma, R. K., & Pandey, R. K. (2014). ‘Comparative analysis of textured and grooved hydrodynamic journal bearing’. *Proceedings of the Institution of Mechanical Engineers, Part J: Journal of Engineering Tribology*, *228*(1), 82-95.

Karasek, F. W., & Clement, R. E. (2012). *Basic gas chromatography-mass spectrometry: principles and techniques*. Elsevier.

Kassfeldt, E., & Dave, G. (1997). ‘Environmentally adapted hydraulic oils’. *Wear*, *207*(1-2), 41-45.

Khasbage, S. S., Dhande, D. Y., & Patil, V. R. (2016). Experimental and CFD performance analysis of hydrodynamic journal bearing using Jatropha blended Copper-Oxide nanoparticle as lubricant. In *Automatic Control and Dynamic Optimization Techniques (ICACDOT), International Conference on* September 9, IEEE, 870-874.

Kasolang, S., Ahmad, M. A., Dwyer-Joyce, R., Jaffar, A., Bakar, M. A. A., Saad, N. H., & Jumahat, A. (2012). Experimental Study of Temperature profile in a Journal Bearing. In *1st Joint Symposium on System-Integrated Intelligence: New Challenges for Product and Production Engineering*, 43-45.

Kasolang, S., Ahmad, M. A., Joyce, R. D., & Tai, C. F. M. (2012). 'Preliminary study of pressure profile in hydrodynamic lubrication journal bearing'. *Procedia Engineering*, *41*, 1743-1749.

Kasolang, S., Ahmed, D. I., Dwyer-Joyce, R. S., & Yousif, B. F. (2013). 'Performance analysis of journal bearings using ultrasonic reflection'. *Tribology International*, *64*, 78-84.

Kerrihard, A. L., Pegg, R. B., Sarkar, A., & Craft, B. D. (2015). 'Update on the methods for monitoring UFA oxidation in food products'. *European Journal of Lipid Science and Technology*, *117*(1), 1-14.

Kiu, S. S. K., Yusup, S., Soon, C. V., Arpin, T., Samion, S., & Kamil, R. N. M. (2017). 'Tribological Investigation of Graphene as Lubricant Additive in Vegetable Oil'. *Journal of Physical Science*, *28*, 257.

Knothe, G., & Steidley, K. R. (2005). 'Kinematic viscosity of biodiesel fuel components and related compounds. Influence of compound structure and comparison to petrodiesel fuel components'. *Fuel*, *84*(9), 1059-1065.

Kondo, H. (1997). 'Effect of double bonds on friction in the boundary lubrication of magnetic thin film media'. *Wear*, *202*(2), 149-153.

Kornaev, A., Savin, L., Kornaeva, E., & Fetisov, A. (2016). 'Influence of the ultrafine oil additives on friction and vibration in journal bearings'. *Tribology International*, *101*, 131-140.

Kučera, M., Hnilicová, M., Turis, J., & Semanova, P. (2013). 'The experimental research of physicochemical and tribological characteristics of hydraulic oils with a low environmental impact'. *Acta Facultatis Technicae Zvolen*, 18(1), 25-31.

Kumar, P., & Gupta, A. K. (2014). 'Experimental Investigation on Hydrodynamic Journal Bearing using SAE 10W30 Multi Grade Oil'. *International Journal*, *2*(1), 166-173.

Loehle, S. (2014). *Understanding of adsorption mechanism and tribological behaviors of C18 fatty acids on iron-based surfaces: a molecular simulation approach.* PhD Thesis. Ecully, Ecole centrale de Lyon.

Lu, X., & Khonsari, M. M. (2007). 'An experimental investigation of dimple effect on the stribeck curve of journal bearings'. *Tribology letters*, *27*(2), 169.

Lu, P., Wood, R. J., Gee, M. G., Wang, L., & Pfleging, W. (2016). 'The friction reducing effect of square-shaped surface textures under lubricated line-contacts—an experimental study'. *Lubricants*, *4*(3), 26.

Lu, X., Khonsari, M. M., & Gelinck, E. R. M. (2006). 'The Stribeck curve: experimental results and theoretical prediction'. *Journal of Tribology,* Vol.128, 789-794.

Lubricants Market (2020). *Lubricant Market by Base Oil (Mineral Oil, Synthetic Oil, Bio-based Oil), Product Type (Engine Oil, Hydraulic Fluid, Metalworking Fluid), Application (Transportation and Industrial lubricants), Region - Global Forecast to 2025.* Retrieved on 15 November 2020 from www.marketsandmarkets.com.

Lundgren, S. M. (2008). *Unsaturated Fatty Acids in Alkane Solution: Adsorption and Tribological Properties.* PhD Thesis. KTH, Stockholm.

Lundgren, S. M., Persson, K., Clarke, J., Nordstierna, L., & Claesson, P. M. (2011). The influence of water on the adsorption and the tribological properties of unsaturated fatty acids in alkane solution. *Proceedings of the Institution of Mechanical Engineers, Part J: Journal of Engineering Tribology*, *225*(10), 1048-1055.

Luther, R. (2000). *Lubricants, 3. environmental aspects. Ullmann's Encyclopedia of Industrial Chemistry*. Wiley-VCH.

Madhujith T., Sivakanthan S. (2018). *Oxidative Stability of Edible Plant Oils*. In: Mérillon JM., Ramawat K. (eds) Bioactive Molecules in Food. Reference Series in Phytochemistry. Springer International Publishing AG.

Mahesh, A., Belkar, S., & Kharde, R. R. (2013). 'Pressure distribution analysis of plain journal bearing with lobe journal bearing'. *International journal of engineering research & technology*, *2*, 1-6.

Malcolm E, Leader P.E (2001). *Understanding Journal Bearings*. Applied Machinery Dynamics Co. Durango Colorado.

Mannekote, J. K., & Kailas, S. V. (2011). 'Experimental investigation of coconut and palm oils as lubricants in four-stroke engine'. *Tribology Online*, *6*(1), 76-82.

Mannekote, J. K., & Kailas, S. V. (2012). 'The effect of oxidation on the tribological performance of few vegetable oils'. *Journal of materials research and technology*, *1*(2), 91-95.

Marotrao, T. K. (2012). Physiochemical properties of oil blend and their effects on lubrication properties. *International journal of advanced engineering research and studies*, *1*(3), 35-38.

Masjuki, H. H., & Maleque, M. A. (1997). 'Investigation of the anti-wear characteristics of palm oil methyl ester using a four-ball tribometer test'. *Wear*, *206*(1-2), 179-186.

Masjuki, H. H., Maleque, M. A., Kubo, A., & Nonaka, T. (1999). 'Palm oil and mineral oil based lubricants—their tribological and emission performance'. *Tribology International*, *32*(6), 305-314.

Matos de Reis, J. O., Rodrigues, G. W., & Bittencourt, M. L. (2019). 'Virtual texturing of lightweight engine crankshaft bearings'. *Journal of the Brazilian Society of Mechanical Sciences and Engineering*, *41*(6), 242.

Meng, F., Yu, H., Gui, C., & Chen, L. (2019). 'Experimental study of compound texture effect on acoustic performance for lubricated textured surfaces'. *Tribology International*, *133*, 47-54.

Minhui, H., Hunter, C. C., & James, M. B. (2005). Fundamentals of Fluid Film Journal Bearing Operation and Modeling. *Dept. of Mechanical Engineering, Texas A&B University, rotating machinery technology, inc., pp.(155-175)*.

Mobarak, H. M., Mohamad, E. N., Masjuki, H. H., Kalam, M. A., Al Mahmud, K. A. H., Habibullah, M., & Ashraful, A. M. (2014a). 'The prospects of biolubricants as alternatives in automotive applications'. *Renewable and sustainable energy reviews*, *33*, 34-43.

Mobarak, H. M., Masjuki, H. H., Mohamad, E. N., Rahman, S. A., Al Mahmud, K. A. H., Habibullah, M., & Salauddin, S. (2014b). 'Effect of DLC coating on tribological behavior of cylinder liner-piston ring material combination when lubricated with Jatropha oil'. *Procedia Engineering*, *90*, 733-739.

Mongkolwongrojn, M., & Arunmetta, P. (2002). 'Theoretical characteristics of hydrodynamic journal bearings lubricated with soybean-based oil'. *Journal of Synthetic Lubrication*, *19*(3), 213-228.

Morais, L., & Ferreira, L. A. (2005). Sensibility Analysis of Design Parameters for Journal Bearings Optimization of Mass Balancing Systems. In *World Tribology Congress III*. 1 January. American Society of Mechanical Engineers. 41-42.

Moreau, H., Maspeyrot, P., & Frene, J. (2002). 'Mesure des épaisseurs de film d'huile dans les paliers de moteur automobile'. *Mécanique & industries*, *3*(6), 607-617.

Muzakkir, S. M., Lijesh, K. P., & Hirani, H. (2014). 'Tribological failure analysis of a heavily-loaded slow speed hybrid journal bearing'. *Engineering Failure Analysis*, *40*, 97-113.

Muzakkir, S. M., Hirani, H., & Thakre, G. D. (2015). 'Experimental investigations on effectiveness of axial and circumferential grooves in minimizing wear of journal bearing operating in mixed lubrication regime'. *International Journal of Current Engineering and Technology*, *5*(1), 486-489.

Nanbu, T., Ren, N., Yasuda, Y., Zhu, D., & Wang, Q. J. (2008). 'Micro-textures in concentrated conformal-contact lubrication: effects of texture bottom shape and surface relative motion'. *Tribology Letters*, *29*(3), 241-252.

Nikolakopoulos, P. G., & Bompos, D. A. (2015). 'Experimental measurements of journal bearing friction using mineral, synthetic, and bio-based lubricants'. *Lubricants*, *3*(2), 155-163.

Ningsih, Y. R. (2017). Utilization of sulphurized palm oil as cutting fluid base oil for broaching process. In *IOP Conference Series: Earth and Environmental Science* (Vol. 60, No. 1, p. 012008). IOP Publishing.

Norizzah, A. R., Norsyamimi, M., Zaliha, O., Nur Azimah, K., & Siti Hazirah, M. F. (2015). 'Physicochemical properties of palm oil and palm kernel oil blend fractions after interesterification'. *International Food Research Journal*, *22*(4).

Nurul, M. A., Syahrullail, S., & Teng, H. W. (2016). 'Alternative lubricants: study on palm oil-based lubricants in metal forming process'. *Journal of Oil Palm Research*, *28*(1), 93-103.

Nuruzzaman, D. M., Khalil, M. K., Chowdhury, M. A., & Rahaman, M. L. (2010). Study on pressure distribution and load capacity of a journal bearing using finite element method and analytical method. *International Journal of Mechanical & Mechatronics Engineering IJMME-IJENS*, *10*(05).

Olver, A. V., Fowell, M. T., Spikes, H. A., & Pegg, I. G. (2006). ''Inlet suction', a load support mechanism in non-convergent, pocketed, hydrodynamic bearings'. *Proceedings of the institution of mechanical engineers, Part J: Journal of Engineering Tribology*, *220*(2), 105-108.

Omer, M. A., Rao, T. V. V. L. N., Rani, A. M. A., Nagarajan, T., & Hashim, F. M. (2014). Pressure distribution in hydrodynamic journal bearing with lubricants additives. In *MATEC Web of Conferences* (Vol. 13, p. 05006). EDP Sciences.

Omrani, E., Menezes, P. L., & Rohatgi, P. K. (2016). 'State of the art on tribological behavior of polymer matrix composites reinforced with natural fibers in the green materials world'. *Engineering Science and Technology, an International Journal*, *19*(2), 717-736.

Panchal, T. M., Chauhan, D. D., Thomas, M., & Patel, J. V. (2014). 'Synthesis and characterization of bio lubricants from tobacco seed oil'. *Research Journal of Agriculture and Environmental Management*, *3*(2), 097-105.

Panchal, T. M., Patel, A., Chauhan, D. D., Thomas, M., & Patel, J. V. (2017). 'A methodological review on bio-lubricants from vegetable oil based resources'. *Renewable and Sustainable Energy Reviews*, *70*, 65-70.

Patir, N., & Cheng, H. S. (1978). 'An average flow model for determining effects of three-dimensional roughness on partial hydrodynamic lubrication'. *J. of Lubrication Tech.* 100(1): 112-17.

Pickering, S. (2011). Tribology of Journal Bearing Subjected to Boundary and Mixed Lubrication‖. *Mechanics of Contact and Lubrication,* Northeastern University.

Quinchia, L. A., Delgado, M. A., Valencia, C., Franco, J. M., & Gallegos, C. (2010). 'Viscosity modification of different vegetable oils with EVA copolymer for lubricant applications'. *Industrial Crops and Products*, *32*(3), 607-612.

Quinchia, L. A., Delgado, M. A., Franco, J. M., Spikes, H. A., & Gallegos, C. (2012). 'Low-temperature flow behaviour of vegetable oil-based lubricants'. *Industrial Crops and Products*, *37*(1), 383-388.

Quinchia, L. A., Delgado, M. A., Reddyhoff, T., Gallegos, C., & Spikes, H. A. (2014). 'Tribological studies of potential vegetable oil-based lubricants containing environmentally friendly viscosity modifiers'. *Tribology International*, *69*, 110-117.

Rahim, E. A., & Sasahara, H. (2017). Performance of palm oil as a biobased machining lubricant when drilling inconel 718. In *MATEC Web of Conferences* (Vol. 101, p. 03015). EDP Sciences.

Rahmani, F., Dutt, J. K., & Pandey, R. K. (2016). 'Dynamic Characteristics of a Finite-Width Journal Bearing Lubricated with Powders'. *Procedia Engineering*, *144*, 841-848.

Rani, S., Joy, M. L., & Nair, K. P. (2015). 'A comparative study of polymeric additives as biodegradable viscosity boosters for biolubricant formulations'. *Proceedings of the Institution of Mechanical Engineers, Part J: Journal of Engineering Tribology*, *229*(9), 1079-1085.

Reddy, K. S. V., Kabra, N., Kunchum, U., & Vijayakumar, T. (2014). 'Experimental investigation on usage of palm oil as a lubricant to substitute mineral oil in CI engines'. *Chinese Journal of Engineering*, *2014*.

Rhee, I. S., Velez, C., & Von Bernewitz, K. (1995). *Evaluation of Environmentally Acceptable Hydraulic Fluids* (No. TARDEC-TR-13640). Tacom Research Development And Engineering Center Warren Mi.

Rodrigues Jr, J. D. A., Cardoso, F. D. P., Lachter, E. R., Estevão, L. R., Lima, E., & Nascimento, R. S. (2006). 'Correlating chemical structure and physical properties of vegetable oil esters'. *Journal of the American Oil Chemists' Society*, *83*(4), 353-357.

Ronkainen, H., Hokkanen, A., Kapulainen, M., Stuns, I., Varjus, S., Turunen, R., & Halme, J. (2012). 'Multichannel optical sensor for oil film pressure measurement in engine main bearing'. *Tribologia-Finnish Journal of Tribology*, *31*(3-4), 20-26.

Rosenkranz, A., Costa, H. L., Profito, F., Gachot, C., Medina, S., & Dini, D. (2019). 'Influence of surface texturing on hydrodynamic friction in plane converging bearings-An experimental and numerical approach'. *Tribology International*, *134*, 190-204.

Rozeanu, L., & Kennedy, F. E. (2001). 'Wear of hydrodynamic journal bearings'. *Tribology Series*. Vol. 39: (161-166).

Rudnick, L. R. (2005). *Synthetics, mineral oils, and bio-based lubricants: chemistry and technology*. CRC press (Taylor and Francis Group).

Rudnick, L. R. (2017). *Lubricant additives: chemistry and applications*. CRC press (Taylor and Francis Group).

Ruger, C. W., Klinker, E. J., & Hammond, E. G. (2002). 'Abilities of some antioxidants to stabilize soybean oil in industrial use conditions'. *Journal of the American Oil Chemists' Society*, *79*(7), 733-736.

Saldaña, M. D. A., & Martínez-Monteagudo, S. I. (2013) *Oxidative stability of fats and oils measured by differential scanning calorimetry for food and industrial applications* in Amal Ali Elkordy (eds) *Appl calorim a wide context-differ scanning calorimetry, isothermal titration calorim microcalorim*. Intechopen 445-474.

Sander, D. E., Allmaier, H., Priebsch, H. H., Reich, F. M., Witt, M., Füllenbach, T.,& Schwarze, H. (2015). 'Impact of high pressure and shear thinning on journal bearing friction'. *Tribology International*, *81*, 29-37.

Sapawe, N., Samion, S., Zulhanafi, P., Nor Azwadi, C. S., & Hanafi, M. F. (2016). 'Effect of addition of tertiary-butyl hydroquinone into palm oil to reduce wear and friction using four-ball tribotester'. *Tribology Transactions*, *59*(5), 883-888.

Schneider, J., Braun, D., & Greiner, C. (2017). 'Laser textured surfaces for mixed lubrication: influence of aspect ratio, textured area and dimple arrangement'. *Lubricants*, *5*(3), 32.

Sellami, M., Ghamgui, H., Frikha, F., Gargouri, Y., & Miled, N. (2012). 'Enzymatic transesterification of palm stearin and olein blends to produce zero-trans margarine fat'. *BMC biotechnology*, *12*(1), 48.

Sep, J., Tomczewski, L., Galda, L., & Dzierwa, A. (2017). 'The study on abrasive wear of grooved journal bearings'. *Wear*, *376*, 54-62.

Sharma, B. K., Adhvaryu, A., & Erhan, S. Z. (2009). 'Friction and wear behavior of thioether hydroxy vegetable oil'. *Tribology International*, *42*(2), 353-358.

Shashidhara, Y. M., & Jayaram, S. R. (2010). 'Vegetable oils as a potential cutting fluid—an evolution'. *Tribology international*, *43*(5-6), 1073-1081.

Shinde, P. D., & Nagare, P. N. (2016) Experimental Evaluation of Performance Parameters of Journal Bearing Operating in Boundary/Mixed Lubrication Regimes. *International Advanced Research Journal in Science, Engineering and Technology (IARJSET)*. Vol 3(1).

Sinanoğlu, C., Nair, F., & Karamış, M. B. (2005). 'Effects of shaft surface texture on journal bearing pressure distribution'. *Journal of materials processing technology*, *168*(2), 344-353.

Singla, A., Singh, P., & Chauhan, A. (2014). 'Experimental determination of temperature and pressure profile of oil film of elliptical journal bearing'. *IJAME*, *4*(5), 469-474.

Singla, A., & Chauhan, A. (2016). 'Evaluation of Oil Film Pressure and Temperature of an Elliptical Journal Bearing-An Experimental Study'. *Tribology in Industry*, *38*(1).

Smeeth, M., Spikes, H. A., & Gunsel, S. (1996). 'The formation of viscous surface films by polymer solutions: boundary or elastohydrodynamic lubrication'. *Tribology Transactions*, *39*(3), 720-725.

Soni, S., & Vakharia, D. P. (2014). Performance Analysis of Short Journal Bearing under Thin Film Lubrication. *ISRN Mechanical Engineering*, *2014*.

Sun, J., & Changlin, G. (2004). 'Hydrodynamic lubrication analysis of journal bearing considering misalignment caused by shaft deformation'. *Tribology International*, *37*(10), 841-848.

Syahrulalil, S., Nakanishi, K. and Kamitani, S. (2005) 'Investigation of the effects of frictional constraint with application of palm olein oil lubricant and paraffin mineral oil lubricant on plastic deformation by plane strain extrusion'. *Japanese Journal of Tribology,* 50(6), pp.727-738

Syahrullail, S., Azwadi, C.S.N. and Ing, T.C. (2011). 'The metal flow evaluation of billet extruded with RBD palm stearin'. *International Review of Mechanical Engineering,* 5(1), pp.21-27.

Syahrullail. S, C.S.N. Azwadi, Tiong Chiong Ing,. (2011) 'The Metal Flow Evaluation of Billet Extruded With RBD Palm Stearin'. *International Review of Mechanical Engineering; (I.R.E.M.E)*; Vol 5, N 1.

Syahrullail, S., Wira, J.Y., Wan Nik, W.B. and Fawwaz, W.N. (2013) 'Friction characteristics of RBD palm olein using four-ball tribotester', *Applied Mechanics and Materials*, (Vol. 315, pp. 936-940).

Syahrullail, S., & Zulhanafi, P. (2014). 'The Oxidation Effect of Palm Oil Based Lubricant Using Four-Ball Tribotester'. *Applied Mechanics & Materials*, (554).

Tala-Ighil, N., Maspeyrot, P., Fillon, M., & Bounif, A. (2007). 'Hydrodynamic effects of texture geometries on journal bearing surfaces', *10th International Conference on Tribology ROTRIB'07,* 8-10 November, *Bucharest, Romania.*

Tala-Ighil, N., Fillon, M., & Maspeyrot, P. (2011). 'Effect of textured area on the performances of a hydrodynamic journal bearing'. *Tribology International*, *44*(3), 211-219.

Tala-Ighil, N., & Fillon, M. (2017, February). Performance evolution of fully and partially textured hydrodynamic journal bearings lubricated with two lubricants. In *IOP Conference Series: Materials Science and Engineering* (Vol. 174, No. 1, p. 012032). IOP Publishing.

Tamboli, K., & Athre, K. (2016). 'Experimental Investigations on Water Lubricated Hydrodynamic Bearing'. *Procedia Technology*, *23*, 68-75.

Tanaka, M. (2000). 'Journal bearing performance under starved lubrication'. *Tribology international*, *33*(3-4), 259-264.

Tomimoto, M. (2003). 'Experimental verification of a particle induced friction model in journal bearings'. *Wear*, *254*(7-8), 749-762.

Tonder, K. (2001). 'Inlet roughness tribodevices: dynamic coefficients and leakage'. *Tribology International*, *34*(12), 847-852.

Totten, G. E., Westbrook, S. R., & Shah, R. J. (2003). 'Fuels and lubricants handbook: technology, properties, performance, and testing'. *American Society for Testing & Materials*, Page 1041 (Chapter 37).

Tribonet (2020). *Reynolds Equation: Derivation and Solutions*. Retrieved on 21/11/2010 from https://www.tribonet.org/wiki/reynolds-equation/.

Ullah, J., Hamayoun, M., Ahmad, T., Ayub, M., & Zafarullah, M. (2003). 'Effect of light, natural and synthetic antioxidants on stability of edible oil and fats'. *Asian J. Plant Sci*, *2*(17-24), 1192-1194.

Ünlü, B. S., & Atik, E. (2007). 'Determination of friction coefficient in journal bearings'. *Materials & design*, *28*(3), 973-977.

Valkonen, A., Juhanko, J., & Kuosmanen, P. (2010, April). Measurement of oil film pressure in hydrodynamic journal bearings. In *7th International DAAAM baltic Conference" Industrial Engineering", Tallin Estonia* (pp. 1-6).

Vižintin, J., Arnšek, A., & Ploj, T. (2000). 'Lubricating properties of rapeseed oils compared to mineral oils under a high load oscillating movement'. *Journal of Synthetic lubrication*, *17*(3), 201-217.

Vorapat Foungjaroen (2008). Effect of Oil Film Temperature on Oil Film Pressure in Journal Bearings Lubricated with Palm Oil. Presented in 22nd Conference of Mechanical Engineering Network of Thailand.

Wang, J. K., & Khonsari, M. M. (2008a). 'Effects of oil inlet pressure and inlet position of axially grooved infinitely long journal bearings. Part I: Analytical solutions and static performance'. *Tribology International*, *41*(2), 119-131.

Wang, J. K., & Khonsari, M. M. (2008b). 'Effects of oil inlet pressure and inlet position of axially grooved infinitely long journal bearings. Part II: Nonlinear instability analysis'. *Tribology International*, *41*(2), 132-140.

Wang, N., Meng, Q., Wang, P., Geng, T., & Yuan, X. (2013). 'Experimental research on film pressure distribution of water-lubricated rubber bearing with multiaxial grooves'. *Journal of Fluids Engineering*, *135*(8), 084501.

Wang, J., Zhang, J., Lin, J., & Ma, L. (2018). 'Study on Lubrication Performance of Journal Bearing with Multiple Texture Distributions'. *Applied Sciences*, *8*(2), 244.

Wood, M. H., Casford, M. T., Steitz, R., Zarbakhsh, A., Welbourn, R. J. L., & Clarke, S. M. (2016). 'Comparative adsorption of saturated and unsaturated fatty acids at the iron oxide/oil interface'. *Langmuir*, *32*(2), 534-540.

Zainal, N. A., Zulkifli, N. W. M., Gulzar, M., & Masjuki, H. H. (2018). 'A review on the chemistry, production, and technological potential of bio-based lubricants'. *Renewable and Sustainable Energy Reviews*, *82*, 80-102.

Zhang, H., Dong, G., Hua, M., Guo, F., & Chin, K. S. (2015). 'Parametric design of surface textures on journal bearing'. *Industrial lubrication and Tribology*. Vol. 67(4): 359-369.

Zuan, A. M. S., Syahrullail, S., Mekanikal, F. K., Ngadi, N., Kimia, F. K., & Ruslan, N. N. (2017). 'Bio-based Lubricants from Modification of RBD Palm Kernel Oil by Trans-Esterification'. *Journal of Mechanical Engineering,(publishing in-progress)*.

Zulhanafi, P., & Syahrullail, S. (2019). 'The tribological performances of Super Olein as fluid lubricant using four-ball tribotester'. *Tribology International*, *130*, 85-93.

Zulkifli, N. W. M., Kalam, M. A., Masjuki, H. H., Shahabuddin, M., & Yunus, R. (2013). 'Wear prevention characteristics of a palm oil-based TMP (trimethylolpropane) ester as an engine lubricant'. *Energy*, *54*, 167-173.

Zulkifli, N. W. M., Azman, S. S. N., Kalam, M. A., Masjuki, H. H., Yunus, R., & Gulzar, M. (2016). 'Lubricity of bio-based lubricant derived from different chemically modified fatty acid methyl ester'. *Tribology International*, *93*, 555-562.

LIST OF PUBLICATIONS

Journal with Impact Factor

1. **Zulhanafi, P.,** & Syahrullail, S. (2019). The tribological performances of Super Olein as fluid lubricant using four-ball tribotester. *Tribology International*, 130, 85-93. https://doi.org/10.1016/j.triboint.2018.09.013. **(Q1, IF: 4.271)**

Indexed Journal

1. **P. Zulhanafi,** S. Syahrullail, M.A. Ahmad. (2020). The Tribological Performance of Hydrodynamic Journal Bearing Using Bio-Based Lubricant. *Tribology in Industry,* Vol. 42, No.2 (278-287). https://doi.org/10.24874/ti.843.02.20.05. **(Indexed by Scopus)**

2. **Zulhanafi, P.**, Syahrullail, S., & Faridzuan, M. M. (2017). Tribological performance of palm kernel oil added with nanoparticle copper oxide using fourball tribotester. *Jurnal Teknologi*, *79*(7-4). **(Indexed by Scopus)**

Non-Indexed Conference Proceeding

1. **Zulhanafi, P.,** Syahrullail, S., & Ahmad, M. A. (2018). The performances of palm mid olein as lubricant in journal bearing application. In *Proceedings of Asia International Conference on Tribology 2018* (Vol. 2018, pp. 382-383). Malaysian Tribology Society.