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Comparative analysis of grease types on bearing performance: time-frequency and statistical investigations

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ABSTRACT

This study focuses on evaluating the behavior of three commercially available lithium-based lubricating greases – 77 EP (from 77 Lubricants), LGMP3 (AXCL Lubes), and LHTG3 (XADO) – when applied to journal bearings operating at low (600 RPM) and high (2400 RPM) speeds. The purpose is to understand how different grease types influence the vibration performance of bearings under dynamic conditions. The analysis includes both time-domain statistical indicators and vibration characteristics in the frequency domain. Measurements such as RMS, standard deviation, skewness, kurtosis, and variance were gathered using a real-time LabVIEW setup. These metrics helped in identifying differences in system response under each lubrication condition. The outcomes revealed that higher rotational speeds significantly amplified both vibration levels and system irregularities. This behavior demonstrates the critical impact of selecting the proper lubricant, particularly in fast-moving machinery. Among the samples tested, LHTG3 achieved the most consistent results, showing lower fluctuations in vibration readings, which implies effective damping properties. LGMP3, on the other hand, showed greater variability in its data, suggesting reduced vibration stability. Although 77 EP did not score highest in time-domain statistics, it performed strongly in frequency-based analysis, reducing the effect of sudden shocks and high-frequency responses. Long-term performance could benefit from LHTG3; 77 EP would be preferable for machines with varying or fast dynamic loads. These results underline the need of choosing lubricant for stability and condition of journal bearings.

Keywords: Lubrication, Vibration, Stability, Bearing Life, Performance

1 INTRODUCTION

Lubrication is absolutely important not only for the performance, but also for the dependability and service life of both rolling and journal bearings. Indeed, while it increases mechanical efficiency particularly in systems exposed to various climatic and load conditions it simultaneously reduces friction and wear. Moreover, many studies have looked at numerous lubrication methods, examining how they influence tribological behaviour and consequently improve bearing performance. Therefore, this section compiles important books on lubrication in rolling and journal bearing applications, in order to provide a comprehensive reference for further study and application.

Under Gupta et al., ball bearing lubrication was examined experimentally under shock pulses [1]. Maximising bearing performance depends on predictive maintenance as it was shown that vibration signals and lubricant quality are connected. Gouda et al. [2] studied radial ball bearing tribology and vibration under several grease types. Their studies of conventional and micro-grooved outer races found that grease compositions

significantly affected bearing dynamics. Han et al. [3] Water-lubricated journal bearings from three materials were tested for tribology. Their findings showed that material parameters affect lubrication effectiveness and wear resistance in various operational scenarios. Ahmed et al. [4] Balanced and unbalanced rotors supported by oil- and water-lubricated journal bearings were tested theoretically and experimentally. Their research on bearing dynamic stability under different lubrication conditions was crucial. Van Eijk [5] We used active ultrasonic spectroscopy to look for contaminated slew bearing lubricant. Effective lubrication monitoring is crucial because contamination reduces bearing lifespan and functionality. Li et al. [6] Played around with sliding building bearings using solid lubricants based on PTFE. Their research suggests that solid lubricants have the potential to decrease structural friction and enhance the effectiveness of lubrication. Wang et al. [7] Examined how texture distributions effect journal bearing lubrication. They discovered that texturing the surface increases the effectiveness of the bearing by improving the formation of the lubrication coating and reducing frictional losses. Sun

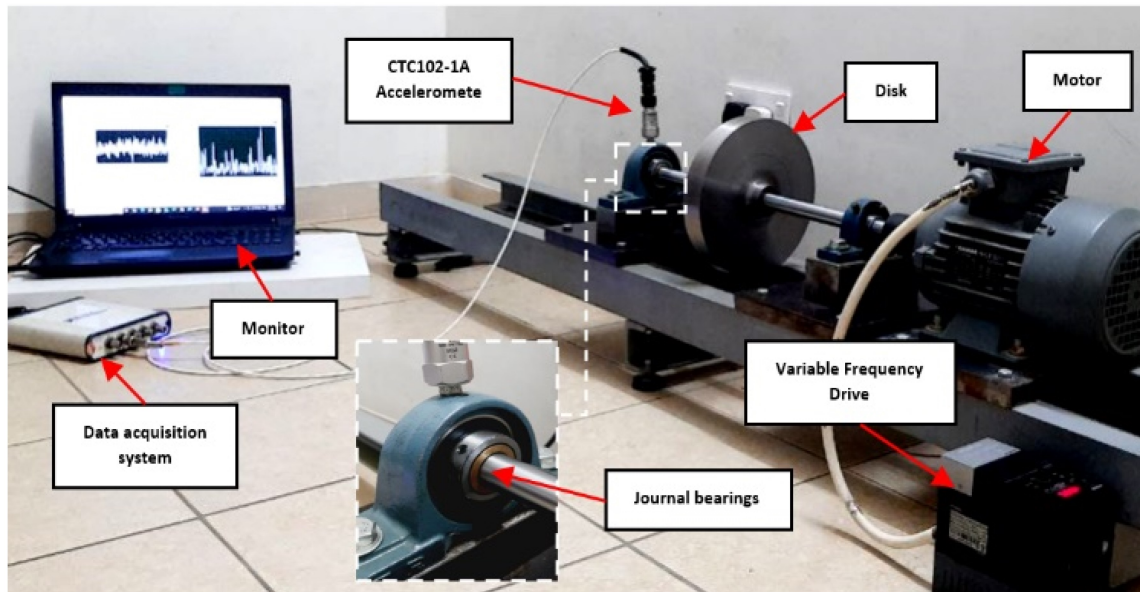


Figure 1 Vibration Sensor Locations for Vibration Analysis

et al. [8] Assessed connecting-rod and main bearing lubrication in various engine running conditions. Their research showed that adaptive lubrication maintains bearing performance. Zhu et al. [9] The effect of lubricant couple stress and shear thinning on misaligned journal bearings. A theoretical analysis of stress distribution and viscosity variations improved lubrication performance et al. [10] Provided a crankshaft main bearing lubrication optimization model using bearing profiles and operating data. Their research suggested ways to improve high-load lubrication. Yusof and Ripin [11] Examined how lubrication affects roller bearing vibration. Their findings stressed the importance of optimum lubrication in decreasing vibrations and stabilizing bearings. Zhao et al. [12] Used fluid-solid coupling study to evaluate coal shearer heavy-duty bearing lubrication. Their research showed that lubricant coating thickness is crucial to bearing durability under extreme loads. Zhu et al. [13] The effects of lubricant pair stress and shear thinning on journal bearings were explored, highlighting their importance in improving lubrication systems. Zhong et al. [14] Investigated connecting rod bearing lubrication performance with AVL EXCITE simulation. They used computer methods to study bearing lubrication dynamics and predict efficiency.

These studies highlight the role of lubrication in enhancing bearing performance, minimizing friction, and extending operational lifespan. Building on these findings, further investigations have focused on lubrication mechanisms and strategies for improving bearing reliability. The objective of the present work is to assess the performance of various greases in journal bearings subjected to vibration, aiming to determine their effectiveness and suitability under different operating conditions. Gaining insight into the influence of grease selection can contribute to improved mechanical efficiency, optimized lubrication practices, and extended journal

bearing service life.

2 EXPERIMENTAL WORK

The vibrations of the journal bearing were examined on an integrated test bench, which consists of a C-45 steel shaft (20 mm diameter, 500 mm length) and a GAMAK three-phase induction motor (1 hp, 2860 rpm) equipped with variable frequency drive speed control, as seen in Figure 1. The utilization of an accurate sensor for measuring vibrations facilitated dependable bearing examination. The spinning speeds of 600 RPM and 2400 RPM were specifically selected to represent two distinct operational conditions. With minimal dynamic excitation, the reduced speed (600 RPM) simulates standard low-speed conditions, facilitating baseline behavior analysis. Conversely, the increased speed (2400 RPM) introduces more dynamic loads and vibration intensity, thereby elucidating the varying responses of different greases to elevated mechanical stress and thermal effects. This comparison facilitates a thorough assessment of lubricant efficacy in both stable and challenging conditions. The system operated continuously for over 10 minutes under each test scenario to ensure mechanical and thermal stabilization. Vibration measurements were taken only when the system reached steady-state behavior, so ensuring that the measured signals accurately represent stable and typical bearing performance.

2.1 Tools and Instruments Employed

This study used precise sensors and modern technology to gather and analyze vibration data. Because of its piezoelectric sensor, the CTC102-1A accelerometer was chosen for its precise vibration measurements and wide frequency range (0.5 Hz to 15 kHz) and 100 mV/g sensitivity. Due to its efficacy in recording vibrations throughout a wide frequency range, this sensor is ideal for accurate data applications. The NI USB-4431 data

Table 1 Key Specifications of the CTC102-1A Accelerometer [20]

Feature	Description
Frequency Range	0.5 Hz to 15 kHz
Sensitivity at 5 kHz	100 mV/g
Dynamic Range	± 50 g, peak
Excitation Voltage (IEPE)	18-30 V DC
Constant Excitation Current	2-10 mA



Figure 2 CTC102-1A accelerometer [15]

acquisition device converted sensor analog signals to digital for processing. The card’s 24-bit ADC accurately digitizes sensor output signals with a 1µV resolution. The collected data will be carefully and reliably reviewed. Standard laboratory conditions were used for all experiments at 25°C. The CTC102-1A accelerometer and NI USB-4431 DAQ card work together to acquire vibration data with high precision and reliability, enabling the extraction of critical features for analysis. Within the frequency range of interest, vibration data were recorded at 1 kHz, which is sufficient for bearing system dynamic analysis. The main specifications of the sensor are provided in Table 1, and its design is illustrated in Figure 2. [15,17].

2.2 Bearing Specifications

In this study, a bushing-type and journal bearing made of the copper alloy, specifically known as UNS copper alloy No. C37000, was used. These bearings were carefully and deliberately selected in order to effectively support the system shaft as well as ensure stability under different and varying operating conditions. Figure 3 shows the detailed design of the axle bearing, and Table 2 below shows the main and essential characteristics of the axle bearings used in the study.



Figure 3 Copper Journal Bearing Design

2.3 Greases Used: Categories

Because of the need to minimize friction, and also lower wear, and to preserve a consistent and stable lubricating film under a variety of different running conditions, greases are considered vital for the effective and reliable operation and extended lifetime of journal bearings. The appropriate and suitable grease type depends on several important factors, including the temperature range, load-bearing capacity, oxidation resistance, and the capacity to withstand external factors such as vibration. Under dynamic load conditions in particular, the choice of grease in journal bearings greatly affects performance, as well as maintenance schedules, and general system dependability. Three different types of grease are investigated and analyzed in this work, based on manufacturer specifications, formulation, and operational temperature range. Every kind of grease shows different and unique characteristics that influence their suitability for journal bearing uses under vibrational influence. The grease was applied manually without using a calibrated instrument; however, care was taken to apply an equal and consistent amount of lubricant in all test cases to ensure comparability between conditions. No additional sealing

Table 2 Key Specifications of the Copper Alloy UNS No. C37000 Journal Bearings

Specification	Value
Bearing Type	Bushing (Journal Bearing)
Material	Copper Alloy UNS No. C37000
Shaft Diameter	20 mm
Clearance	0.05 mm
Bearing Length	28 mm
Outer Bearing Diameter	30 mm
Young's Modulus	7476.255 MPa



Figure 4 77 Grease EP NLGI 2 - Industrial Lithium Grease



Figure 5 LGMP3 - Multi-Purpose Lithium Grease

method was employed; the grease was retained within the bearing housing by the mechanical design of the test setup. The greases selected for this study consist in:

Grade 2 Grease EP NLGI – 77 EP – As illustrated in the figure 4. Made by 77 Lubricants, this lithium-based grease has outstanding extreme pressure resistance and operates throughout the temperature range of -30°C to $+140^{\circ}\text{C}$. Under normal running conditions, it is expected to perform effectively; yet, it may show limitations in response to prolonged vibration and high temperatures [18].

Made by AXCL Lubes, this lithium-based grease, Lithium-Based Multi-Purpose Grease NLGI 3 (LGMP3) is designed to run throughout a temperature range of -30°C to $+220^{\circ}\text{C}$, As shown in Figure 5 hence fitting for uses needing exceptional thermal stability. Its better temperature resistance makes it likely to provide improved performance under vibrational loads comparing to conventional greases [19].

High-Temperature Grease NLGI 3 Based on Lithium (LHTG3) – As illustrated in the figure 6 designed to withstand extreme temperatures and having an operational range of -20°C to $+130^{\circ}\text{C}$, this grease is formulated by XADO. Although its resistance to high temperatures qualifies it for demanding conditions, its performance under strong vibrating conditions calls further attention [20].



Figure 6 LHTG3 - High-Temperature Lithium Grease

2.4 Data collection and feature extraction

Precise statistical data extraction from a piezoelectric sensor yielded extensive vibration data. Root mean square (RMS), variance, standard deviation, skewness, and kurtosis were the statistical metrics extracted and analyzed to identify patterns and assess the bearing condition. Utilizing real-time signal processing techniques, these attributes were calculated directly within the LabVIEW environment, ensuring precise and reliable feature extraction from the time-domain vibration signals. Table 3 presents the mathematical formulas that are utilized in order to calculate each individual statistical feature derived from the vibration signals, thereby clearly delineating the essential and fundamental criteria for evaluating the operational condition as well as the efficacy of different types of lubrication. Each statistical instrument or metric serves a specific and distinct purpose in evaluating and

Table 3 Feature Formulas

Feature Name	Formula
Root Mean Square (RMS)	$\text{RMS} = \sqrt{\frac{1}{N} \sum_{i=1}^N x_i^2}$
Variance	$(\sigma^2) = \frac{1}{N} \sum_{i=1}^N (x_i - \mu)^2$
Standard Deviation	$(\sigma) = \sqrt{\frac{1}{N} \sum_{i=1}^N (x_i - \mu)^2}$
Kurtosis	$= \frac{N(N+1)}{(N-1)(N-2)(N-3)} \sum_{i=1}^N \left(\frac{x_i - \mu}{\sigma}\right)^4 - \frac{3(N-1)^2}{(N-2)(N-3)}$
Skewness	$= \frac{N}{(N-1)(N-2)} \sum_{i=1}^N \left(\frac{x_i - \mu}{\sigma}\right)^3$

interpreting the vibration characteristics of the bearing system. Root Mean Square (RMS) serves as an effective metric for detecting significant alterations in system dynamics, providing an assessment of the overall energy content of the vibration signal. Variance and standard deviation elucidate the dispersion of the signal around the mean, indicating the extent of fluctuation in vibration amplitude. Skewness quantifies the asymmetry of the signal distribution, so revealing whether the vibration pattern is biased towards positive or negative values. Kurtosis measures the “tailedness” or presence of outlier data, hence facilitating the detection of transitory shocks or impulsive events indicative of bearing defects. These criteria were selected due to their efficacy in detecting alterations in mechanical condition and grease performance across different operational speeds. [21,22,23]

Additionally, to assess vibration damping in a logarithmic scale, the RMS values were converted to decibels (dB) using the following equation:

$$L_{dB} = 20 \times \log_{10}(A / A_{ref})$$

where A is the RMS value of acceleration (in g), and A_{ref} is the reference value taken as 1 g.

3 RESULTS AND DISCUSSION

3.1. Time Domain Analysis

Figures 7 and 8 show journal bearing vibration signals at 600 and 2400 RPM in time domain analysis. At 600 RPM, all greases appear steady with modest changes around zero, indicating equivalent low-speed performance. However, oscillations rise dramatically around 2400 RPM. 77 EP exhibits the lowest peak dispersion among all the other greases, which suggests a better capability for vibration dampening when compared to LGMP3 as well as LHTG3. Furthermore, 77 EP is more effective at reducing vibrations at higher speeds, a factor that is particularly important for maintaining the stability and improving the efficiency of journal bearings in dynamic operating applications.

3.2. Frequency Domain Analysis

Figures 9 and 10 illustrate the frequency-domain

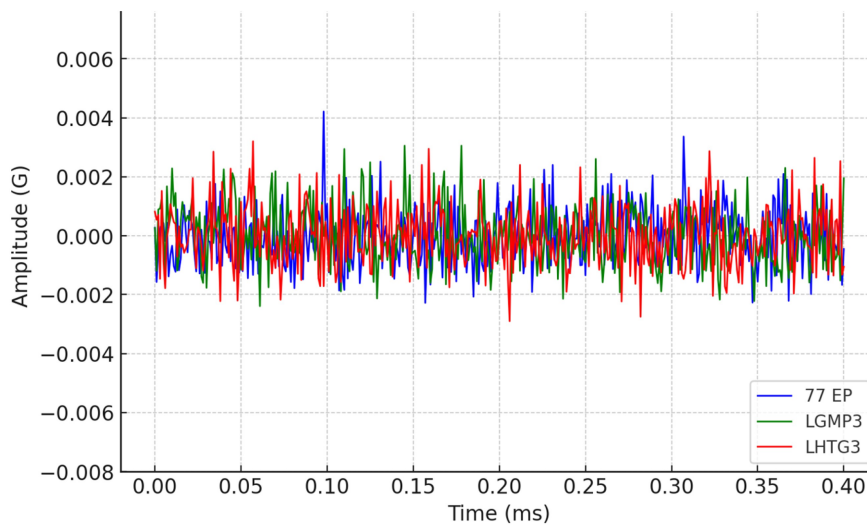


Figure 7 Time domain signals at 600 RPM for 77 EP, LGMP3, and LHTG3 greases.

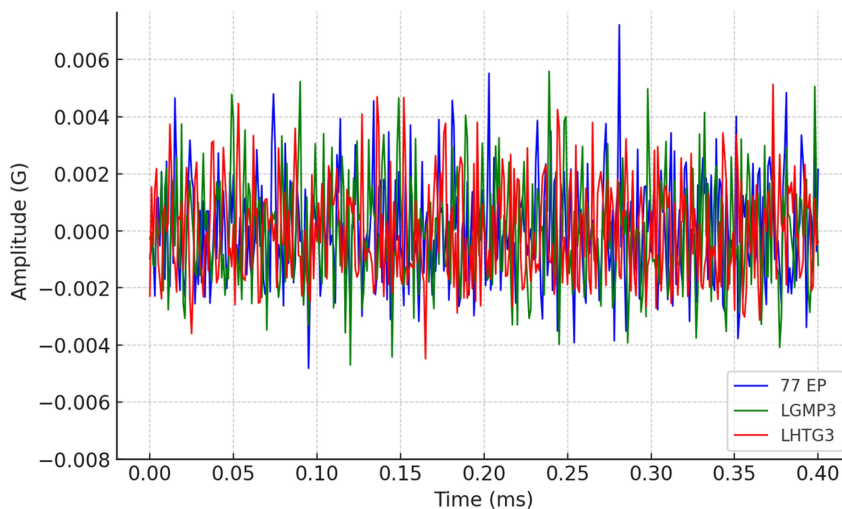


Figure 8 Time domain signals at 2400 RPM for 77 EP, LGMP3, and LHTG3 greases.

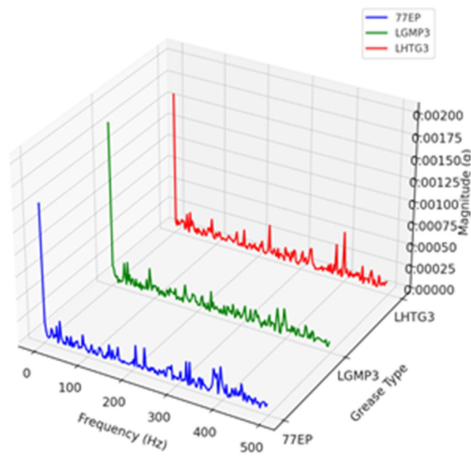


Figure 9 3D frequency domain analysis of 77 EP, LGMP3, and LHTG3 greases at 600 RPM.

analysis of the vibration signals, respectively depicting the spectrum characteristics of various grease kinds at 600 RPM and 2400 RPM. At 600 RPM, all greases exhibit homogeneous, smooth frequency spectra lacking distinct peaks (Figure 9). Decreased rotational velocities signify diminished dynamic excitation and a stable vibrational response. Although there are minor peaks at approximately 229 Hz and 396 Hz, their amplitudes are minimal and exhibit no variation across the greases. Conversely, particularly at 120 Hz, 200–205 Hz, and 320 Hz, at 2400 RPM (Figure 10), distinctly recognizable and pronounced frequency peaks are observable. The peaks correspond to the rotational frequency and harmonics of the shaft, indicating increased vibrational activity at elevated speeds. LGMP3 had the highest spectral magnitudes among the greases, indicating greater sensitivity to excitation and potential instability in dynamic conditions. Through a more uniform frequency profile and reduced amplitude peaks, 77 EP exhibited the most consistent spectrum attenuation, consequently demonstrating superior damping and vibration absorption capabilities. LHTG3 demonstrated a moderate behavioral pattern, marked by distinct yet less prominent peak amplitudes when compared to those observed in LGMP3. The findings clearly show that 77 EP exhibits a more stable and consistent performance throughout the full frequency spectrum, especially under high-speed operating conditions. When considering the time-domain behavior, as presented in Figures 7 and 8, it becomes apparent that 77 EP achieves superior efficiency in minimizing vibration amplitude, while at the same time preserving mechanical stability within dynamically loaded journal bearing systems.

3.3 Vibration Damping Evaluation Using dB Scale at Different Rotational Speeds

The conventional logarithmic formula was used to convert RMS values to dB to assess grease vibration damping. Figures 11 and 12 illustrate the time-domain vibration levels corresponding to the three different grease

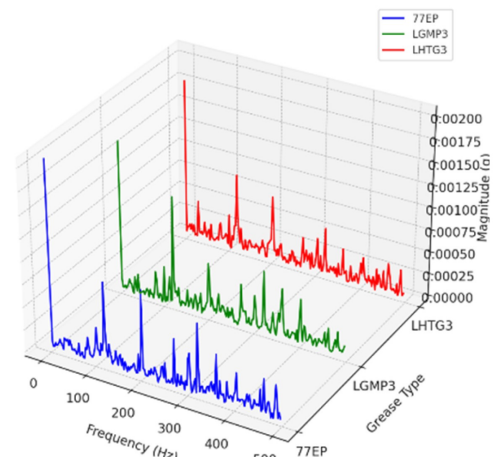


Figure 10 3D frequency domain analysis of 77 EP, LGMP3, and LHTG3 greases at 2400 RPM.

types at rotational speeds of 600 and 2400 RPM. At 600 RPM, the 77 EP grease demonstrated the most effective vibration dampening, as it consistently recorded the lowest dB values throughout the entire measurement interval. In contrast, LHTG3 exhibited the highest vibration levels, which indicates a lower efficiency in damping under low-speed conditions, whereas LGMP3 showed a moderate performance in comparison to the other two greases. At 2400 RPM, damping changed. LHTG3 had the lowest dB vibration levels, suggesting it is better for high-speed applications. LGMP3 had higher dB levels and greater variation, indicating fewer damping capabilities at high speeds, while 77 EP grease performed mid-range. These findings support Itagaki et al. [24], who found that grease composition significantly affects ball bearing abnormal vibration under axial loads. Speed-dependent grease selection is crucial in vibration-sensitive bearing applications.

3.4. Statistical Analysis of Grease Performance at 2400 RPM

For clarity and comparative purposes, Figures 13 to 17 present the statistical distributions of all grease types combined within a single plot. Each lubricant is color-coded consistently across all figures (77 EP in blue, LGMP3 in green, and LHTG3 in red) to allow for direct visual comparison and efficient interpretation. While individual plots could be presented, this combined format was chosen to highlight relative performance differences more effectively.

1-Standard deviation distribution of 2400 RPM lubricant variants

Figure 13 illustrates the standard deviation values of the three grease types—77 EP, LGMP3, and LHTG3—at 2400 RPM, derived from time-domain vibration data collected during testing. The Y-axis indicates the relative frequency corresponding to the computed standard deviation values derived from the vibration signal, whereas the X-axis represents the range of those values.

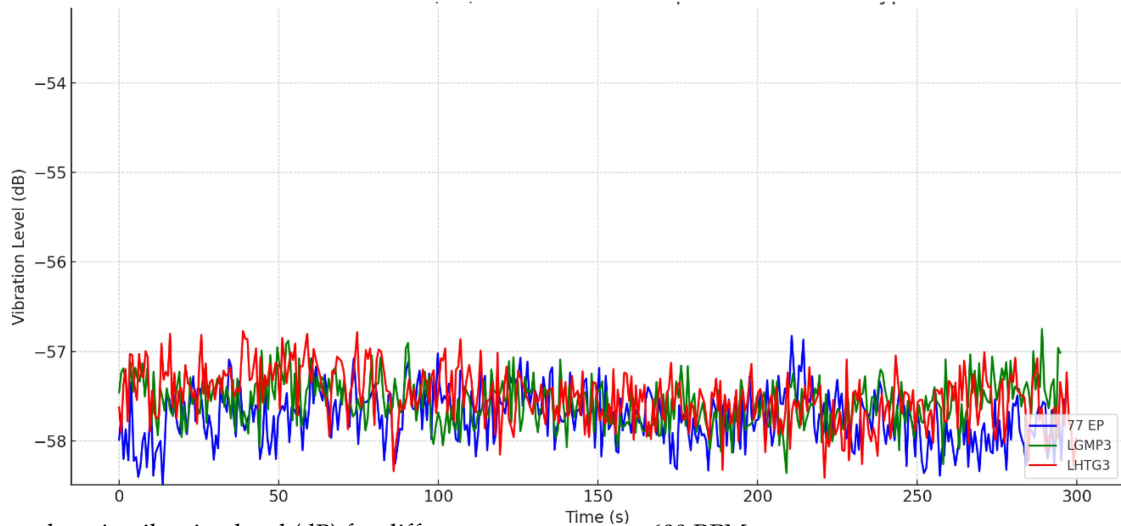


Figure 11 Time-domain vibration level (dB) for different grease types at 600 RPM

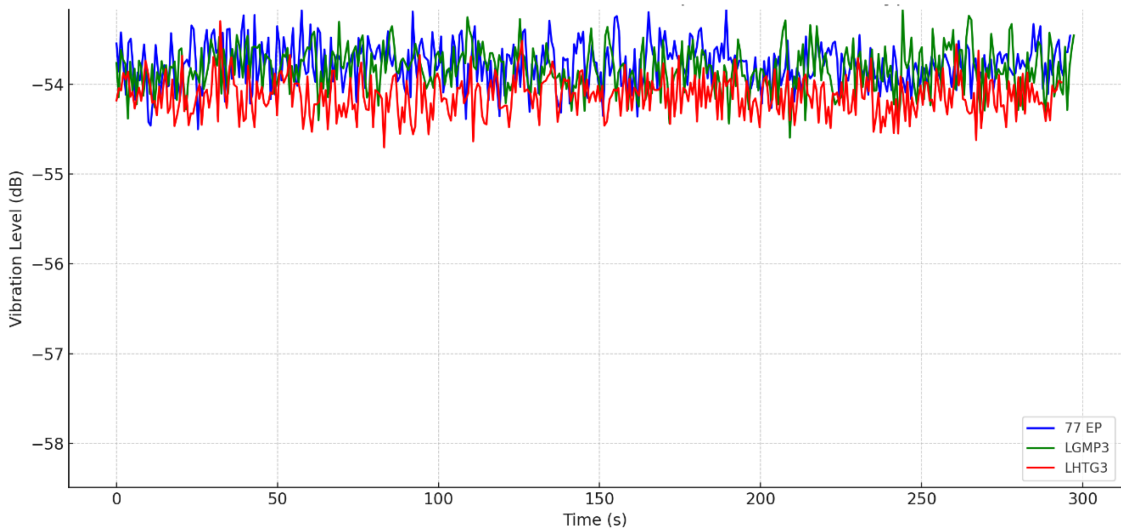


Figure 12 Time-domain vibration level (dB) for different grease types at 2400 RPM

This type of statistical representation facilitates the assessment of vibration stability associated with each lubricant, particularly under high-speed operational conditions. The LHTG3 grease (represented by the red curve), which exhibits lower standard deviation values, also shows the widest distribution range—thereby indicating a higher level of performance consistency and reduced variability across the measurements. Indicating modest stability, 77 EP (blue curve) exhibits a distinct peak about 0.00180, suggesting a recurrent presence of same vibrational frequencies. With increased deviation values, LGMP3 (green curve) exhibits a more uniform and broader distribution, indicating greater variability and diminished stability at elevated speeds. The distribution analysis indicates that LHTG3 provides superior vibration stability at elevated RPM compared to the other greases.

2-Grease type variation distribution at 2400 RPM

Figure 14 presents the distribution of variance values for the three grease types—77 EP, LGMP3, and LHTG3—at

2400 RPM, derived from time-domain vibration signals. The X-axis presents the computed variance values of the vibration signals, whereas the Y-axis illustrates their relative frequency across the entire dataset. This type of distribution provides insight into the stability and consistency of each lubricant under conditions of high-speed rotation. The LHTG3 lubricant, represented by the red curve, shows lower variance values that are spread across a broader range, indicating enhanced capability for vibration damping and a decrease in operational variability. On the other hand, 77 EP, shown by the blue curve, presents a distinct and narrow peak centered at approximately 3.2×10^{-6} , which reflects a moderate level of operational stability, with consistent and repetitive vibration behavior. In comparison, LGMP3, represented by the green curve, exhibits a broader and less uniform distribution skewed toward higher variance values, indicating increased sensitivity to dynamic loading and reduced consistency in vibration behavior. While LHTG3 outperforms the other greases in maintaining stable

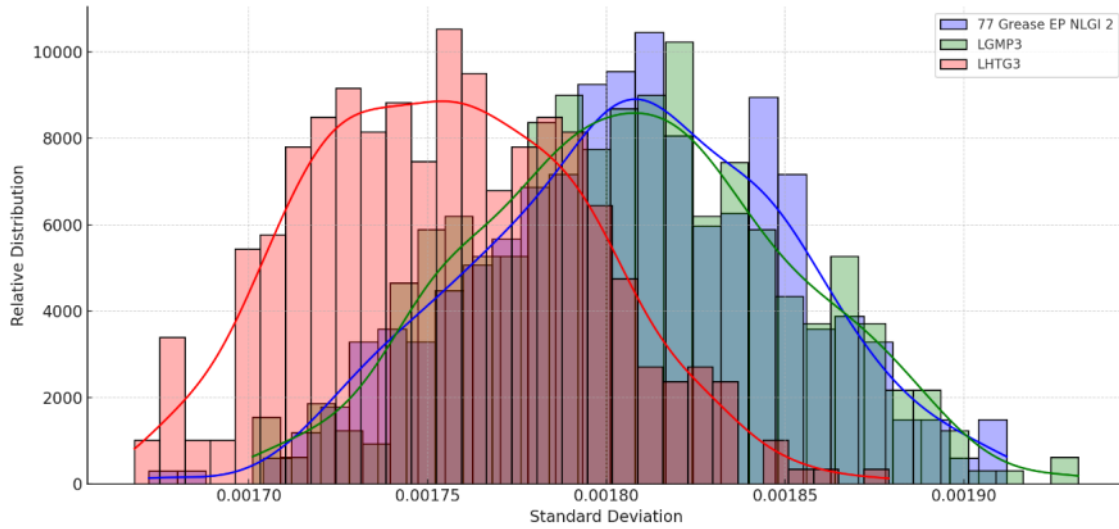


Figure 13 Distribution of Standard Deviation for Grease Types 77 EP, LGMP3, and LHTG3 at 2400 RPM: Analysis of Performance Stability

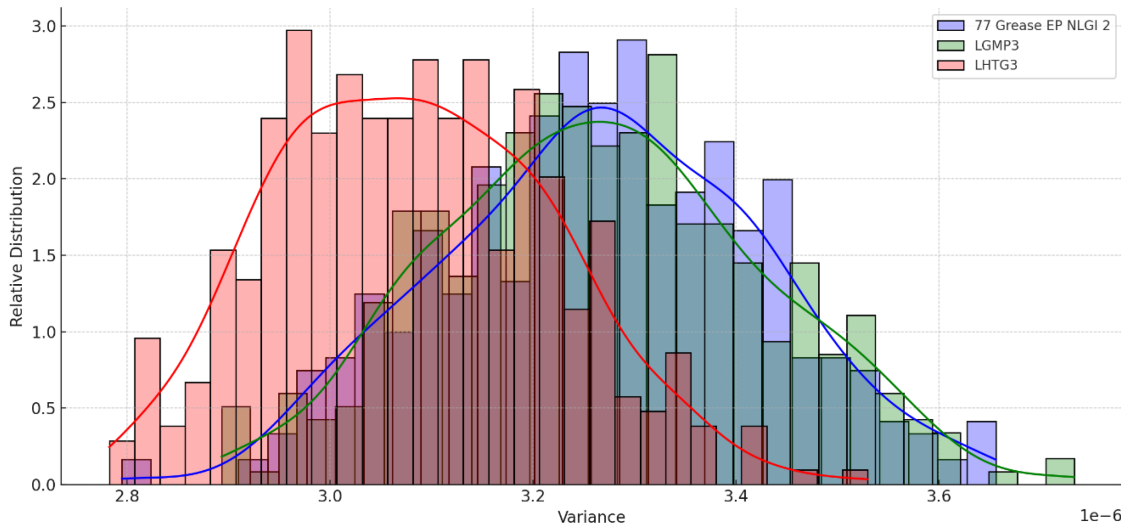


Figure 14 Performance Stability Analysis of Grease Types 77 EP, LGMP3, and LHTG3 at 2400 RPM: Variation Distribution

vibration patterns at high speeds, LGMP3 shows notable fluctuations, suggesting potential instability under similar operating conditions.

3-Analysis of Grease Type RMS Value Distribution at 2400 RPM

Based on time-domain analysis, Figure 15 shows the distribution of Root Mean Square (RMS) vibration signals for grease types 77 EP, LGMP3, and LHTG3 at 2400 RPM. The Y-axis represents the relative frequency of each RMS value, whereas the X-axis displays the raw RMS values of the vibration signal. RMS serves as a measure of the system’s overall energy and vibrational intensity, making it a key metric for evaluating dynamic performance. The distribution curve of LHTG3, illustrated in red, is concentrated around lower RMS values, indicating its effective capability in minimizing vibrational energy and sustaining operational stability, particularly under high-speed conditions. In contrast, 77 EP, shown in blue, reveals

a distinct and narrow peak near 0.00205, signifying more concentrated and elevated vibration levels. Meanwhile, LGMP3, depicted in green, presents a broader and asymmetrically skewed distribution toward higher RMS values, implying increased vibrational energy and reduced consistency in performance. These observations reinforce the conclusion that LHTG3 exhibits the most stable vibrational behavior, aligning with its favorable outcomes previously identified in the evaluations of standard deviation and variance. LHTG3 appears to be the most suitable lubricant among those assessed for high-speed applications where minimizing vibration intensity is critical.

4-Kurtosis distribution analysis for 2400 RPM grease types

Figure 16 illustrates the kurtosis distribution of vibration signals at 2400 RPM for grease types 77 EP, LGMP3, and LHTG3, extracted from time-domain data.

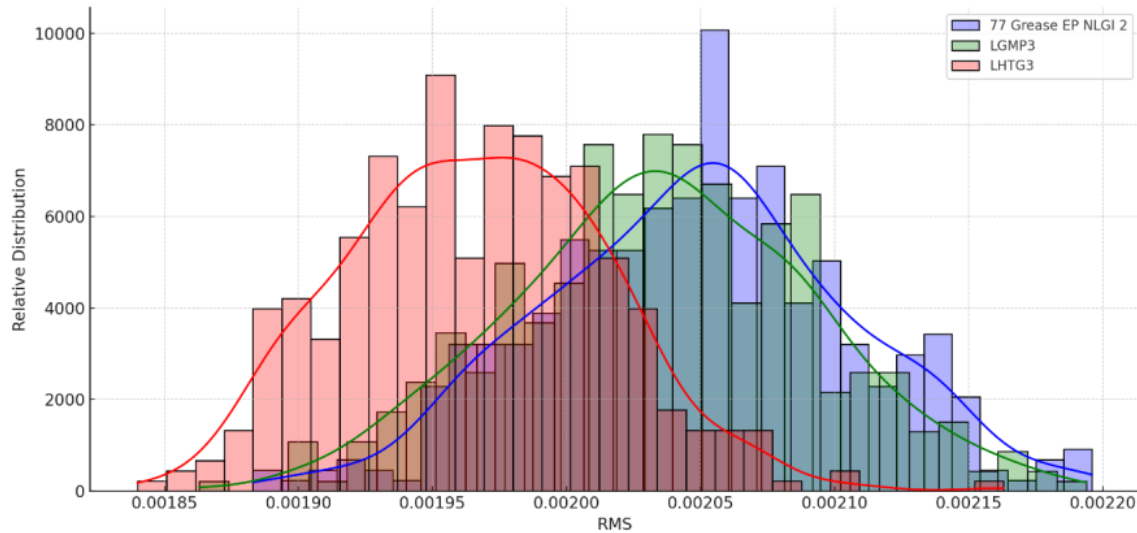


Figure 15 Root Mean Square (RMS) Value Distribution of Grease Types 77 EP, LGMP3, and LHTG3 at 2400 RPM: Vibration

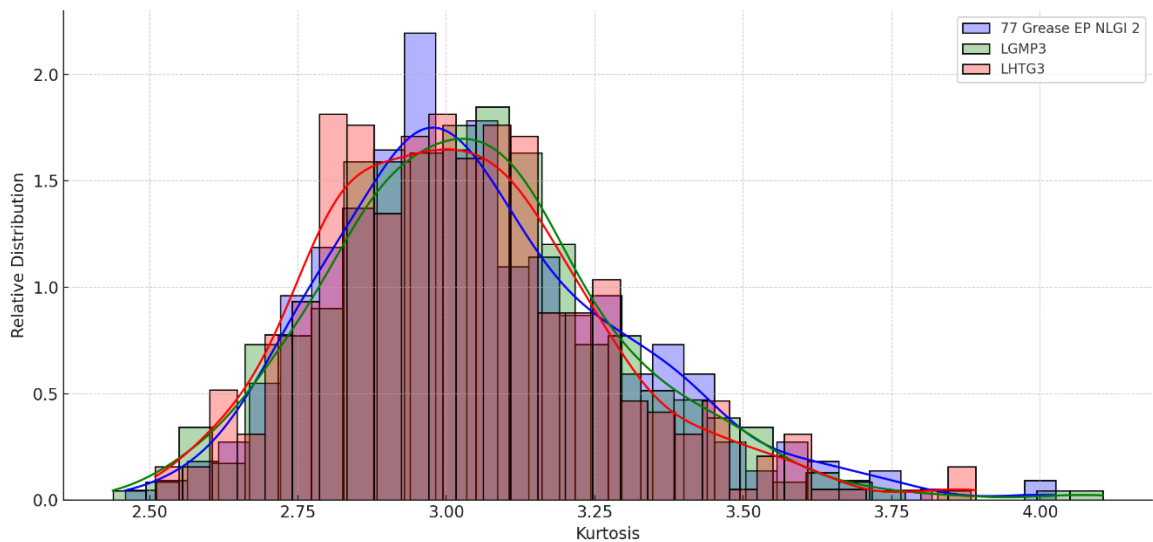


Figure 16 Kurtosis Distribution of Grease Types 77 EP, LGMP3, and LHTG3 at 2400 RPM: Outlier Dispersion Analysis

The Y-axis indicates the relative frequency of occurrence for each estimated kurtosis value derived from the vibration signal, whereas the X-axis shows the corresponding values. Kurtosis serves as an important statistical metric for identifying vibration spikes or abnormalities in rotating machinery, as it reflects the “tailedness” of the data, or the presence of extreme outlier values within the distribution. All three grease types exhibit mesokurtic characteristics, meaning their distributions neither show excessive flatness nor sharp peaks, and are generally aligned with a normal distribution centered at a kurtosis value of 3.0. Among them, 77 EP (represented by the blue curve) exhibits a more distinct peak at this reference point, which suggests a higher frequency of consistent, outlier-free vibration patterns. LGMP3 (green) and LHTG3 (red) have comparable yet broader distributions due to their somewhat higher kurtosis values, likely indicating occasional significant oscillations. The overall results indicate that all three

greases exhibit comparable performance for peak vibration dispersion, with no significant abnormalities or extreme occurrences observed at high speeds.

5-Skewness Distribution Analysis for Grease Types at 2400 RPM

Figure 17 illustrates the skewness distribution of vibration signals for the three grease types—77 EP, LGMP3, and LHTG3—at 2400 RPM, based on time-domain statistical analysis. The X-axis illustrates the calculated skewness values for individual segments of the vibration signal, whereas the Y-axis shows the relative frequency associated with each value. Skewness serves as a statistical indicator used to assess the asymmetry within a data distribution; values near zero reflect symmetry, while positive skewness suggests a distribution skewed toward higher amplitude values, typically associated with irregular or unstable vibrational behavior. According to the results, all three lubricants show a consistent, albeit slight,

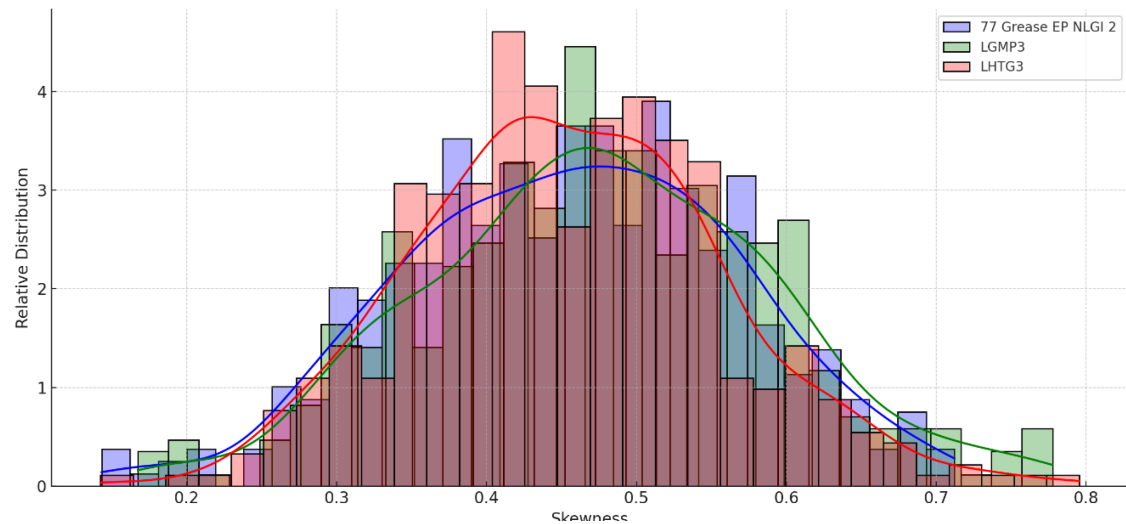


Figure 17 Analysis of Skewness Distribution for Grease Types 77 EP, LGMP3, and LHTG3 at 2400 RPM: Examination of Data Distribution Symmetry

inclination toward elevated vibration amplitudes, with moderate positive skewness values observed in the range of 0.2 to 0.8. Under high-speed conditions, LHTG3 (represented by the red curve) demonstrates a balanced and stable response, with a pronounced peak centered near a skewness value of 0.5, highlighting its reliable performance. Despite exhibiting a less pronounced concentration of elevated skewness values, 77 EP (blue) displays a comparable profile and indicates mild asymmetry. In contrast, LGMP3 (green) demonstrates a wider range skewed towards elevated values, indicating greater performance variability and reduced predictability in vibration response. The results indicate that LHTG3 exhibits more consistent and symmetric vibrational behavior, which is crucial for dynamic stability in journal bearing systems, hence corroborating previous findings from standard deviation and variance analyses.

4 CONCLUSION

This study confirmed that rotational speed and grease type significantly affect the vibration characteristics of journal bearings. A comparative analysis at 600 and 2400 RPM, using both frequency- and time-domain metrics, revealed clear differences in grease performance. LHTG3 showed the most consistent behavior—particularly at 2400 RPM—by maintaining the lowest standard deviation and RMS values, with skewness centered around 0.5, indicating stable vibration behavior under high-speed conditions. In contrast, LGMP3 exhibited the highest variance, RMS, and skewness, suggesting less damping capability and greater vibration irregularity, with a standard deviation peak of 0.00180 and variance near 3.2×10^{-4} . 77 EP delivered intermediate results, reflecting stable and predictable performance overall. Modest increases in LGMP3 and LHTG3 revealed that kurtosis analysis indicated mesokurtic distributions (~ 3.0) for all greases, suggesting occasional transitory spikes. In dynamic scenarios characterized by quick mechanical disturbances, 77 EP

demonstrated superior performance in the frequency domain by effectively mitigating abrupt spectral peaks. However, LGMP3 exhibited superior sensitivity to excitation, demonstrating heightened frequency peaks at both velocities, particularly at harmonic levels of the shaft frequency. Ultimately, although 77 EP is optimal for systems exposed to dynamic shocks and rapid frequency variations, LHTG3 is the superior choice for applications requiring prolonged vibrational stability. Developing improvements could enable LGMP3 to perform more effectively in high-speed or high-impact scenarios.

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