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Investigation of Vibrational Response of Bio-Lubricants and SAE40 for Journal Bearing Application

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ABSTRACT

Amidst the burgeoning landscape of contemporary industrial growth, journal bearings have become integral components extensively employed across diverse rotating machinery. The intricate dynamics of journal bearings, particularly the robust nonlinear characteristics manifesting in the oil film pressure, constitute a focal point in this study. The research endeavours involve designing a journal bearing test rig (JBTR) to unravel the dynamic properties of journal bearings through a series of experimental trials. The operational speed for the analysis is set to 900 rpm and 1200 rpm to simulate low and high speed operations. The test sample includes conventional lubricants, SAE40 and bio-lubricants, palm olein, soybean and rapeseed oil. The bio-lubricants are compared to SAE40 to validate its vibrational response. The static characteristics (viscosity, eccentricity ratio, attitude angle) which represent the operational factors are also presented. A thorough analysis of the influences of bearing load, eccentric mass and rotational speed on dynamic characteristics yields nuanced insights and specific findings. Journal bearings, essential machine components facilitating relative movement among working parts, bear the dual role of load distribution and preservation of positional stability. Vibrational diagnostics, tantamount to the meticulous scrutiny of vibrational parameters, emerges as a pivotal technique for the comprehensive diagnostics of critical machinery in industrial plants. Earlier studies underscore the significance of bearing issues, attributing approximately 40% of machine failures to such concerns. Consequently, researchers actively discern the causative factors of bearing damage and pioneering innovative techniques for detecting destructive bearing issues. The experimental result from JBTR showcase the capabilities of bio-lubricants during operations yielding results such that, at 900 rpm the velocity reactions is at 14% average difference compared to SAE 40, displacement value at 1% and 46% average percentage difference at 25%. While at 1200 rpm, the velocity value also shows at 14% differences compared to SAE40, displacement percentage at 25% and acceleration percentage difference of 44%. The initial hypothesis may suggest a probable application of bio-lubricants within rolling bearings system.

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1. Introduction

Journal bearings are essential components in machinery such as gas turbines and electric pumps. A rotor-bearing system is complex and requires thoroughness to ensure it runs smoothly. Rotating machinery frequently experiences vibrations caused by critical speeds, imbalance, and instability [1]. The most cost-effective modification to make on a machine is typically the replacement of the bearing [2]. Viscosity is the most crucial element in understanding how lubricating fluid affects the performance of journal bearings over a long period. Viscosity analyses the journal bearing's operational performance, such as load-carrying capacity, pressure, and temperature [3-5]. As a result, much research has been done on journal bearing malfunction analysis [6]. Oil whip and oil whirl are typical ways for journal bearings brought on by oil film instability when the shaft's rotational speed is faster than the rotor system's critical speed [7-8].

Mechanical components are ubiquitous to various plant machinery, making them more susceptible to issues and defects. The system's condition can be monitored using various methods, including vibration and spectroscopic analyses [9-10]. One of many techniques for fault diagnostics is vibration analysis, which has been regarded as the principal preventative maintenance technique. Vibration measurement and analysis are the most crucial plant status monitoring techniques for several reasons, including the fact that they are the best instruments for monitoring and identifying startup issues. It can be a diagnostic tool to identify specific machine problems. This analysis is considered as non-destructive and can be carried out while the plant runs. It is also very effective in detecting a variety of machine defects and enable to detect failures early enough to allow for corrective action.

1.1 Sources of Bearing Failures

The common factors that often associated with premature bearing failure are issues such as contamination, inadequate lubrication, misalignment, extreme temperatures, poor fitting, and shaft imbalance. These factors raise bearing vibration levels significantly making it very susceptible to costly and lengthy failures. Though through condition monitoring systems, is often utilized to detect deterioration before catastrophic failure and costly downtime occur. Rolling element bearings, frequently used in noise-sensitive equipment like household appliances and electric motors, are especially affected. Consequently, controlling bearing vibration is increasingly essential not only for environmental reasons but also as an indicator of product quality and operational reliability.

Despite the high precision and rigorous cleanliness standards in rolling bearing manufacturing, minor imperfections or defects are inevitable, leading to vibrations from surface interactions involving both rolling and sliding motions. Current machining practices keeps surface roughness at nanometer scales; however, these tiny imperfections can still generate substantial vibrations across the audible frequency range. Another factor is contamination, which is a common cause of bearing wear and premature failure, often due to presence foreign particles within the bearing, often associated with poor handling. The resulting vibration varies and can be challenging to detect in early stages, depending on the contaminants’ characteristics. Contamination damages rolling surfaces and generates broad-frequency vibration; in the initial phase, the time signal’s crest factor may increase, though it might go unnoticed among other vibrations.

1.2 Vibrations Measurement

A proactive and robust approach that ensures the proper upkeep or maintenance of such complex system must be thoroughly understood. Vibration detection typically relies on basic broadband measurements, covering frequencies of 10–1000 Hz or 10–10,000 Hz depending on the scale of the system. In machinery with minimal other sources of vibration, an increase in the vibration signal’s “spikiness,” indicated by the Crest Factor (peak-to-RMS ratio), may suggest early-stage defects. Conversely, a high RMS value often signals more advanced, severe defects. By means of this, frequency analysis is crucial for identifying machine faults especially for bearings, as it distinguishes individual sources of vibration, like shaft imbalance or gear issues, that are harder to isolate in the time domain. In the frequency domain, faults such as developing bearing defects appear as increasing vibration levels at characteristic frequencies, allowing for much earlier detection of correlated failures.

1.3 Journal Bearing

Journal bearings are the most frequently utilized component in high-speed rotary machines must function correctly and receive high-quality lubrication to ensure regular rotational operation. These factors highlight the importance of ongoing investigation and study of anomalies in journal-bearing performance. Two types of self-excited vibrations, known as oil-whirl and oil-whip, are present in rotating machinery supported by journal bearings and potentially cause the system to become unstable [11-13]. When the shaft's rotating speed exceeds the rotor system's critical speed, oil whirl and oil whip—common journal bearing failures are brought on by the instability of the oil film [14-15].

This study aims to enhance the correlation between lubrications action within the journal and the vibrations it produces. Moreover, the comprehension of this study may enable us to find the optimal monitoring, and planning of bearing system maintenance that help extend its lifespan and detect early signs of potential failure. Relating both components where lubrication is present, continuous monitoring of vibration and temperature is crucial for detecting and preventing failures. Without lubrication, increased friction from metal-to-metal contact raises vibration levels and heats the components. This effect intensifies with higher machine speeds. By continuously tracking these parameters, subtle changes can be identified early through data trend analysis, allowing for timely interventions before actual failures occur. This proactive approach is vital for maintaining system reliability and performance.

1.4 Bio-lubricants Capabilities

Much of the research highlights bio-lubricants potential to replace conventional lubricants. This is because bio-lubricants show good tribological properties when tested and compared with mineral-based lubricants [16-18]. Likewise, another significant advantage offered by bio-lubricants is their eco-friendly and bio-degradation properties, which have attracted many researchers to study them. The static and dynamic performance of rotor bearings is reviewed, and the bio-lubricating performance is studied in the journal bearings [19-20]. The vibration is also a critical parameter during design consideration of rotating machinery [21-23]. The three main factors influencing lubricant rheological behaviors are temperature, water content, and shear rate [24-28].

In this study, bio-oils' dynamic properties will be compared to a mineral-based lubricant in a fluid film journal bearing, aiming to support further exploration of bio-lubricants in rotating machinery and it's operational capabilities in low speed applications. Although influenced by factors like operating speed, load conditions, friction types, and industry standards, selecting a proper lubrication system remains essential to ensure smooth machine function and mitigate potential issues. This comparison could provide foundational insights for bio-lubricant applications in various industries.

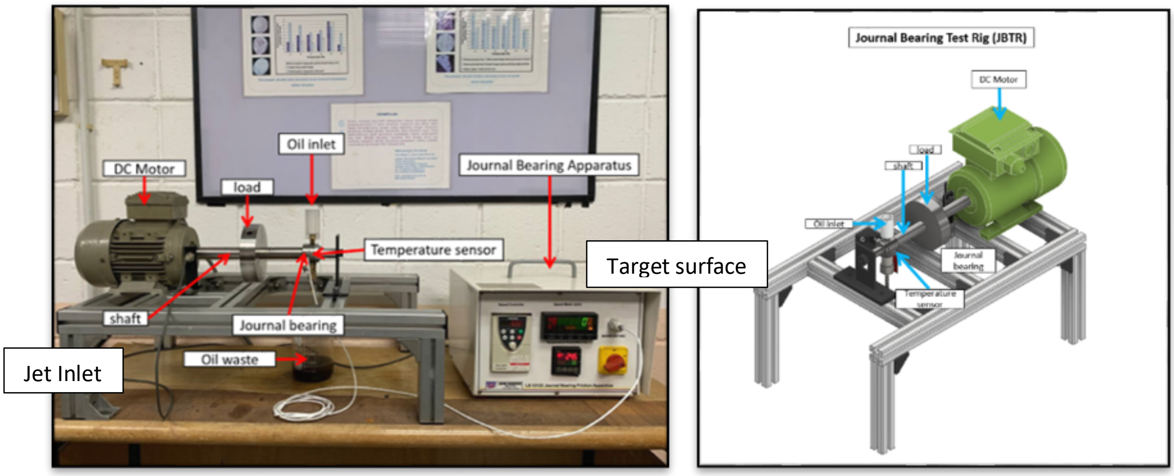
2. Methodology

2.1 Journal Bearing Test Rig (JBTR) Design Specification

Experiments are conducted to analyze the comparison of different bio-oils with conventional lubricants. The system's vibration is also carefully analyzed following the vibration data generated by the dynamic behavior of the journal-bearing system. To find out more about the issues that affect the performance and service life of journal bearings, a designated machine that can accurately measure the vibrations of the rig is utilized. There are characteristics of bio-based lubricants that should be studied as alternative lubricants other than conventional lubricants. For this purpose, the vibrational response of the JBTR, a vibration analyzer, will be used to measure the response of different oil samples used in the study accurately. The aim is to explore the feasibility of bio-based lubricants. The study focuses on two main objectives, namely:

- To study the vibrational performance of different bio-based lubricants in journal bearings
- To analyze the velocity, acceleration and displacement of different oil sample

The oils used in the experiments are SAE 40, palm olein, rapeseed oil, and soybean oil. SAE 40 is one of the lubricants often used in industry, and it represents a conventional lubricant for comparison with the bio lubricant used. In the experiment, the journal speed setting is at two-speed levels: 900 rpm and 1200 rpm.



(a) (b)

Fig. 1. (a) Actual design of Journal Bearing Test Rig (JBTR) (b) 3D Diagram of JBTR

For this purpose, a journal bearing test rig (JBTR) is developed and designed to experimentally verify bio-oil's physical properties and response to pressure, temperature, and vibrations and compare it with SAE40. The journal bearing system follows design according to the established design guidelines and is based on the hydrodynamic theory of lubrication. Some critical parameters that can be directly controlled are viscosity, load, speed, and bearing dimensions, including length, diameter, and radial clearance [29]. Several other parameters depend on the friction coefficient f; the temperature rises ΔT, the volume flow rate Q, and the minimum oil film thickness h0. These parameters describe the performance of the journal bearing in operation. The rotor is supported on short-length hydrodynamic journal bearings and possesses nonlinear dynamic behavior [30].

The actual model and system (JBTR) can be seen in Figure 2. Oil was supplied to the bearing through an oil inlet at the top of the journal bearing. It can hold up to 15 ml of oil. Depending on the need, provision has also been made for recirculation, refilling, and oil replacement. A DC motor with a speed control unit that can operate up to 3000 rpm (50 Hz) has been mounted directly on the journal. A tachometer is placed near the shaft to record the shaft speed in revolutions per minute (RPM). The load is applied to the journal bearing through a disc mounted on the journal and can be changed according to the loading. A specific sensor connects the journal-bearing apparatus to the DC motor and inner bearing surface. Temperature measurement of this test rig uses a thermocouple sensor. The central control unit sets the desired rpm, records the shaft rpm, and records the oil temperature.

The specifications of the journal bearing test rig (JBTR) are given in Table 1, and Table 2 below refers to the mechanical properties of the journal bearings used. The system is quite flexible because it can be easily modified and re-fixed. Also, there is a provision for the recirculation of oil and its replacement.

Table 1
Physical properties of Journal Bearing Test Rig (JBTR)

	Description	Specification
1	Bearing length (L)	12.5 mm
2	Inner diameter for plain bearing (d)	25.14 mm
3	Shaft diameter (Φ)	25 mm
4	Weight of journal shaft (W)	9 N
5	Weight of Load	25 N
6	Total clearance (CT)	0.14 mm
7	Radial clearance (CR)	0.07 mm
8	L/D ratio	0.5
9	Operating speed	1000, 1500, 2000 rpm

Table 2
Mechanical properties of stainless steel

Properties	Value
Density	.75 × 10−6 kg mm−3
Young's modulus (MPa)	1.93 × 105
Poisson's ratio	0.31
Bulk modulus (MPa)	1.693 × 105
Shear modulus (MPa)	73,664

Figure 2 below shows the flow of oil into the journal by using a syringe and the cross-section of the inner workings of the JBTR journal portions. The comprehensive system may enable us to visualize better the data produced by JBTR as it often appears in a functioning system and enhance our comprehension of how temperature, load, and speed affect the stiffness and damping properties of foil air journal bearings. This information will result in a more capable bearings design.

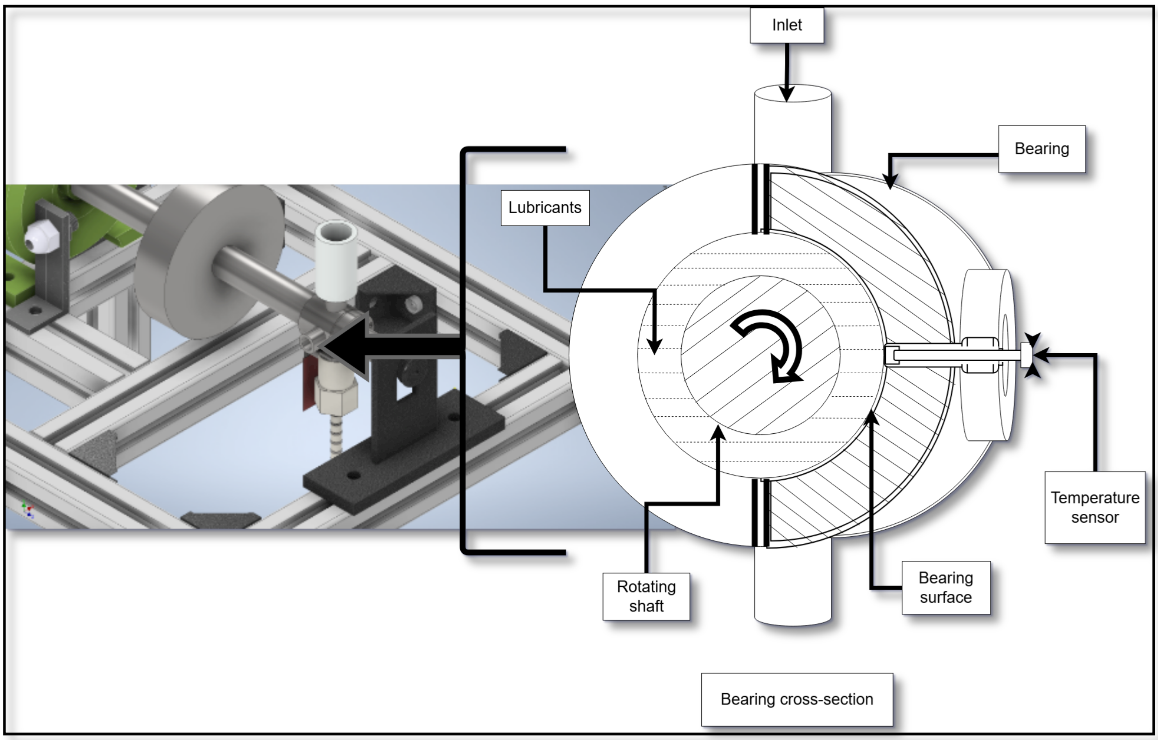
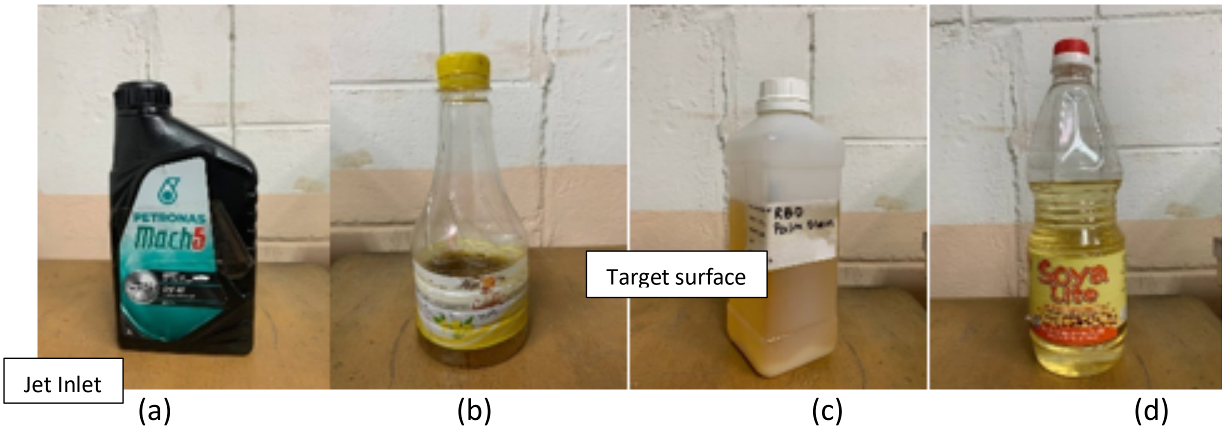


Fig. 2. The cross-section of journal bearing

Figure 3 below shows the sample used for temperature analysis in the journal bearing test rig. As mentioned, the samples used are SAE40, rapeseed oil, palm olein, and soybean oil. The static performance of bio-oils is evaluated in actual operating conditions, and the results of bio-oil were compared with SAE40, a mineral-based lubricant. The (JBTR) system was designed to operate at different speeds for different types of oil samples. The primary purpose of operating the (JBTR) is to observe the extended reaction of the bio-oils under actual operating and loading conditions. The working conditions between the journal and the bearing, via which the load is transferred from one surface to another, typically influence lubrication regimes [9]. Thus, by carrying out the above-described procedures, the leading hypothesis is to obtain actual experimental results and investigate the bio-oils responses when tested under stable operating conditions.

2.2 Bio-oils and lubrication properties

Tables 3 and 4 below describe the physical and static characteristics of the oil used in the experiment using the journal bearing test rig (JBTR). The static and physical characteristics of this oil are essential to determine the performance capability of the oil used, which has been verified and evaluated numerically. The main parameter emphasized is viscosity because it can explain the load-carrying capacity of the oil [18].



(a) (b) (c) (d)

Fig. 3. (a) SAE 40 (b) rapeseed oil (c) palm olein (d) soybean oil

Table 3
Static characteristics of the oils

No	Temp (°C)	SAE40			Rapeseed			Palm Olein			Soybean		
		μ	ε	ϕ	μ	ε	Φ	μ	ε	ϕ	μ	ε	ϕ
1	40	0.096	0.195	75.8°	0.0357	0.39	61.7°	0.033	0.41	60.2°	0.0263	0.46	56.9°
2	50	0.058	0.29	68.9°	0.0225	0.49	54.4°	0.0175	0.54	50.7°	0.015	0.57	48.5°
3	100	0.012	0.61	45.6°	0.0085	0.66	41.8°	0.0075	0.68	40.2°	0.005	0.74	35.5°
4	125	0.004	0.74	35.5°	0.0053	0.73	36.3°	0.005	0.74	35.5°	0.0038	0.77	33°

Table 4
Physical characteristics of the oils

Properties	SAE40	Rapeseed	Palm Olein	Soya Bean
Flashpoint (°C)	235	326	324	330
Specific heat, Cp (KJ/Kg-C)	2.53	1.96	1.9	1.88
Thermal conductivity (W/m-C)	0.145	0.168	0.172	0.185
Density at 15 °C (g/cm3)	0.890	0.915	0.912	0.924

Viscosity is generally expressed in millipascal seconds (mPa-s) or centipoise (cP). Fluid viscosity changes with temperature. The increase in temperature causes a decrease in fluid viscosity. The viscosity of a liquid is measured using a device called a viscometer. Brookfield Viscometer is used to test the viscosity of each of the oil samples. Higher lubricant viscosity essentially is a thicker lubricant film, and higher energy can be absorbed [5]. Dynamic viscosity measures the shear stress per unit area required before a sample begins to deform. Lubricants are characterised by their viscosity as a function of temperature, pressure, and shear rates. However, viscosity is influenced mainly by the working temperature of the liquid. Using the dynamic viscosity μ, which is experimentally measured, the eccentricity ratio Ɛ and attitude angle ϕ can then be solved analytically [18].

Larger values (ε,ϕ) of dynamic viscosity give lower eccentricity ratios(ε) and higher attitude angles(ϕ) (Sadiq, M I. 2022). This is because the high viscosity of the lubricant enables a higher load-carrying capacity. Linear stiffness and damping coefficients can be used to represent the dynamic characteristics of a hydrostatic bearing operating in the small eccentricity ratio range (e<0.3–0.4), according to Du, J., and Liang, G. (2020). However, because of the nonlinearity of the dynamic coefficients, the linear dynamic coefficients model will result in more significant inaccuracies in larger eccentricity ratios (e >0.3–0.4). However, when the lubricant becomes less viscous with increasing temperature, the value of the eccentricity ratio increases, and the attitude angle decreases. The significance of this study is particularly for lubricants operating at higher steady-state temperatures.

Bio-oil has shown superior characteristics at higher temperatures (100, 125°C) where the eccentricity ratio values (ε,ф) are almost the same for all types of oil [18].

2.3 Vibrational diagnostics setup

In the industry, vibrational analysis is applied to resolve issues, including damage monitoring, diagnosis, and future technical condition prognosis. Finding defects in the elements and monitoring the damage estimation can assist in reducing costs as well as prevent an unintended catastrophe of machinery in the long run. The resultant vibration signal will exhibit a variety of frequencies and specific vibrational attributes [22].

For this experiment, we use Rion's VA-12 vibration analyser for this case, an innovative, robust (yet user-friendly), practical, and self-standing machinery vibration analyser. The full-color, backlit panel that displays the measurement data may be viewed on-site and is visible in all lighting circumstances. Any display-displayed object may be saved as a bitmap. The VA-12 can also store measurement results in standard formats (CSV and calibrated WAV files) on an SD card to facilitate further post-processing. It will simultaneously display overall acceleration, velocity, and displacement levels using the VA-12 as a vibration meter. The data output from the analyser can yield the result that display the acceleration, velocity, or displacement spectrum (instantaneous, linear, exponentially averaged, or maximum). The waveform of acceleration, velocity, or displacement can be observed. The velocity and displacement signals can be produced by monitoring the vibration acceleration signal and integrating the acceleration signal [10].

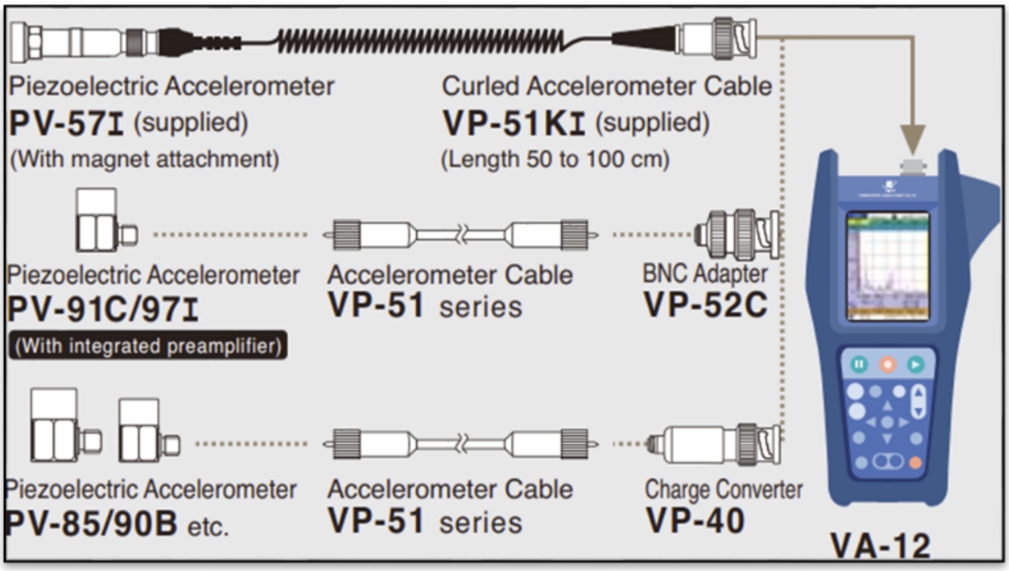


Fig. 4. Accelerometer configuration for Rion VA-12

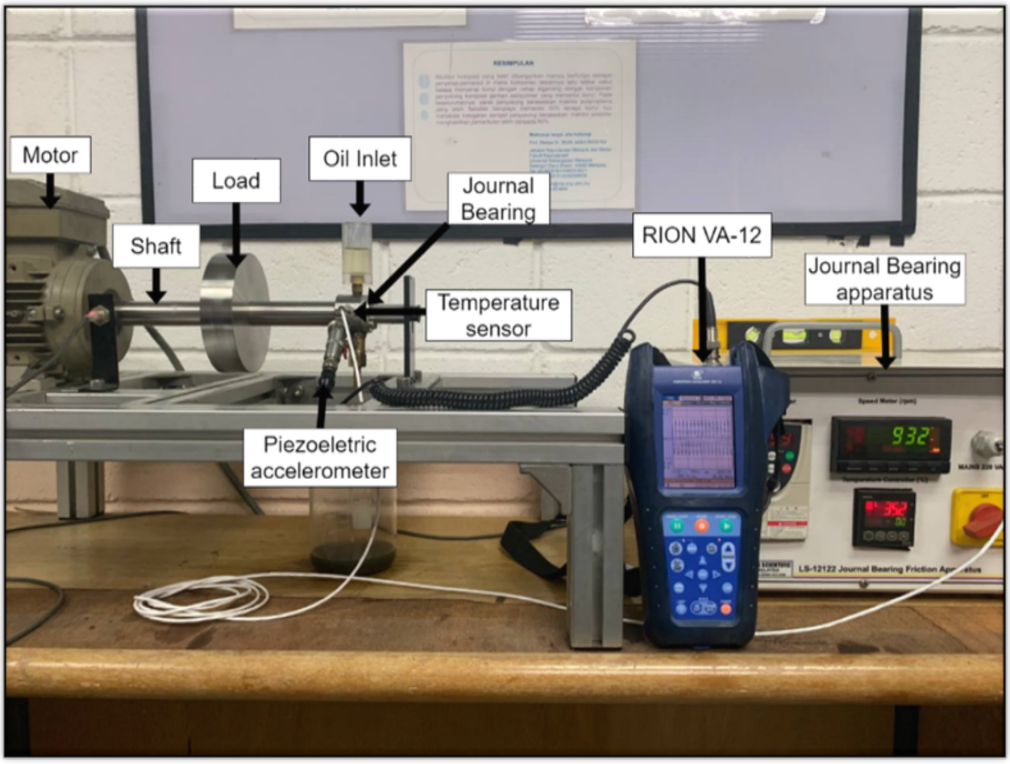


Fig. 5. Vibrational analysis configuration using Rion VA-12 for the Journal Bearing Test Rig

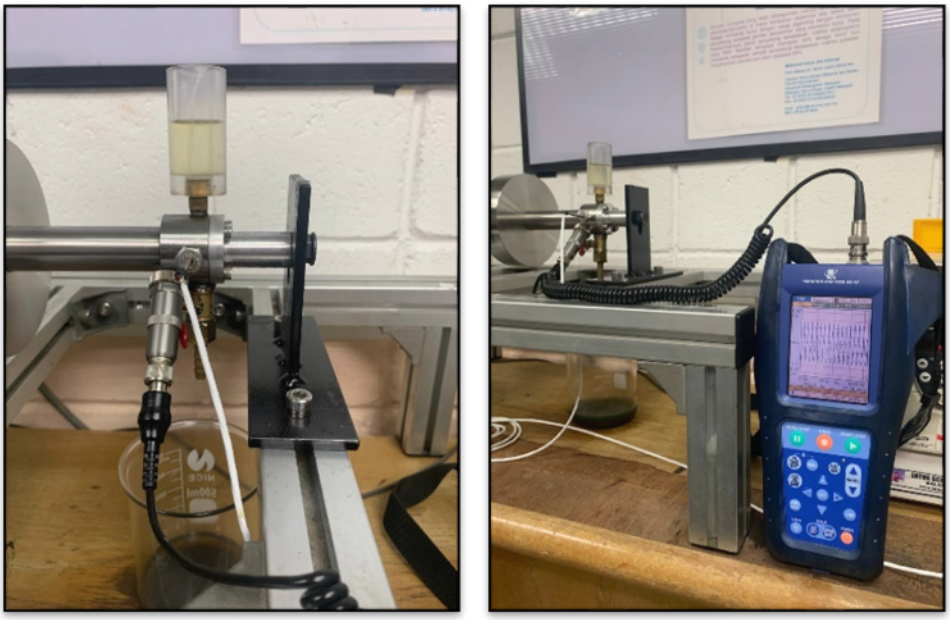


Fig. 6. Location of Accelerometer probe attached directly to the journal

Figures 4 and 5 show the setup for the accelerometer of VA-12 and the overall setup of how the vibrational diagnostics is used for the experiment. As shown in Figure 6, The piezoelectric accelerometer is attached directly to the right side of the journal bearing next to the temperature sensor, which is the ideal position to measure the vibrational response. Two speed levels are set for all oil samples at 900 and 1200 rpm. Each speed of the oil sample test is set for 5 minutes to monitor the steady state of the vibration. The figure above shows the JBTR setup for the vibrational response experiment and the exact position of the piezoelectric accelerometer on the journal bearing.

The frequency range used in this study is 1 - 1000 Hz, where the data collection and processing procedures can be seen in the results table. The data obtained from the measurement results are then recorded and graphed in Excel. The equipment used in the collection of vibration measurement data is as follows:

- The accelerometer used is a piezoelectric accelerometer made by Rion Japan Corporation type CCLD type, PV-571. The accelerometer functions to measure vibration response.
- The frequency span is 100 Hz with a line analysis of 1600 using a linear function window.
- Actual Sensitivity Num 510 and actual sensitivity magnify x0.01.

3. Results

The journal bearing test rig (JBTR) was used in this study to study the static characteristics of the journal bearing system. The static performance will provide an overview of the capability and potential of lubricants and oils in two levels of rotation speed, which rotates at 900 rpm and 1200 rpm. Temperature and pressure parameters are emphasised because they are essential for detailing the lubricant's actual feasibility. Viscosity value is an essential parameter in lubricants. Lubricating fluid is responsible for determining static factors such as fluid friction involved in lubrication, the load-carrying capacity of the lubricating film, the resistance to the start of relative movement of moving parts and the sealing capacity, pumping ability, and heat transfer properties of the lubricant.

To benchmark the performance of the lubricants, SAE 40 will act as the control for the experiment to verify the capability of the lubricants when subjected to two rotational speeds at 900 rpm and 1200 rpm. Therefore, the results for each displacement, velocity, and acceleration data will be compared to that of the SAE 40. The range of the waveform for lower or higher amplitude than SAE 40 should give insight into the feasible performance of bio-lubricants.

The 5-minute interval set to monitor the vibrations should give us precise results on the overall performance of each lubricant. The displacement from a vibrating object is to measure the vibration amplitude. The displacement is the vibration distance from a reference position or equilibrium point. Velocity is the rate of change of displacement and is measured in units of meters per second. The acceleration is the rate of velocity change measured in units of G, or the average acceleration due to gravity at the earth's surface. From this analysis, a precision diagnostic of journal-bearing test rig can be observed. Observing the waveform, we can detect any bearing problems or abnormalities in the repeat cycle. Misalignment and imbalance within the system are validated through these experiments.

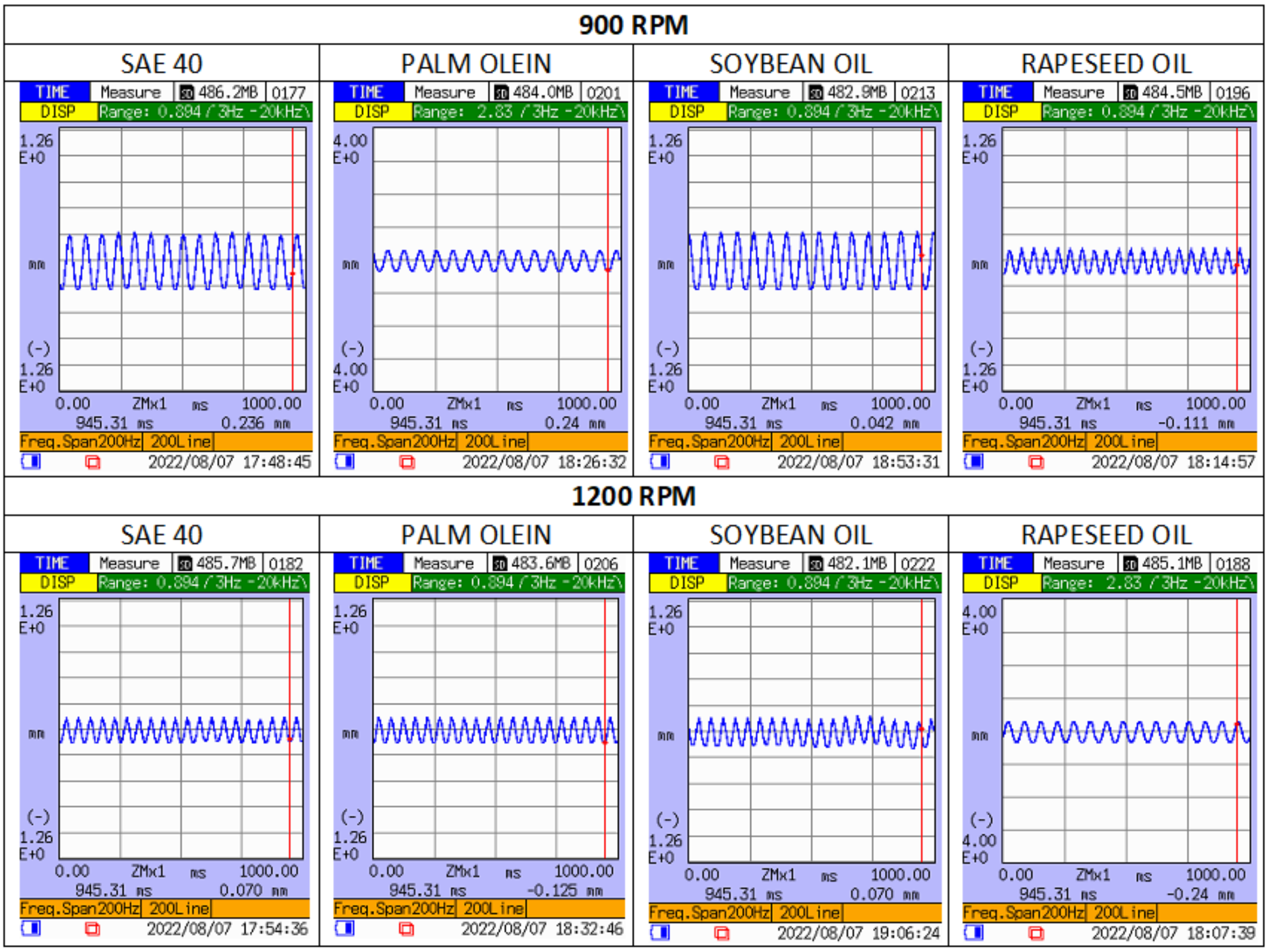


Fig. 7. Velocity waveform at 900 RPM & 1200 RPM

The velocity spectrum data enables us to monitor the velocity signal of the JBTR. Based on the result in Figure 7 above, it is observed that the data signal vibrations for the velocity spectrum at 900 rpm remain steady in a uniform signal for all oils tested. The maximum amplitude is observed in rapeseed oil, with the highest amplitude value of 33.51 mm/s. The data shows only slight differences in max amplitude comparatively between all oils tested. Similarly, at 1200 rpm, data acquired shows a similar velocity response between all oils tested, with the highest velocity amplitude at 14.77 mm/s recorded by rapeseed oil, although, again, relatively similar between all oils. This data evaluation indicates that the relative performance is comparable to SAE 40, which shows a good sign that our objective to measure bio-oil feasibility as an alternative could be verified.

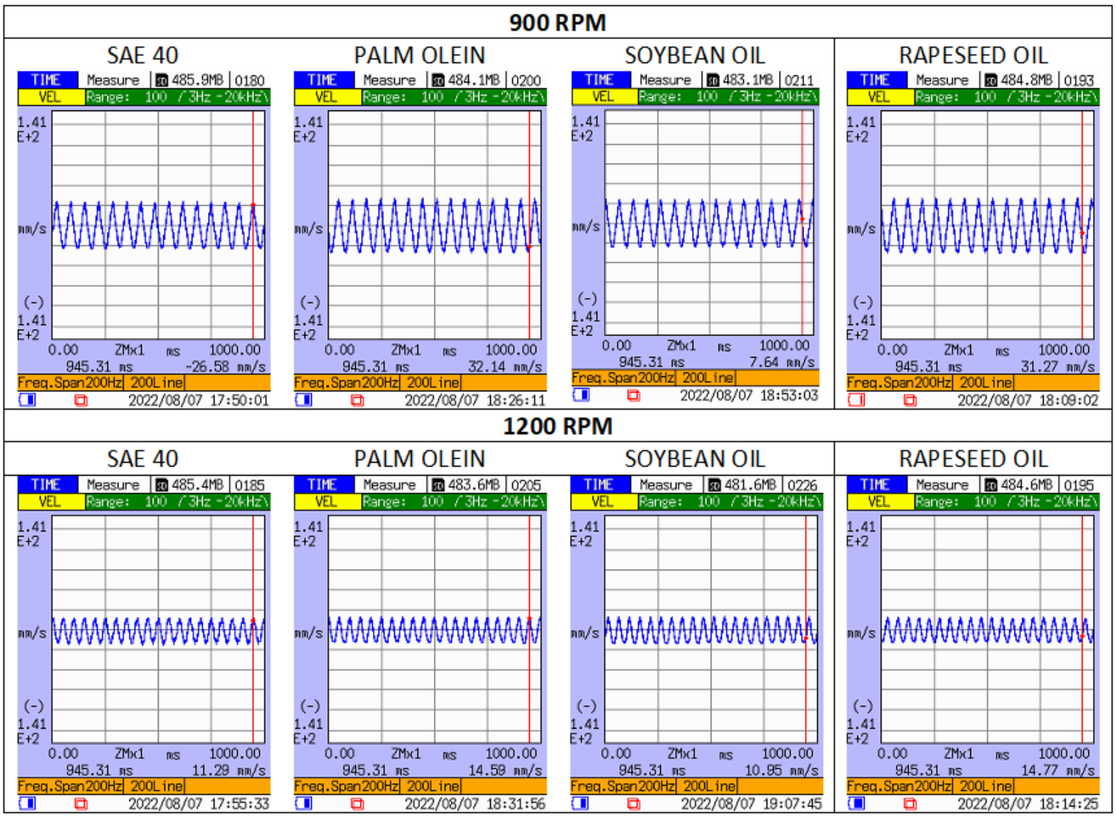


Fig. 8. Displacement waveform at 900 RPM & 1200 RPM

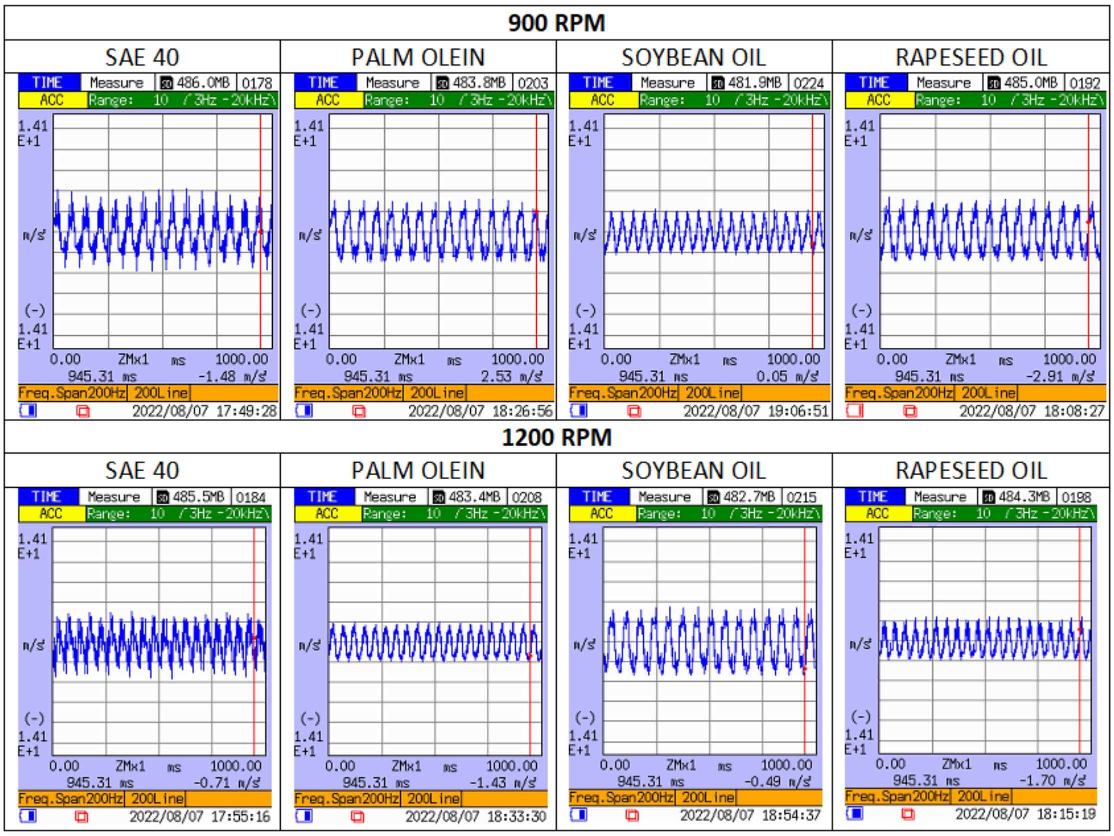


Fig. 9. Acceleration waveform at 900 RPM & 1200 RPM

The data trends for displacement waveform show variations in all oils tested in Figure 8. At 900 rpm, it is observed that the displacement for rapeseed oil shows a higher displacement compared to other oils tested. The maximum displacement is 0.042mm. However, at 1200 rpm, the displacement shows quite a similar response for all oils when comparing the displacement waveforms. The variations in displacement may show the difference in bearing response to the fluid film action of the lubricants used. The difference in viscosity may reflect and explain the displacement data gathered above.

Figure 9 shows the acceleration waveform gathered, we can observe a similar stable response of each lubricants, meaning there is no imbalance occurring as shown by the similar waveform pattern generated by the probe. Though, we can also observe a quite different waveform generated using SAE 40 compared to bio-lubricants where the waveform generated has a higher amplitude than other lubricants at 900 rpm and 1200 rpm. At 900 rpm soybean oil shows the most stable response compared to the lubricants with peak amplitude at 0.05m/s2. At 1200 rpm Palm olein shows the most stable response with peak amplitude at 1.43 mm/s2.

The overall response from Figures 7, 8, and 9 can be explained comparatively by relating the data from Table 3 to the stiffness and damping response of the lubricants [18]. At the lower speed of 900 rpm, the overall response is more stable, with fewer variations in the response of all oils due to the operating conditions being less intense temperature-wise. At 1200 rpm, we observed that the vibration response was more varied as the heat generated was greater across all oils tested. The response to this reflects the decrease in dynamic viscosity with increasing temperature and becomes more eccentric [19].

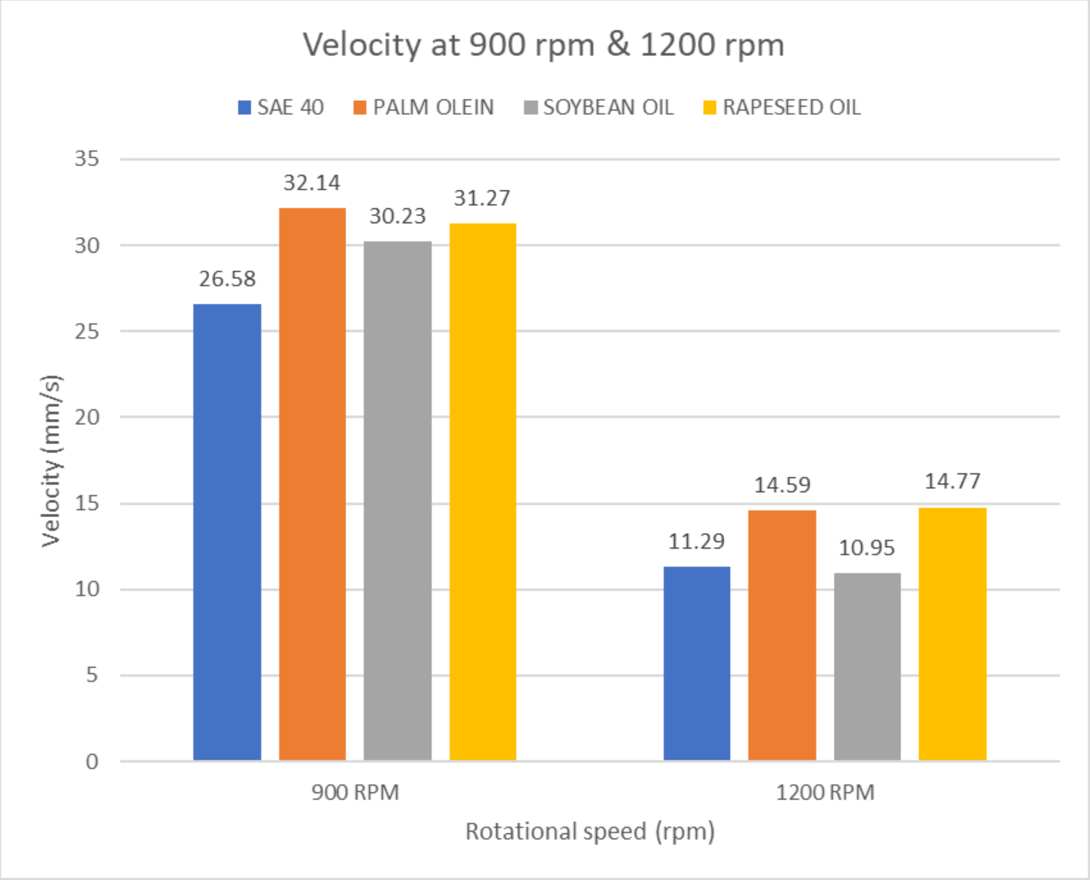


Fig. 10. Max Amplitude (Velocity) at 900 RPM & 1200 RPM

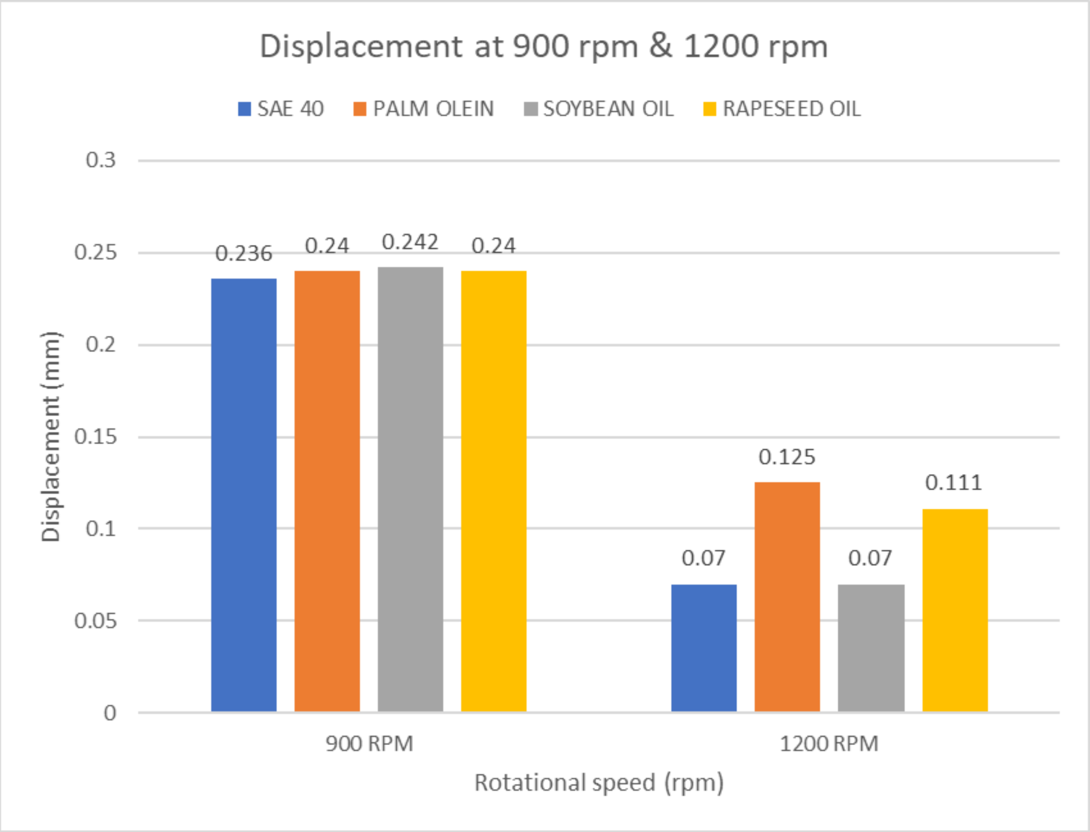


Fig. 11. Max Amplitude (Displacement) at 900 RPM & 1200 RPM

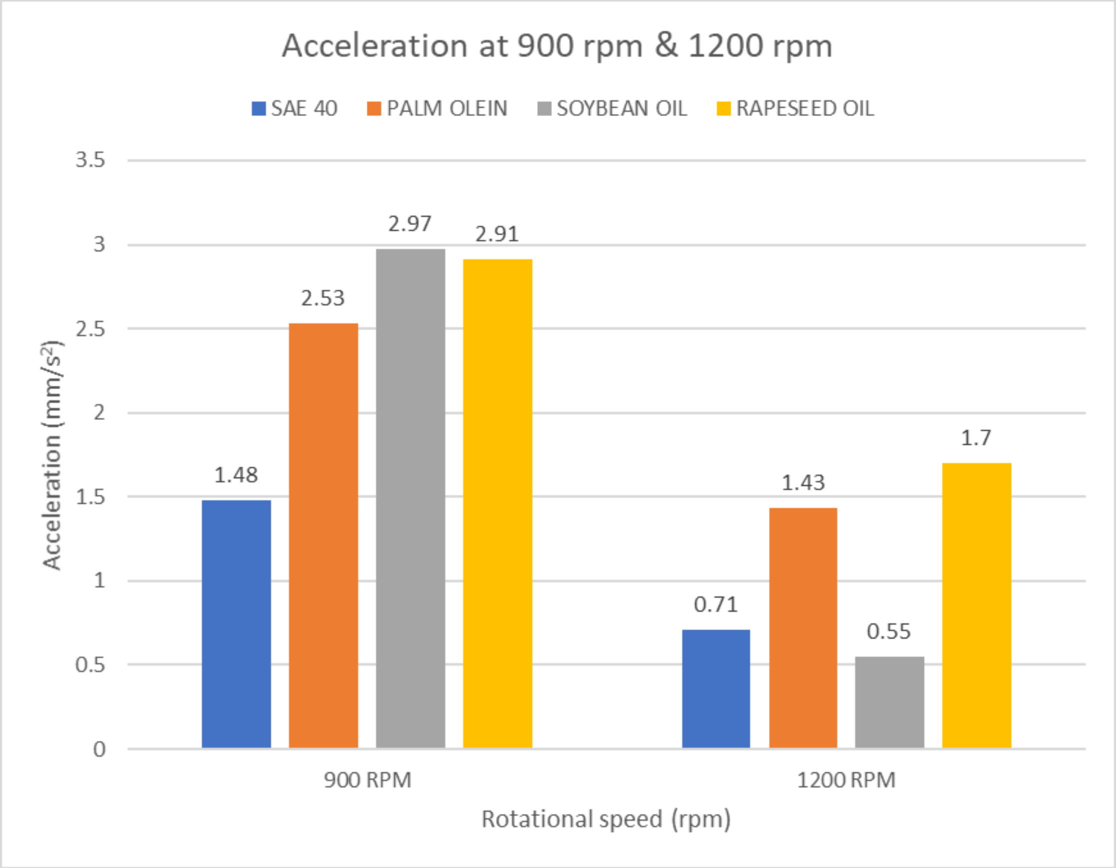


Fig. 12. Max Amplitude (Acceleration) at 900 RPM & 1200 RPM

The Graph above shows the maximum velocity, displacement, and acceleration amplitude. The velocity data shows a high amplitude of 32.14 mm/s for palm olein at 900 rpm, while at 1200 rpm, it shows a max amplitude of 14.77 mm/s for rapeseed oil. The trend shows a decrease in velocity for higher rotational speed for all oils.

The displacement data shows quite a similar response with not much variance between oils at 900 rpm, but the data at 1200 rpm shows palm olein has the highest displacement at 0.125 mm. The increase in rotational speed may elude to higher displacement.

On the other hand, the acceleration data shows the lowest reading for SAE 40 at 1.48 mm/s^2 and the highest reading at 2.97 mm/s^2 for soybean oil, both at 900 rpm. At 1200 rpm, the response for soybean oil is at the lowest, while rapeseed oil's highest is at 1.7 mm/s^2.

Overall, we can observe variance in all oils' responses when increasing the rotational speed from 900 rpm to 1200 rpm. The substantial increase in rotational speed may give us insight into the performance of the lubrication measures against already established lubricants like SAE40. The proven performance of the bio-lubricants is deemed comparable to SAE 40, which can serve as a benchmark for future potential utilisation of this organic fuel source [18].

Regarding journal bearing dynamic properties, it may be hypothesised that when rotational speed increases, the combined impact of cross-coupled stiffness in multiple directions provides a force in the swirl direction, increasing shaft vibration [18]. This process has the potential to induce the oil to rotate rapidly, leading to the development of oil whip, a condition in which the rotor experiences substantial bending. The phenomenon of bearing instability caused by the presence of a fluid coating is referred to as self-excited vibration [29]. One can choose a lubricant with appropriate damping and stiffness coefficients based on the specific working conditions to prevent this [3]. The damping and stiffness coefficients of the oil layer in a journal bearing are influenced by the eccentricity ratio, which is determined by the oil's viscosity and other factors such as rotational speed, length, diameter, and applied load of the bearing [18].

4. Conclusions

An experimental study was performed on the Vibrational Response of SAE40 and Bio-Lubricants for Journal Bearing system. The lubricant's behavior was measured using a vibration analyser (VA-12) at operating conditions of 900 rpm and 1200 rpm. This vibration level was deemed stable and operational in the velocity, displacement, and acceleration waveform regions generated by the oils. The system's vibration intensity is directly proportional to the system speed and load. The vibration intensity peaked in the transitional zones between the torque and power ranges of the system (Santana 2020). In all operating conditions at 900 rpm and 1200 rpm, the signal showcases that oil of higher viscosity attenuates the level of vibration of the journal bearing.

- At 900 rpm, the percentage differences with SAE40 show an increasing velocity waveform around 19%, 13%, and 16% for palm olein, soybean, and rapeseed oil, respectively.
- For displacement waveform, the percentage difference with SAE 40 shows a slight increase with only 2-3% percentage differences for all oils tested.
- However, acceleration data shows a high variance with more than half percentage differences at 52%, 67%, and 65% for palm olein soybean and rapeseed, respectively.
- At 1200 rpm, the percentage difference shows a higher variation since the lubricant's action decreases at higher speeds.
- The velocity response at 1200 rpm shows a 26% increase for palm olein and rapeseed but 3% lower for soybean oil.

- Meanwhile, the displacement shows similar results between SAE 40 and soybean oil but a steep 56% and 45% difference for palm olein and rapeseed oil, respectively.
- Moreover, the acceleration response shows an even higher variance, with 67% and 82% for palm olein and rapeseed oil and an overall 25% lower response for soybean oil.

Increasing the rotational speed affects bio-oil performance more than mineral-based oils. Nevertheless, although the performance may seem lower, it should be highlighted that the bio-oils do perform similarly at a lower speed, as shown by the low percentage difference. It is also worth noting that the evaluation only showcases the performance of raw oil without additives or special treatment properties. (Suryawashi SR 2023) Bio-oil treatment according to operating conditions and requirements can also enhance their physical and dynamic properties.

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