VIBRATION SIGNAL-BASED FAULT DIAGNOSIS OF GEARBOX

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ABSTRACT: Gear-Box is an essential component in the automobile industry. The gearbox transfers the power from the motor or engine to the wheels by performing speed reductions. When the gearbox is malfunctioning, a decrease in speed or performance is seen. In order to monitor the health of automobiles, gearbox maintenance is essential. Condition monitoring is one of the predictive maintenance strategies that help in lowering maintenance costs in contemporary industrial applications. In this study, the gearbox's vibration signal is employed to diagnose the malfunction. The findings of an analysis of the gearbox's sound signal under both healthy and unhealthy situations are reported.

I. Introduction

Gears are a key player and a regulating element in power transmission systems. Because it contains mechanical components that are frequently used in a wide range of industrial applications, the gearbox transmission system is one of the crucial components [1]. This is because it is required to manage a range of rotating speeds and maintain a set of torques between the electric machines and the load mechanics.

When a defect like a gear tooth crack appears after some time of operation, it will cause some sort of vibration that will cause supporting parts like bearings and shafts to fail. By performing routine maintenance and inspections on the gearbox, defects can be avoided. There are various maintenance methods, and one of them is predictive maintenance, which looks for abnormalities in equipment while it's still in good working order so that the problem can be found before the breakdown happens. A key component of preventive maintenance is condition monitoring (CM), which involves tracking a machine's condition parameter (temperature, vibration, etc.) to spot any significant changes that could signal an impending equipment fault. The indicators enable the detection of gear anomalies and help prevent catastrophic failure before the fault progresses. By Vikas Sharma and Anand Parey [2], these indicators are discussed domain-by-domain, and their properties are listed.

For example, oil analysis, infrared thermography, vibration analysis, magnetic particle inspection, acoustic emission analysis, Motor current signature analysis (MCSA), strain gauges, and X-ray inspection are some of the condition monitoring techniques used to find faults in gearboxes. An approach for diagnosing gearbox faults utilizing oil analysis data and a wavelet packet analysis technique was put forth by Yujian Zhang et al. [3]. To complete the study, oil samples from the gearbox must be collected and examined for characteristics including entropy, energy, and standard deviation. The main issues with gearbox health monitoring were covered by Sivasankaran et al. in their discussion on [4] as well as how infrared thermography can be utilized asa non-invasive and non-destructive method to identify and diagnose gearbox defects. A thorough analysis of the application of magnetic particle inspection (MPI) for gearbox defect diagnostics was provided by S. Narasimhan et al. in their publication [5]. Additionally, they discussed the benefits and drawbacks of different MPI approaches, including fluorescent, dry, and wet MPI, for detecting gearbox faults. Overall, they concluded that MPI is a useful technique for diagnosing gearbox issues, particularly for finding surface-level gear faults like fractures and pitting. Yan Li et al. [6] 6] showed that the high-frequency acoustic emissions generated by the gear system might be utilized to detect and diagnose gear faults using AE technology. These emissions can provide information about the location and severity of the fault. A novel approach for diagnosing gear faults utilizing wavelet analysis and motor current signature analysis (MCSA) was put out by Saeed Soltani et al. [7]. They noted that MCSA is a non-invasive technology for monitoring the health of electrical motors, which can be utilized for problem diagnosis in gear systems. The accuracy of fault diagnosis can be increased by using a method that the authors suggested for analyzing the motor current signal using the wavelet transform. The strain gauge sensor signals were subject to analysis using a method proposed by L. Wang et al [8]. The technique entails applying a wavelet transform to the signals, allowing for time-frequency analysis and the detection of specific fault signatures. The scientists carried out experiments using a gearbox test rig with purposely created faults to gauge the efficacyof their technique. To find the problems, they gathered data from strain gauge sensors and used their analysis technique. The process used for X-ray inspection, including how to prepare the gear assembly, how to take X-ray images, and how to evaluate them, was reported by Yufei Ma et al. in 2021 [9]. Following that, they give a thorough study of the X-ray images, highlighting various fault types such as fractures, corrosion, and wear. The authors examine the consequences of gear assembly maintenance and repair in light of their findings. They contend that X-ray inspection can offer useful data for condition monitoring and can lessen the likelihood of catastrophic breakdowns.

X. Zhang et al proposed a method for gearbox fault diagnosis using deep learning and multi-sensor vibration signal analysis. The vibration signals gathered by numerous sensors are processed by the authors using a convolutional neural network to extract features [10]. Time-frequency analysis and support vector machines were employed by X. Liu et al. The authors train a support vector machine classifier to identify gearbox faults by training it with features extracted from the vibration signals using the wavelet transform [11]. J. Hu et al. employed wavelet packet energy entropy and spectral kurtosis. The authors use spectral kurtosis and wavelet packet energy entropy to extract characteristics from the vibration data and then apply a decision tree classifier to identify the gearbox problems [12]. Extreme learning machine and hybrid features were used by Y. Chen et al. To identify gearbox defects, the authors employ an extreme learning machine classifier to extract characteristics from the vibration signals using time-domain statistical parameters and frequency-domain data [13]. A group learning and enhanced empirical wavelet transform were applied by X. Zhang et al. The authors employ an ensemble learning classifier to identify gearbox problems after extracting features from the vibration data using the improved empirical wavelet transform [14]. Spectral envelope and adjusted multiscale entropy were employed by H. Su et al. The authors use the spectral envelope and modified multiscale entropy to extract characteristics from the vibration signals and then apply a support vector machine classifier to identify the gearbox problems [15]. A method for diagnosing gearbox faults using improved morphological gradient spectrum and severe gradient boosting was proposed by Y. Liu et al. The authors employ an extreme gradient boosting classifier to diagnose gearbox defects by extracting features from the vibration signals using a better morphological gradient spectrum [16].

The gearbox's vibration signals are captured and analyzed in this investigation. The analysis of the vibration signals allowed us to identify any abnormal vibrations that may be present in the gearbox. After analyzing the vibration signals, graphs are plotted to visualize the results.

II. Construction of experimental work

1. Specifications of Gearbox:

The Splendor bike gearbox is selected for experimentation. Its specifications are given.

Gear No.	Teeth on the input shaft's gear	Teeth on the output shaft’s gear	Gear-ratio
Gear 1	35	11	3.1818
Gear 2	29	17	1.7058
Gear 3	26	21	1.238
Gear 4	23	24	0.958

Table 1 Gearbox details

2. Specifications of Electric Motor:

For our needs, a single-phase, 50 Hz-operated electric induction motor of the AC typeis selected. Its characteristics are as follows.

Speed	Power	Operating voltage	Shaft diameter
1440 rpm	0.25 HP	230V	11mm

Table 2 Electric motor specifications

A strong coupling connects the output shaft of the electric induction motor indicated above to the input shaft of the gearbox mentioned above. The entire assembly is mounted on a wooden board using bolts, nuts, washers, and dampers. Dampers are available to ensure the accuracy of the readings and to lessen unwanted noise or vibration. The entire assembly is covered, protecting it from outside disturbance.

III. Experimentation

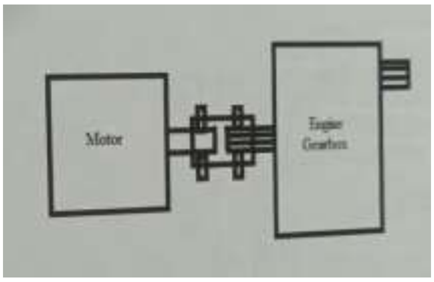


Fig.1. Assembly line diagram

Fig.2. Experimental set-up

Fig.3. Final Assembly

Fig.4. Data acquisition system The

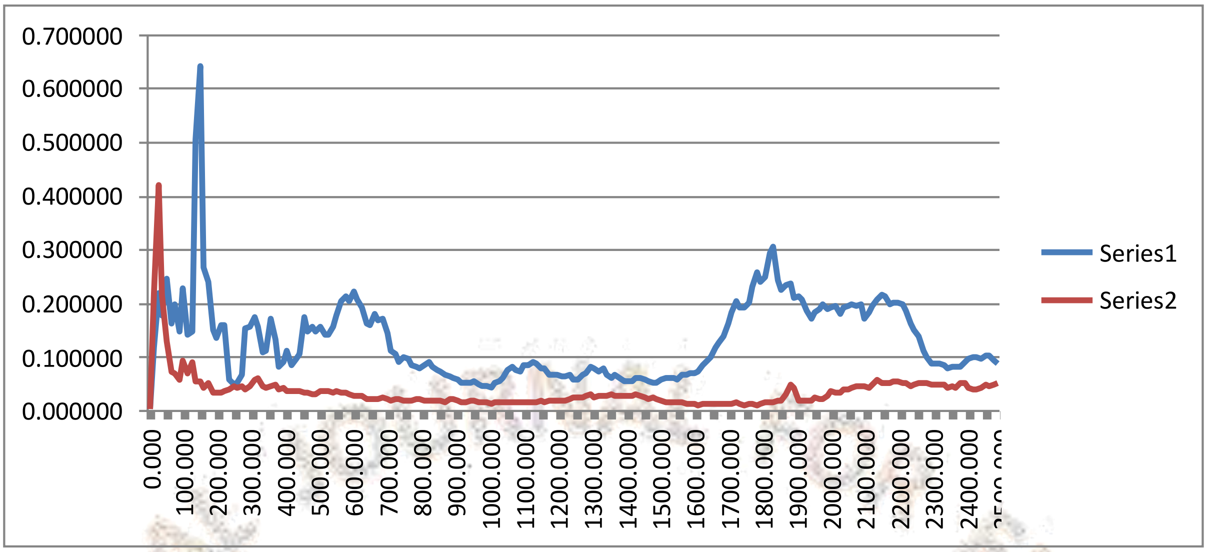
motor, gearbox, and tri-axial accelerometer are the three main pieces of equipment that make up the experimental setup. The gearbox drive operates at a steady pace and is powered by motor power. Tri-Axial Piezo electric accelerometer is used to collect vibration data, and it is temporarily fastened to the top of the gearbox using additive glues. The experiment is based on experimental settings such as a constant motor input speed, four gear speeds, and a gear fault condition. The accelerometer's output is coupled to the DAQ system.

The test began with a motor input speed of 1440 rpm and the gearbox engagedin first gear because the gearbox was initially equipped with all good gears. Different types of vibration sensors, including accelerometers or velocity sensors, can be used to capture the gearbox vibration data. The sensors are mounted on the gearbox at specific points to evaluate the vibration response. Once the vibration data has been gathered, it must be examined for any patterns or anomalies that might point tothe existence of defects. Specific gearbox defects can be discovered based on the vibration analysis's findings. These faults can include gear wear, bearing defects, gear tooth breakage, and misalignment. Once the faults have been identified, it is important to determine the severity of each fault. This can be done by analyzing the frequency and acceleration of the vibrations associated with each fault. Based

on the severity of the faults, corrective action can be determined. This may include replacing damagedcomponents or adjusting the gearbox alignment.

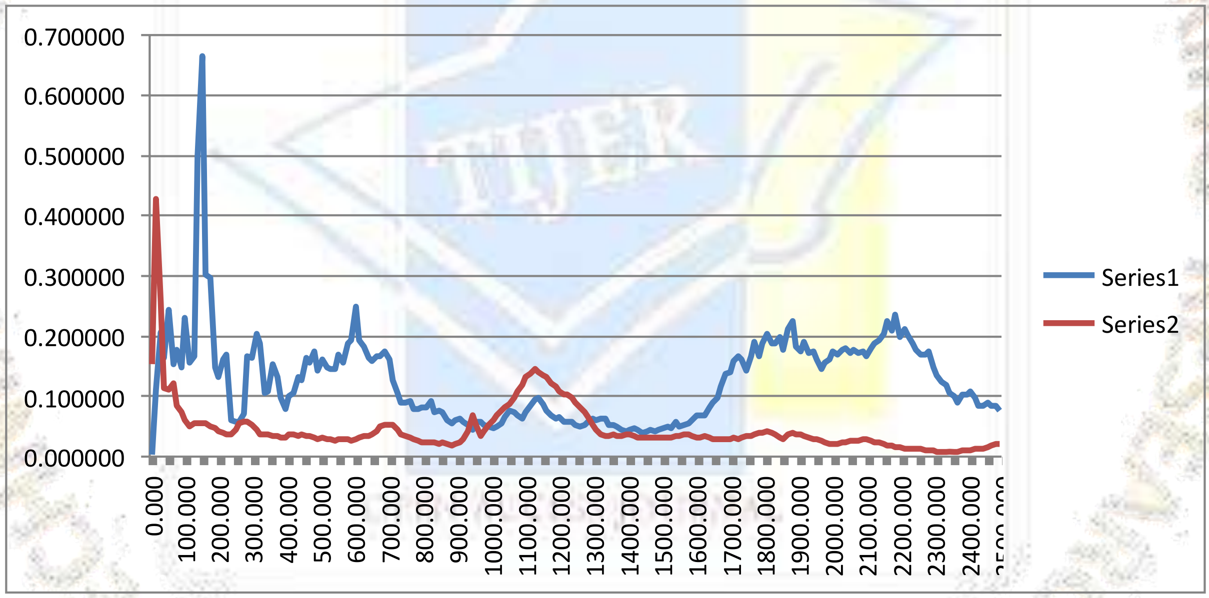
IV. Plots of recorded Vibrational signals

Gear-1:



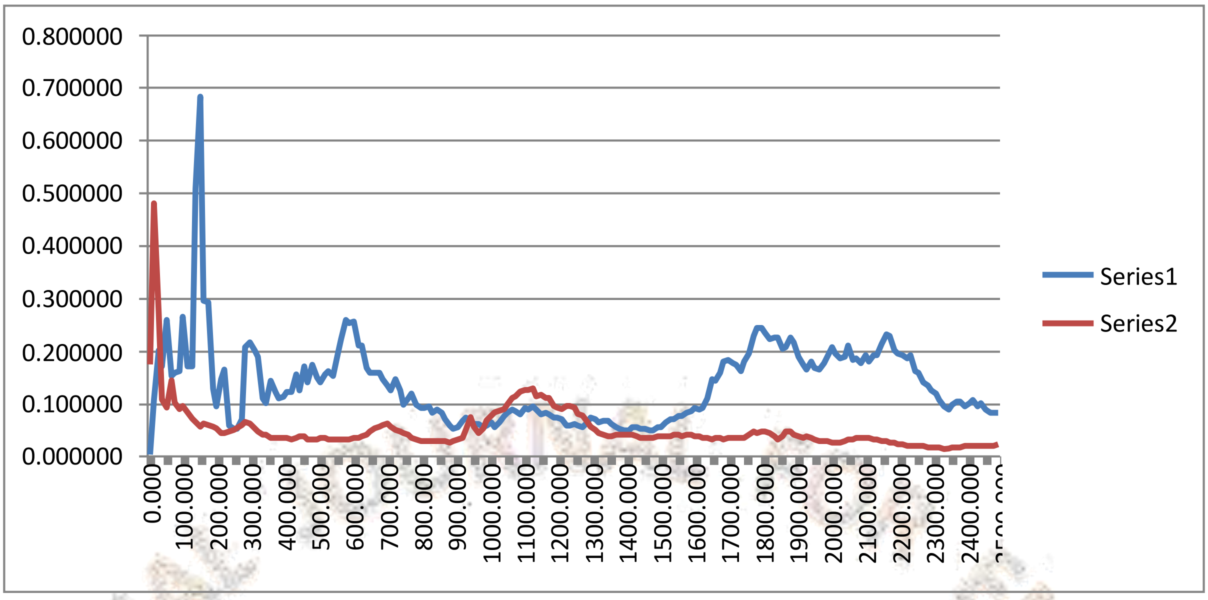
Frequency and acceleration values for the first gear in both healthy and faulty gearboxes are presented in this graph. Where the x-axis represents frequency and the y-axis represents acceleration. Here, the healthy gearbox is represented by the red curve, and the faulty gearbox is represented by the blue curve. The healthy gearbox's highest acceleration and frequency parameters are 0.421453 and 12.5000. While the highest acceleration and frequency parameters of the faulty gearbox are 0.642496 and 150.000. As a result, the defective gearbox has higher frequency and acceleration values than the healthy gearbox.

Gear -2:



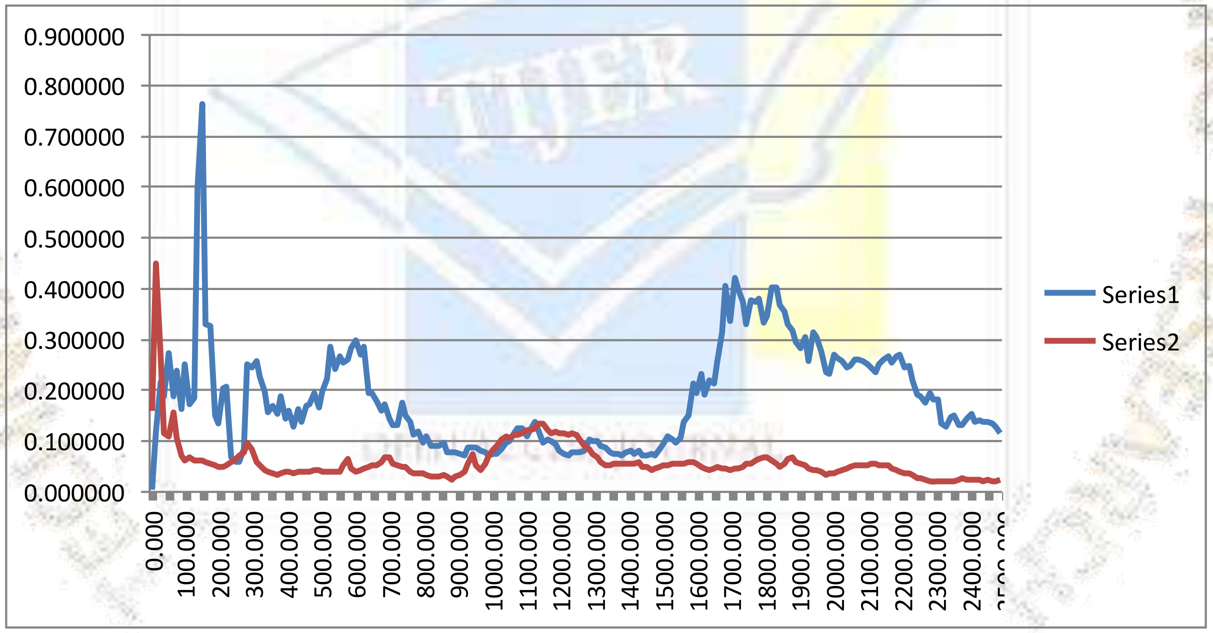
Frequency and acceleration values for the second gear in both healthy and faulty gearboxes are presented in this graph. Where the x-axis represents frequency and the y-axis represents acceleration. Here, the healthy gearbox is represented by the red curve, and the faulty gearbox is represented by the blue curve. The healthy gearbox's highest acceleration and frequency parameters are 0.428558 and 12.500. While the highest acceleration and frequency parameters of the faulty gearbox are 0.665223 and 150.000. As a result, the defective gearbox has higher frequency and acceleration values than the healthy gearbox.

Gear-3:



Frequency and acceleration values for the third gear in both healthy and faulty gearboxes are presented in this graph. Where the x-axis represents frequency and the y-axis represents acceleration. Here, the healthy gearbox is represented by the red curve, and the faulty gearbox is represented by the blue curve. The healthy gearbox's highest acceleration and frequency parameters are 0.481499 and 12.500. While the highest acceleration and frequency parameters of the faulty gearbox are 0.684092 and 150.000. As a result, the defective gearbox has higher frequency and acceleration values than the healthy gearbox.

Gear-4:



Frequency and acceleration values for the fourth gear in both healthy and faulty gearboxes are presented in this graph. Where the x-axis represents frequency and the y-axis represents acceleration. Here, the healthy gearbox is represented by the red curve, and the faulty gearbox is represented by the curve. The healthy gearbox's highest acceleration and frequency parameters are 0.450194 and 12.500. While the highest acceleration and frequency parameters of the faulty gearbox are 0.764319 and 150.000. As a result, the defective gearbox has higher frequency and acceleration values than the healthy gearbox

V. Results and discussion

Gear no.	Healthy gearbox		Faulty gearbox	
	Acceleration (cm/s2)	Frequency(Hz)	Acceleration (cm/s2)	Frequency(Hz)
Gear 1	0.421453	12.500	0.642496	150.000
Gear 2	0.428558	12.500	0.665223	150.000
Gear 3	0.481499	12.500	0.684092	150.000
Gear 4	0.450194	12.500	0.764319	150.000

The max value for a healthy gearbox is attained at an average acceleration of 0.445 cm/s2 and a frequency of 12.5 Hz. The peak value for a defective gearbox is attained at an average acceleration of 0.685 cm/s2 at a frequency of 150 Hz. Analysis of the vibrational signal allows for fault diagnosisand monitoring of the apparatus.

VI. Conclusion

In conclusion, vibrational analysis is a powerful tool for diagnosing faults in gearboxes. The method entails measuring and examining the gearbox's vibration patterns to look for any irregularities that might point to a problem. The analysis's findings can then be utilized to identify the fault's primary cause and take the necessary steps to fix or replace the defective component. Engineers can improve the performance of mechanical systems, lower maintenance costs, and increase the safety and dependability of gearboxes by employing vibrational analysis.

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