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Analysis of the application of vibration diagnostics and thermography methods for an early detection of defects in an industrial mixer-gearbox system – a case study

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Abstract:

Introduction/purpose: Bearings constitute essential components without which the functioning of systems subject to significant loads would be inconceivable. The bearing installation process in rotational systems diligently influences their longevity, reliability, and efficiency. Accurate and meticulous bearing installation is of paramount importance to ensure optimal operational performance of rotational systems. A proper bearing assembly assists in the even distribution of loads, reduction of friction, and minimization of wear. Additionally, appropriately mounted bearings decrease the risk of vibrations, noise, and potential system failures. Therefore, the bearing installation process represents a crucial step in maintaining the reliable and efficient operation of rotational systems, thereby extending their operational lifespan and reducing the need for repairs.

Methods: The methodology employed in this study combines vibrodiagnostic analysis of an industrial mixer equipped with a planetary gearbox and the concurrent application of thermographic techniques. This integrated approach provides a comprehensive understanding of the system's condition and helps identify potential sources of heating within both the gearbox and the mixer. Vibrodiagnostic examinations encompassed the analysis of vibrations generated by the planetary gearbox during its operation, coupled with the interpretative scrutiny of results aimed at detecting possible imbalances, damage, or irregularities within the mechanical system. On the other hand, the application of thermography contributed to generating a visual representation of temperature distributions at critical points of the gearbox, facilitating the identification of thermal anomalies. The integration of these methods enables a holistic scientific approach to the analysis of the planetary gearbox system, allowing for detailed diagnostics and an understanding of the root causes of potential operational issues in the gearbox.

Results: The meticulous interpretation of the acquired data facilitated the identification of potential causes of thermal loading in the planetary gearbox, providing a comprehensive insight into the mechanical and thermal facets of the entire system. The integration of vibrodiagnostic and thermograpfic methods constitutes a pivotal component of a holistic analytical approach, crucial for an exhaustive understanding of the performance and overall condition of the planetary gearbox and the industrial mixer. The obtained results serve as the foundation for the development of precise diagnostic procedures, laying the groundwork for the implementation of pertinent improvements or maintenance strategies within the system. This, in turn, holds the potential to optimize the operational performance of the planetary gearbox and extend its operational lifespan.

Conclusion: The applied methodology, based on vibrodiagnostic analyses and thermographic techniques, has provided a comprehensive insight into the condition of both the planetary gearbox and the industrial mixer containing it, with all analyses described in the text conducted on each component within the mixer system. The detailed interpretation of data has enabled the identification of potential causes of gearbox heating, offering a deeper understanding of the mechanical and thermal aspects of the system. In this manner, the efficiency of maintaining the examined system can be enhanced.

Key words: planetary gearbox, industrial mixer, vibrodiagnostic, thermograpfic, analysis, bearing, reliability, maintenance.

Introduction

Planetary gearboxes have a wide range of applications, starting from the automotive industry, extending through the aerospace industry, and reaching heavy metal industries (Guo & Parker, 2011; McNames, 2002). This type of gearbox is primarily utilized in harsh working conditions, which significantly affects the lifespan of the system and its components. Such conditions directly contribute to damage within the system, most commonly resulting from material fatigue (Cheng et al., 2012). The foundation of a reliable and high-quality operation of any technical system lies in the design of its transmission system, aiming to ensure optimal energy efficiency and proper lubrication. This approach helps to maintain system performance and prolong the lifespan of its components (Zhang, 2013). Bearings, as fundamental components of any gearbox, endure significant loads during operation and are therefore prone to frequent potential failures, as described in the paper (Lu et al., 2020). Testing the operational integrity of planetary gearboxes can involve various diagnostic methods. In the study by (Lei et al., 2013), an adaptive resonance method is described for diagnosing planetary gearbox faults. Planetary gearboxes are frequently subjected to dynamic loads, as outlined in the paper (Batinic, 2013), which can lead to elevated vibrations within the gearbox. Modern diagnostic methods for assessing the condition of planetary gearboxes are integral to implementing higher-quality maintenance practices, with some primary diagnostics described in studies (Chatterjee & Dethlefs, 2021; Lei et al., 2010). Vibration diagnostics is a crucial method for monitoring and diagnosing the condition of rotating equipment, such as pumps, compressors, turbines, gears, and other machinery systems in industrial and engineering facilities. Since rotating equipment is continuously subjected to mechanical loads and dynamic stresses, timely detection of irregularities and the early stages of damage is essential for ensuring the reliability and longevity of these systems.

Vibration diagnostics methodologies include signal analysis in both the frequency and time domains, with advanced techniques increasingly being used for more precise diagnostics. Frequency spectrum analysis enables the detection of dominant frequencies, which facilitates the identification of specific system components, such as gears and bearings, which show signs of failure. Wavelet transformation, as a modern technique, provides additional insight into short-term changes that often go unnoticed in traditional frequency analyses, further enhancing the precision of problem detection. Finally, time-domain signal analysis through parameters such as RMS values and peak values enables the direct detection of system performance changes, thereby simplifying the identification of irregularities (Aherwar, 2012; De Silva, 2007; Goyal & Pabla, 2016; Rai & Upadhyay, 2016; Singh & Sehgal, 2022; Vishwakarma et al., 2017).

The thermography method enables visualization of temperature distribution on the surface of machine components and the identification of zones with elevated temperatures, which may indicate potential issues such as friction, inadequate lubrication, wear, or localized mechanical stresses. The use of thermography aids in detecting these anomalies at early stages, allowing for preventive interventions before more serious failures or machine downtime occur. Thermography finds wide applications across fields, from the construction industry to the process and gas industries, and even aerospace, as illustrated in studies (Jakubek et al., 2022; Ristić et al., 2013).

As opposed to vibration diagnostics, which focuses on analyzing vibration patterns to identify mechanical irregularities, thermography provides a different set of insights by relying on temperature variations caused by increased mechanical load or friction. Thermographic analysis is often useful in cases where vibration signals cannot fully reveal the problem, such as issues related to thermal overheating of bearings or electrical components in motors. Integrating these methods offers a comprehensive view of equipment condition, which is especially valuable in critical industrial processes where high machine reliability is essential. In this way, a diagnostic approach that combines thermal and vibration analyses is becoming increasingly important in modern industrial applications to extend the service life of rotating equipment and minimize the risk of unexpected failures (Gawde et al., 2023; Shaalan et al., 2024; Thomas et al., 2001; Watban Khalid Fahmi et al., 2022).

Material and methods

In the pursuit of diagnosing faults in planetary gear reducers, researchers increasingly employ advanced techniques such as vibrodiagnostics and thermography. Vibrodiagnostic methodology involves data acquisition on the vibrations of the reducer through the placement of accelerometers at the key points within the system. Frequency analysis of these vibrations facilitates the identification of characteristic patterns associated with potential malfunctions such as imbalance or gear damage. The sensitivity to changes in the reducer's condition over time allows for an early detection of potential issues. Conversely, thermography relies on infrared cameras to measure temperatures on the surface of the reducer. Through the analysis of thermal profiles, researchers can identify regions with abnormal temperatures, indicative of problems such as friction or inadequate lubrication. The amalgamation of vibrodiagnostics and thermography provides a comprehensive assessment of the planetary gear reducer's condition, enabling precise diagnostics and efficient maintenance of the system. In this case, thermography is utilized for the analysis of temperature elevation on the bearings of a planetary gearbox within an industrial mixer system with a power rating of 1.5 MW, undergoing a speed reduction from 990 rpm to 49 rpm. Based on the presented formulas, it is possible to determine the frequencies at which failures occur in specific bearing components within the system, such as the inner ring, the outer ring, the rolling elements, and the train. The Ball Pass Frequency Outer Ring is represented by Equation (1):

$$BPFO = RPM\frac{n}{2}(1-\frac{d}{D_p}\cos\beta) \tag{1}$$

The Ball Pass Frequency Inner Ring is represented by Equation (2):

$$BPFI = RPM\frac{n}{2}(1+\frac{d}{D_p}\cos\beta) \tag{2}$$

The Fundamental Train Frequency is represented by Equation (3):

$$FTF = \frac{RPM}{2}(1-\frac{d}{D_p}\cos\beta) \tag{3}$$

The Ball Spin Frequency is represented by Equation (4):

$$BSF = RPM\frac{D_p}{d}\left[1-(\frac{d}{D_p}\cos\beta)^2\right] \tag{4}$$

Analysis of vibration and thermal heating in an industrial mixer and a planetary gearbox system

A comprehensive assessment of the condition of a planetary gearbox installed in an industrial mixer system, as well as the issue of heating in specific components of both the gearbox and the mixer, can be achieved by fully integrating both methods for evaluating the condition of individual elements within the gearbox and the mixer. Vibration analysis is used to evaluate the condition of a gearbox by examining dynamic loads that occur during the operation of individual components, such as the gear meshing points and tooth contacts, the condition of ball bearings within the gears, and the alignment of the drive and the driven gear shafts. This method provides insight into mechanical wear, alignment issues, and potential imbalances that may affect gearbox performance and longevity. On the other hand, infrared thermography offers a complete overview that can detect current or potential issues leading to elevated temperatures within the gearbox. Thermal imaging can reveal temperature anomalies often associated with friction, lubrication issues, or excessive loads. By visualizing the thermal distribution, especially in the lubricating fluid and other critical parts of the gearbox and the industrial mixer system, infrared thermography allows for early detection of issues that may not be immediately apparent through vibration analysis alone. This dual-method approach ensures a thorough examination of both the mechanical and thermal conditions, enhancing predictive maintenance and overall system reliability.

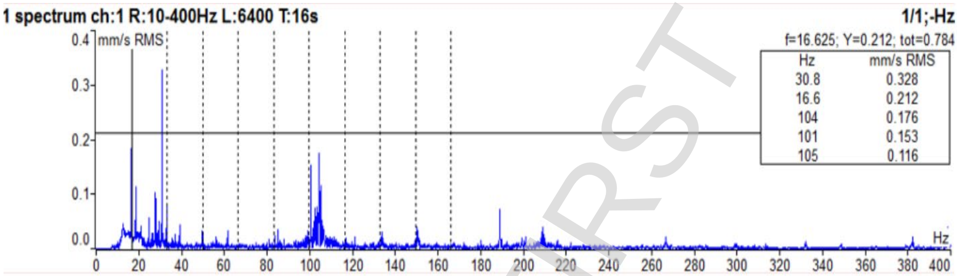

Figure 1 – Spectrum of vibrations at the measurement point of the gearbox input

In Figure 2, the demodulated acceleration spectrum (in g RMS) is shown, aiding in the identification of high-frequency vibrations often associated with bearing defects. Through demodulation, peaks are observed at very low frequencies around 0.75 Hz, 16.5 Hz, and 0.375 Hz. Although the values are relatively low (up to 0.005 g RMS), the presence of pronounced peaks at these frequencies may indicate early signs of wear or faults in the bearings.

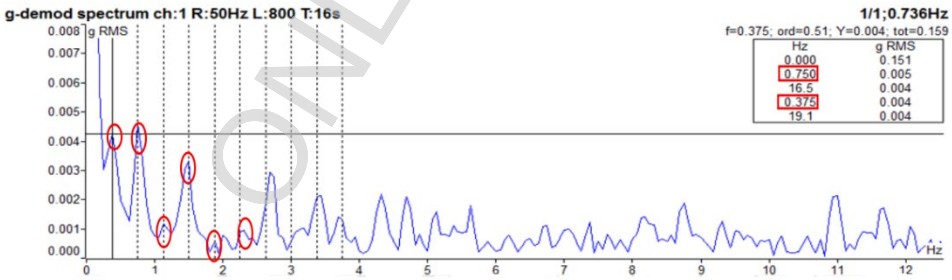

Figure 2 – Demodulated spectrum of vibrations at the reducer outlet - bearing

Based on the FFT analysis of the gearbox, slight looseness was detected in the bearing at the gearbox output. Given the very low vibration levels at the gearbox output, it is recommended to monitor the bearing condition and respond promptly if necessary. Obtain data on the bearings in the gearbox for further analysis.

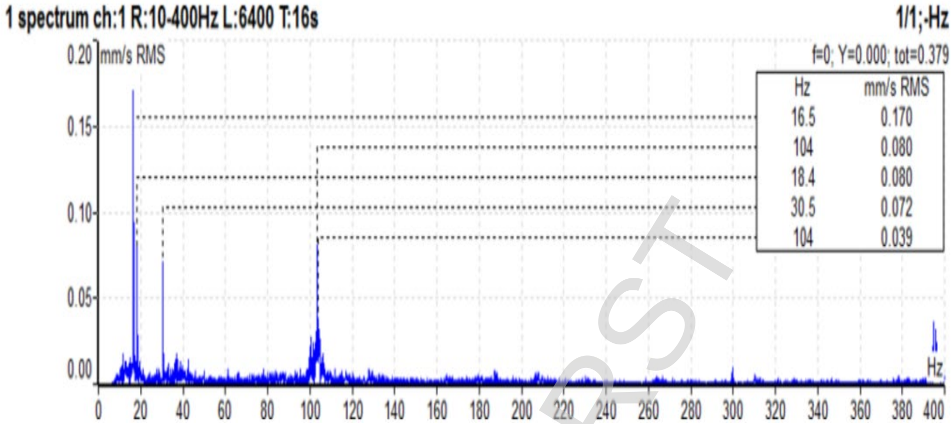

Figure 3 – Spectrum of vibrations at the measurement point of the mixer input

Figure 4 shows the demodulated vibration spectrum at the mixer inlet.

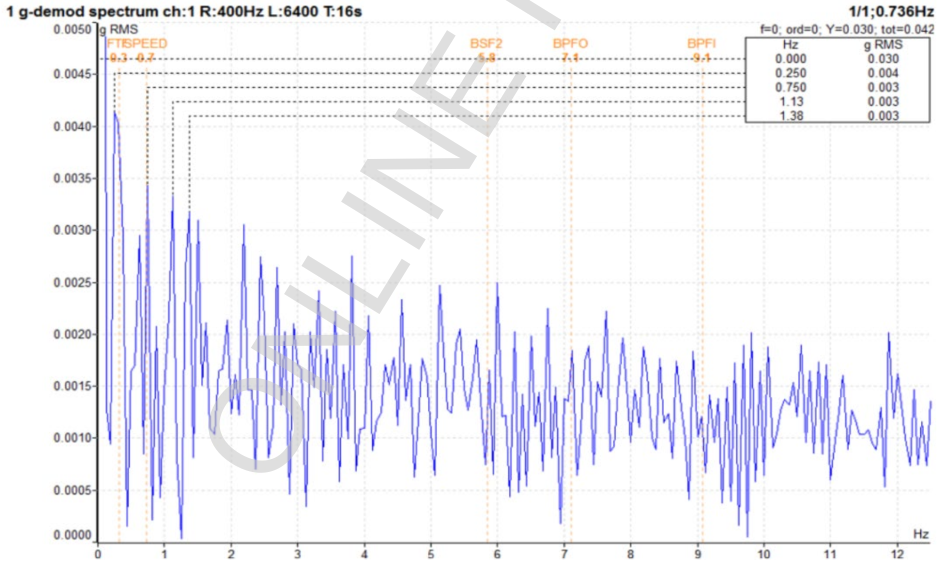

Figure 4 – Demodulated spectrum of vibrations at the mixer input

Based on the vibration spectra shown in Figures 3 and 4, it can be concluded that there are no elevated vibrations beyond acceptable limits, nor any detected irregularities in the mixer’s operation at the bearing measurement point at the inlet.

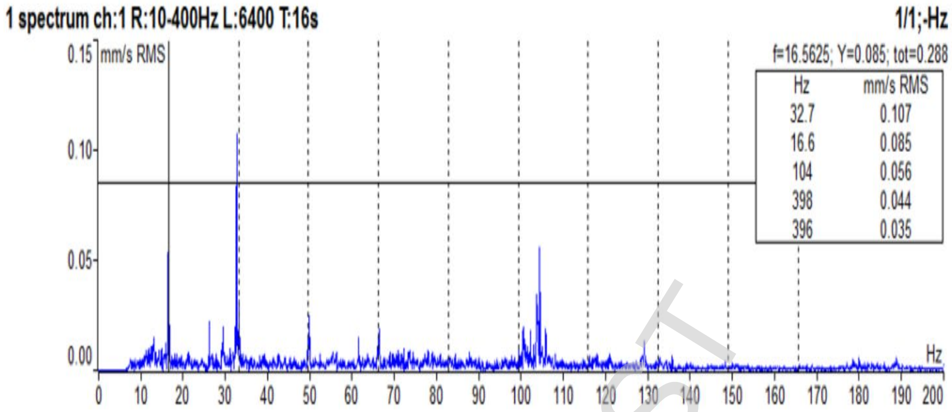

Figure 5 – Spectral analysis of vibrations at the mixer outlet

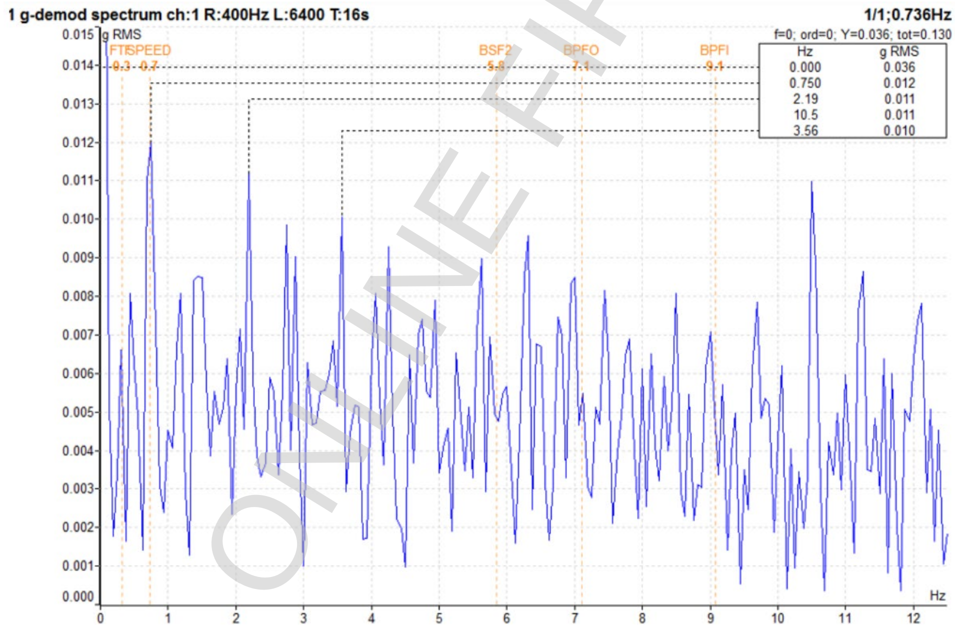

Figure 6 – Demodulated vibration spectrum at the mixer inlet

Given the visually identified potential malfunction of the bearing at the mixer outlet, along with increased lubricant leakage, an additional time-domain vibration acceleration analysis was conducted.

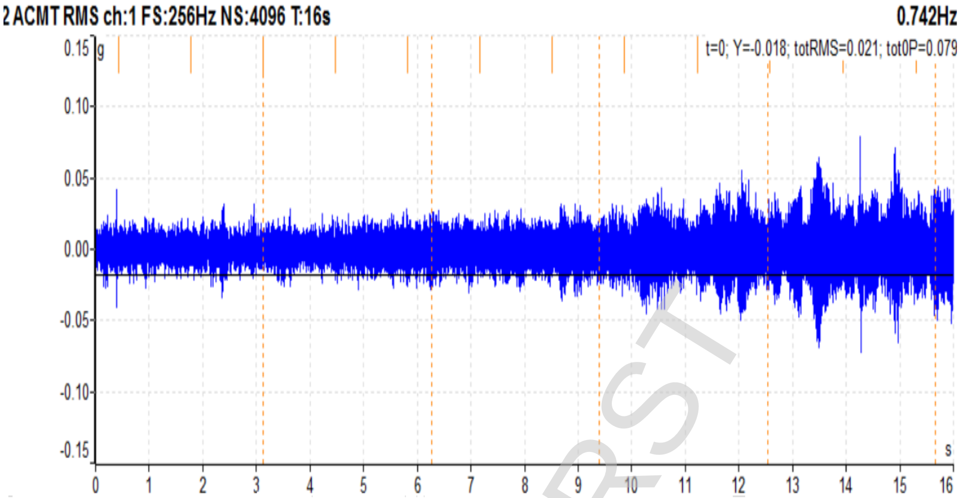

Figure 7 – Time spectrum of vibrations at the mixer outlet

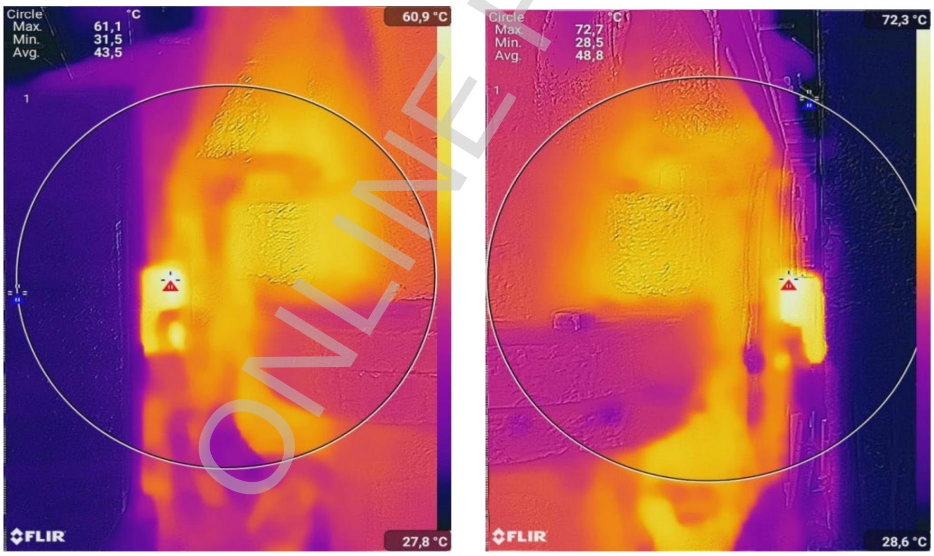

Figure 8 – Thermal image of the gearbox at the inlet

The spectral analysis shows that vibrations are generally stable and low-intensity, with RMS values close to zero for most of the measurement duration. However, certain peaks (more pronounced increases in vibration) occur at specific times, particularly after the 12th second, where the vibration level rises. The overall RMS value measured during this period is 0.021 g, indicating a relatively low level of vibration, though periodic peaks may suggest occasional impacts or asymmetric loads within the system.

Figure 9 – Thermal image at the gearbox output

Since the vibration analysis did not reveal any specific faults in the operation of the gearbox and the mixer, a thermographic inspection method was applied to the gearbox and the mixer to obtain a comprehensive view and identify any potential system malfunctions.

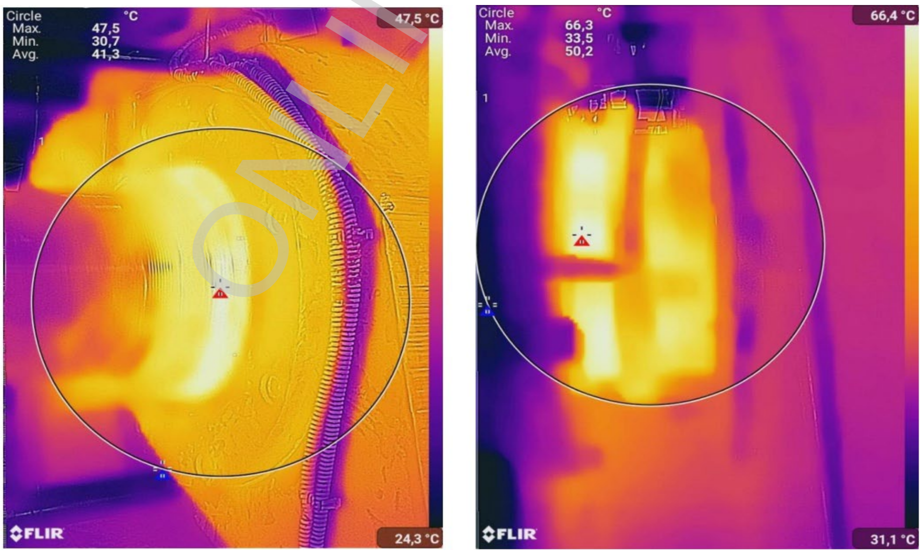

Figure 10 – Thermal image at the mixer inlet

According to Figure 8 and the operational parameters of the gearbox, the recorded temperatures and the heating levels captured by the camera fall within the allowable temperature range, indicating no operational anomalies at the gearbox input.

Additionally, the temperatures at the gearbox output are considered within the tolerance range for optimal operation of both the gearbox and the output bearings.

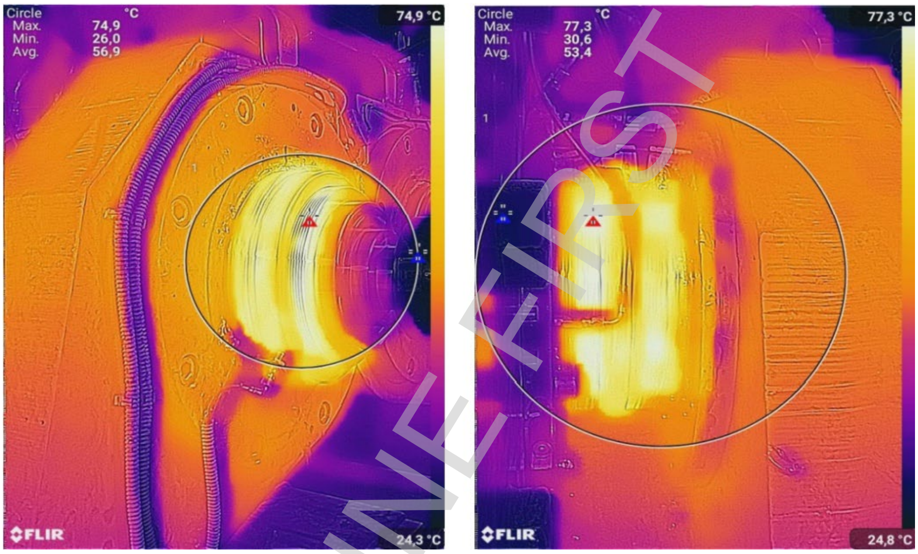

Figure 11 – Thermal image at the mixer outlet

Based on the thermal image of the mixer, it is possible to analyze the presence of high temperatures in specific areas, which may indicate lubrication issues. In particular, the maximum temperature values are relatively high, reaching 74.9°C and 77.3°C, which suggests intense friction in certain zones of the mixer. These temperature peaks may be associated with lubricant leakage problems, often manifesting through specific thermal patterns. Lubricant leakage can lead to a loss of the necessary amount of lubricant at friction points, resulting in increased friction and higher temperatures, as shown in the image.

If leakage occurs, the lack of lubricant at critical points causes overheating because there is insufficient lubricant to form a protective film between contacting surfaces. In the images, we can observe concentrated zones of high temperature, potentially indicating that certain parts of the mixer are inadequately lubricated due to possible lubricant loss. When lubricant leaks or is excessively lost from the system, heat tends to concentrate in specific areas, while other parts may remain cooler. This uneven temperature distribution may point to potential leakage points.

Based on the FFT analysis of the mixer shaft at the output, a minor axial clearance in the bearing at position 1 was detected, attributed to improper bearing installation during assembly. Visual inspection revealed an incorrectly positioned seal on bearing 1, showing signs of wear. Consequently, lubricant leakage from the bearing and the ingress of contaminants into its interior occur, which explains the temperature difference compared to other bearings, given that the seal does not function adequately.

Figure 12 – Point of the mixer outlet

From Figure 12, it is clearly seen that there is leakage at the mixer outlet, causing an excessive concentration of heat on the bearing located at the output section of the shaft. Given that lubricant leakage has been identified in the mixer outlet area, a more detailed lubrication analysis of the bearing at the mixer outlet is necessary. Figure 13 illustrates the lubrication spectrum at the mixer outlet.

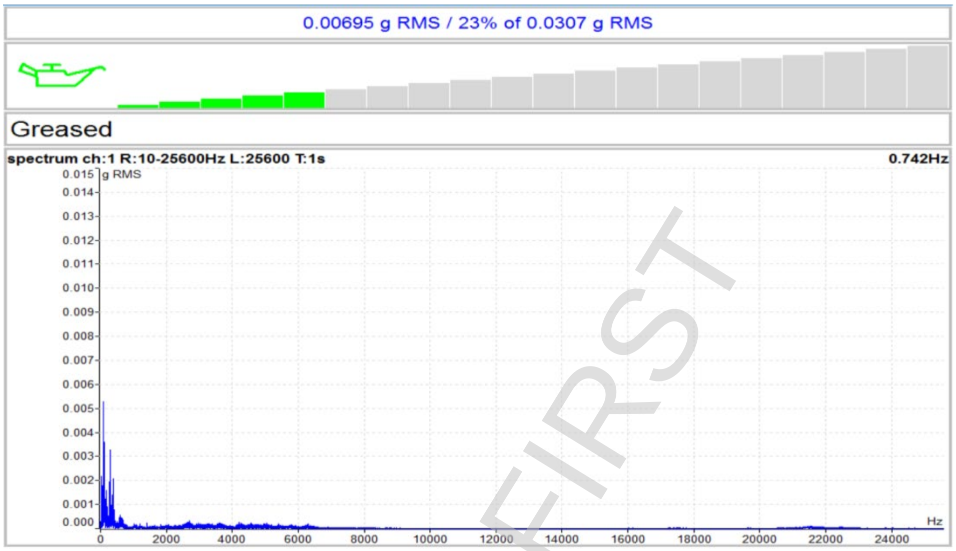

Figure 13 – Lubrication at the mixer outlet

A detailed lubrication analysis of the mixer outlet bearing was conducted using Lubri Mode. According to the data from the obtained spectrum, the lubrication condition of the bearing at the time of inspection is satisfactory, likely due to recent lubricant application to the bearings. However, given that the visual inspection revealed leakage, there is a tendency for peak values on the diagram to increase, potentially placing the lubrication level in the red zone, which necessitates re-lubrication of the examined bearing.

Results and discussion

Based on all applied diagnostics, including vibration analysis, thermography, and additional tools for bearing lubrication assessment, it can be concluded that current testing does not always provide a fully accurate picture of the condition. However, the diagnostic methods performed enable a predictive assessment of the examined component's condition, allowing for timely implementation of appropriate maintenance procedures to prevent extended and unplanned downtimes.

Vibrations, as a parameter, indicate potential damage to both the planetary reducer bearings and the mixer itself. According to the measured values, no critical values were identified per the ISO standard (ISO 20816-

3:2022), and the measured vibration values for the reducer's measuring points are shown in Table 1.

Table 1 – Vibration on the gearbox

Point	1V	1H	2V	2H	3V	3H	3A
Velocity (mm/s)	0,912	0,328	1,030	0,816	0,421	0,637	0,192
Acceleration (g)RMS	0,252	0,380	0,377	0,316	0,229	0,092	0,146

The measurement results indicate that the RMS values of the vibration velocity range from 0.192 mm/s to 1.030 mm/s, with the highest value recorded at the measurement point 2V (1.030 mm/s) and the lowest at the point 3A (0.192 mm/s). All velocity values are below the reference threshold of 2.8 mm/s, indicating a low level of vibration consistent with the standards for rotating machinery. Regarding the RMS values of vibration acceleration, the range is from 0.092 g to 0.380 g, with the maximum value observed at the point 1H (0.380 g) and the minimum value at the point 3V (0.092 g). All acceleration values are below the 0.5 g threshold, indicating the absence of impact vibrations that could compromise the structural integrity of the bearings. Collectively, these data suggest a stable dynamic condition of the system, with no elevated or critical vibrations that would require corrective action.

Table 2 – Vibration on the mixer

Point	**1V**	**1H**	**1A**	**2V**	**2H**	**2A**
Velocity (mm/s)	0,281	0,170	0,116	0,357	0,164	0,150
Acceleration (g)RMS	0,021	0,047	0,036	0,045	0,072	0,021
Point	**3V**	**3H**	**3A**	**4V**	**4H**	**4A**
Velocity (mm/s)	0,240	0,113	0,107	0,377	0,091	0,119
Acceleration (g)RMS	0,013	0,037	0,054	0,045	0,012	0,038

The vibration analysis on the industrial mixer indicates that the RMS values of the vibration velocity at the inlet points range from 0.116 mm/s to 0.357 mm/s, while at the outlet points, they range from 0.091 mm/s to 0.377 mm/s. The highest velocity values were recorded at the points 2V and 4V, yet all values are significantly below the threshold of 2.8 mm/s, indicating a low level of vibration throughout the system. Regarding vibration acceleration, the inlet points show the values between 0.021 g and 0.072 g, while the outlet points range from 0.012 g to 0.054 g, with the highest values at the points 2H and 3A. All acceleration values are below the reference threshold of 0.5 g, indicating the absence of impact vibrations that could compromise the system's integrity. Overall, the results indicate a stable dynamic condition of the mixer, with no elevated vibrations requiring corrective action.

Conclusion

In this study, advanced vibration diagnostics and thermography methods were applied and their results analyzed for an early detection of defects in industrial systems such as gearboxes and mixers. Given that these systems operate under substantial load, monitoring both vibrational and thermal stresses is essential for the timely identification of irregularities that could shorten service life and elevate maintenance costs.

Vibration diagnostics was employed to assess vibration levels accurately during system operation, facilitating the identification of potential issues in bearings, gears, and other moving components. By measuring the RMS values of the vibrations at different bearing measurement points, oscillations were detected that, while within permissible limits according to ISO standard 20816-3, may indicate gradual wear or the onset of damage. The vibration levels at critical points also revealed frequent peaks at specific frequencies, potentially linked to minor axial clearances due to improper bearing installation. These findings underscore the importance of continuous vibration monitoring to reduce the risk of more severe failures.

Thermographic analysis further contributed by identifying key thermal anomalies on bearings and critical gear contact points, which may signal lubrication issues. The elevated temperatures recorded in specific bearing zones exceeded optimal operational thresholds, suggesting intensified friction resulting from either a deficiency in lubricant or inadequate lubrication application. This thermal concentration likely stems from lubricant leakage or uneven distribution, leading to overheating that would not be detectable through vibration analysis alone.

The thermographic measurements enabled the visualization and quantification of thermal peaks, with the highest temperatures observed at the mixer and gearbox output bearings. The analysis of these thermal deviations pointed to uneven lubrication and pronounced thermal zones, which may represent potential hotspots for wear. This thermal data allows for more precise control over lubrication quality, facilitating preventive corrective actions, such as timely lubricant replenishment or replacement, and thus mitigating the risk of further thermal damage to the system.

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Análisis de la aplicación de métodos de diagnóstico de vibraciones y termografía para la detección temprana de defectos en un sistema mezclador-caja de cambios industrial: un caso de estudio

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CAMPO: Ingeniería mecánica

TIPO DEL ARTÍCULO: Artículo científico original

Resumen:

Introducción/objetivo: Los rodamientos constituyen componentes esenciales sin los cuales el funcionamiento de sistemas sometidos a cargas significativas sería inconcebible. El proceso de instalación de los rodamientos en sistemas rotacionales influye considerablemente en su longevidad, fiabilidad y eficiencia. Una instalación precisa y meticulosa de

los rodamientos es fundamental para garantizar un rendimiento operativo óptimo de los sistemas rotacionales. Un montaje correcto de los rodamientos facilita la distribución uniforme de las cargas, reduce la fricción y minimiza el desgaste. Además, un montaje correcto de los rodamientos reduce el riesgo de vibraciones, ruido y posibles fallos del sistema. Por lo tanto, la instalación de los rodamientos es un paso crucial para mantener el funcionamiento fiable y eficiente de los sistemas rotacionales, prolongando así su vida útil y reduciendo la necesidad de reparaciones.

Métodos: La metodología empleada en este estudio combina el análisis vibrodiagnóstico de un mezclador industrial equipado con una caja de cambios planetaria y la aplicación simultánea de técnicas termográficas. Este enfoque integrado proporciona una comprensión completa del estado del sistema y ayuda a identificar posibles fuentes de calentamiento tanto en la caja de cambios como en el mezclador. Los exámenes vibrodiagnósticos abarcaron el análisis de las vibraciones generadas por la caja de cambios planetaria durante su funcionamiento, junto con el análisis interpretativo de los resultados para detectar posibles desequilibrios, daños o irregularidades en el sistema mecánico. Por otro lado, la aplicación de la termografía contribuyó a generar una representación visual de las distribuciones de temperatura en puntos críticos de la caja de cambios, facilitando la identificación de anomalías térmicas. La integración de estos métodos permite un enfoque científico holístico para el análisis del sistema de caja de cambios planetaria, lo que permite un diagnóstico detallado y la comprensión de las causas raíz de los posibles problemas operativos en la caja de cambios.

Resultados: La meticulosa interpretación de los datos adquiridos facilitó la identificación de las posibles causas de la carga térmica en el caja de cambios planetaria, proporcionando una visión completa de los aspectos mecánicos y térmicos de todo el sistema. La integración de métodos de vibrodiagnóstico y termografía constituye un componente fundamental de un enfoque analítico holístico, crucial para una comprensión exhaustiva del rendimiento y el estado general de la caja de cambios planetaria y del mezclador industrial. Los resultados obtenidos sirven de base para el desarrollo de procedimientos de diagnóstico precisos, sentando las bases para la implementación de mejoras o estrategias de mantenimiento pertinentes en el sistema. Esto, a su vez, tiene el potencial de optimizar el rendimiento operativo de la caja de cambios planetaria y prolongar su vida útil.

Conclusión: La metodología aplicada, basada en análisis vibrodiagnósticos y técnicas termográficas, ha proporcionado una visión completa del estado tanto de la caja de cambios planetaria como del mezclador industrial que lo contiene. Todos los análisis descritos en el texto se realizaron en cada componente del sistema mezclador. La interpretación detallada de los datos ha permitido identificar las posibles

causas del calentamiento de la caja de cambios, lo que proporciona una comprensión más profunda de los aspectos mecánicos y térmicos del sistema. De esta manera, se puede mejorar la eficiencia del mantenimiento del sistema examinado.

Palabras claves: caja de cambios planetaria, mezclador industrial, vibrodiagnóstico, termografía, análisis, rodamiento, confiabilidad, mantenimiento.

Анализ применения методов вибродиагностики и термографии с целью выявления дефектов на ранней стадии в промышленной системе смеситель-редуктор – тематическое исследование

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РУБРИКА ГРНТИ:
30.19.00 Механика деформируемого твердого тела,
30.15.35 Теория механизмов и машин,
55.43.00 Автомобилестроение,
ВИД СТАТЬИ: оригинальная научная статья

Резюме:

Ведение/цель: *Подшипники являются важнейшими компонентами, без которых невозможно представить функционирование механических систем, подверженных серьезным нагрузкам. Процесс установки подшипников в роторных системах существенно влияет на срок их службы, надежность и эффективность. Точная и правильная установка подшипников имеет важнейшее значение для обеспечения оптимальных эксплуатационных характеристик роторных систем. Правильный подшипниковый узел способствует равномерному распределению нагрузок, снижению трения и минимизации износа. Кроме того, правильно установленные подшипники уменьшают вибрации, шум и снижают риск от возможных отказов системы. Таким образом, процесс установки подшипников является важным этапом в обеспечении надежной и эффективной работы роторных систем, что позволяет продлить срок их службы и снизить потребность в ремонте.*

Методы: Методология, использованная в данном исследовании, сочетает в себе вибродиагностический анализ промышленного смесителя, оснащенного планетарным редуктором, и одновременное применение термографических методов. Такой комплексный подход обеспечивает всестороннее понимание состояния системы и помогает выявить потенциальные источники возможных дисбалансов, повреждений или неровностей в механической системе. Помимо того, применение термографии позволило получить визуальное представление о распределении температуры в критических точках коробки передач, что облегчило идентификацию тепловых аномалий. Интеграция этих методов обеспечивает целостный научный подход к анализу системы планетарной коробки передач, позволяющий проводить детальную диагностику и понимать первопричины потенциальных проблем в работе коробки передач.

Результаты: Тщательная интерпретация полученных данных помогла выявить потенциальные причины тепловой нагрузки в планетарной коробке передач, на основании чего складывается полное представление о механических и тепловых аспектах всей системы. Интеграция методов вибродиагностики и термографии является ключевым компонентом целостного аналитического подхода, который имеет решающее значение для полного понимания характеристик и общего состояния планетарного редуктора и промышленного смесителя. Полученные результаты являются основой для разработки точных диагностических процедур, закладывая фундамент для внедрения соответствующих усовершенствований или стратегий технического обслуживания системы. А это, в свою очередь, позволит оптимизировать эксплуатационные характеристики планетарной коробки передач и продлить срок ее службы.

Выводы: Примененная методология, основанная на вибродиагностическом анализе и термографических методах, позволила получить всестороннее представление о состоянии как планетарного редуктора, так и промышленного смесителя. Причем все анализы, описанные в статье, были проведены по каждому компоненту системы смесителя. Подробная интерпретация данных способствовала выявлению возможных причин перегрева коробки передач, что позволило глубже понять механические и тепловые аспекты системы. Руководствуясь результатами данного исследования, можно повысить эффективность обслуживания тестированной системы.

Ключевые слова: планетарная коробка передач, промышленный смеситель, вибродиагностика, термография, анализ, подшипник, надежность, техническое обслуживание.

Анализа примене метода вибродијагностике и термовизије у циљу откривања ране фазе дефеката на индустријском систему мешач-редуктор – студија случаја

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ОБЛАСТ: машинство
КАТЕГОРИЈА (ТИП) ЧЛАНКА: оригинални научни рад

Сажетак:

Увод/циљ: Лежајеви представљају кључне компоненте без којих би функционисање система изложених знатним оптерећењима било незамисливо. Процес уградње лежајева у ротационе системе значајно утиче на њихов век трајања, поузданост и ефикасност. Тачна и прецизна монтажа лежајева је од суштинског значаја за постизање оптималних радних перформанси ротационих система. Правилна уградња лежајева доприноси равномерној расподели оптерећења, смањењу трења и минимизацији хабања. Поред тога, адекватно монтирани лежајеви смањују ризик од вибрација, буке и потенцијалних отказа система. Стога, процес уградње лежајева представља кључни корак у одржавању поузданог и ефикасног рада ротационих система, чиме се продужава њихов радни век и смањује потреба за поправкама.

Методе: Методологија примењена у овом истраживању комбинује вибродијагностичку анализу индустријског мешача опремљеног планетарним мењачем и истовремену примену термографских техника. Овај интегрисани приступ омогућава свеобухватни увид у стање система и помаже у идентификацији потенцијалних извора загревања, како у мењачу, тако и у мешачу. Вибродијагностичка испитивања обухватила су анализу вибрација које генерише планетарни мењач током рада, уз интерпретацију резултата ради откривања могућих неуравнотежености, оштећења или неправилности у механичком систему. С друге стране, примена термографије допринела је стварању визуелног приказа дистрибуције температуре на критичним тачкама мењача, олакшавајући идентификацију термичких аномалија. Интеграција ових метода омогућава холистички научни приступ анализи система планетарног мењача, што омогућава детаљну дијагностику и спознавање основних узрока потенцијалних оперативних проблема у мењачу.

Резултати: Пажљива интерпретација прикупљених података омогућила је идентификацију потенцијалних узрока термичког оптерећења у планетарном мењачу, пружајући свеобухватан увид у механичке и термичке аспекте целокупног система. Интеграција *вибродијагностичких и термографских метода представља кључну компоненту холистичког аналитичког приступа, који је неопходан за потпуни увид у перформансе и укупно стање планетарног мењача и индустријског мешача. Добијени резултати служе као основа за развој прецизних дијагностичких процедура, постављајући темељ за имплементацију одговарајућих побољшања или стратегија одржавања у систему. То може довести до оптимизације радних перформанси планетарног мењача и продужетка његовог радног века.*

Закључак: Примењена методологија, заснована на вибродијагностичким анализама и термографским техникама, пружила је свеобухватан увид у стање како планетарног мењача, тако и индустријског мешача у којем се он налази, при чему су све описане анализе спроведене на свакој компоненти унутар система мешача. Детаљна интерпретација података омогућила је идентификацију потенцијалних узрока загревања мењача, што доприноси бољем разумевању механичких и термичких аспеката система. На овај начин може се унапредити ефикасност одржавања испитиваног система.

Кључне речи: планетарни мењач, индустријски мешач, вибродијагностика, термографија, анализа, лежај, поузданост, одржавање.

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