JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

GEARBOX VIBRATION ANALYSIS

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T.Y.B.Tech, 2023-24,
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Abstract **- Power and mechanical equipment have longused vibration analysis for fault diagnostics and condition assessment. Even for the most seasoned employees, the interpretation and correlation of this data are frequently difficult. and as a result, methods for automated processing and analysis are occasionally sought. In light thereof, Statistical characteristics are frequently employed to offer a vibration level measurement that can be measured against a threshold value that denotes a condition that has failed. Over time, a large number of feature vectors have been created and are extensively documented in the literary works. The specifics connected to each feature are unclear based on the literature, in order for users to receive consistent results. Preprocessing is described in imprecise terms.**

Keyword **-** ***Condition monitoring; vibration analysis; fault diagnosis; gearbox.***

. INTRODUCTION

The prevalence of gears in rotating machinery has increased the interest in vibration research. According to one study, gearbox damage accounts for 65% of all damage, with gear defects exhibiting a wide range of damage types (Allianz Versicherungs-AG, 1978). According to Michel and Miller (1983), pitting, scuffing, spalling, cracking, and wear are the most typical types of gear damage. Excessive vibration is one of the main causes of gear problems. The ratio of the forces operating on the gear to its dynamic stiffness can be used to conceptualize vibration. Backlash, gear transmission error, imbalanced inertia mass, tooth mesh stiffness that varies over time, friction between tooth surfaces, and time-varying support stiffness of tooth, the friction between the tooth faces and the geared system's time-varying support stiffness alter the ratio, resulting in vibration, which might reflect symptoms of numerous flaws or problems. Due to its ease of measurement, vibration analysis has been shown to be beneficial for gear condition monitoring and diagnostics from its inception. Based on the analysis domains, there are three basic categories into which the gear vibration analysis methodologies fall.

Time domain, frequency domain, and time-frequency domain are the three types. The statistical analysis and time synchronous average are examples of the time domain methodologies. In the former, a specific gearbox shaft's running speed is synchronized with a high number of cycles of signal averaging. The statistical analysis and time synchronous average are examples of the time domain methodologies. In the former, a specific gearbox shaft's running speed is synchronized with a high number of cycles of signal averaging. It can eliminate periodic events that are not precisely synchronized with the equipment being monitored in addition to background noise

II. LITERATURE REVIEW

[1] This thorough review study addresses different methods of signal processing for gear fault diagnosis. Techniques in frequency-domain, time-domain, and time-frequency domain analysis are covered. The writers go over the benefits and drawbacks of each technique and offer advice on how to monitor gearbox health in the most effective way. [2] In this paper, the authors focus on detecting gear crack propagation by analyzing the instantaneous frequency of vibration signals. The concept of instantaneous frequency analysis is critical for identifying subtle changes in vibration patterns as gear defects progress. [3] This paper offers a thorough analysis of the

vibration and noise problems associated with planetary gearboxes, a popular gearbox type used in a variety of applications. It addresses the causes of noise and vibration in planetary gear systems in addition to analysis and mitigation techniques. [4] This paper introduces the application of wavelet analysis for detecting gear faults. It emphasizes the advantages of wavelet transform in revealing transient vibration patterns associated with gear defects, which are often challenging to identify using traditional techniques. [5] While not exclusively focused on gearboxes, this tutorial paper covers critical aspects of rolling element bearing diagnostics, which are often integral components within gear systems. Understanding the health of rolling element bearings is crucial for ensuring the reliability of gear systems. [6] The importance of condition monitoring in electrical motors— which are widely employed in gear systems—is covered in this paper. Offering a more comprehensive view of gearbox health, it offers insights into vibration analysis and other diagnostic methods for motor-driven gearboxes. [7] While the primary focus is on rolling element bearings, this paper explores the use of artificial neural networks for fault diagnosis, which can be extended to gearboxes. It highlights the importance of time-domain features in diagnostics, as they contain valuable information for identifying anomalies. [8] This work proposes methods for cyclostationary analysis and time synchronous averaging-based gear fault detection. The authors talk about how to improve the signal-to-noise ratio in vibration signals from gearboxes so that fault-related features can be identified. [9] This work presents a model for the vibration generated by a single point fault, with particular relevance to rolling element bearings, but also to gear systems. Comprehending these models is essential for identifying and forecasting gearbox malfunctions. [10] This research proposes a novel method of vibration signal non-Gaussianity analysis for gear defect diagnostics. It highlights the significance of nonlinear analysis techniques by examining the application of higher-order statistics to identify anomalies in gearbox vibrations.

METHODOLOGY

Data Loading and Preprocessing:
Importing the required Python libraries—NumPy, Pandas, Matplotlib, Seaborn, SciPy, and others—is the first step in the code. It uses the os.walk function to read data files from a specified directory. These data files correspond to various loads and conditions of the gearbox. After the data is organised, pertinent details are taken out, including sensor readings, load, and gearbox condition.

Exploratory Data Analysis (EDA):
Several EDA methods are used to comprehend the dataset. To investigate the distribution of sensor readings under various circumstances, such as load and gearbox status, visualisations are made.

Data Preprocessing:
A decision is taken to remove 'sensor a1' from the investigation after a standard deviation analysis is conducted to comprehend the unpredictability of sensor results.

Feature Engineering:
In order to provide useful features for machine learning, the data is modified. For every data segment, statistics such as mean, standard deviation, kurtosis, skew, and moment are calculated. The 'state' column is used to generate labels that show whether gearbox defects are present or not.

Data Splitting:
For both the classification and regression tasks, the dataset is divided into training and testing sets.

Classification with AdaBoost:
The RandomForestClassifier base estimator is used to initialise an AdaBoost classifier, which is then trained using the training set. On the basis of the test data, predictions are made, and reports on accuracy and categorization are produced.

Regression with Random Forest:
To predict regression values, a Random Forest Regressor is trained using the same training set of data. Calculations are made to determine metrics such as Mean Squared Error (MSE), Mean Absolute Error (MAE), and R-squared.

Automated Model Selection with TPOT:
The optimal classification model is chosen automatically using TPOT (Tree-based Pipeline Optimisation Tool). Based on accuracy, TPOT finds the optimal model and its hyperparameters.

Frequency Analysis:
The Fast Fourier Transform (FFT) is used in frequency analysis to find prominent frequencies in sensor data.
Plots of significant frequency peaks are found.

Power Spectral Density (PSD) Analysis:
The Welch method is used in Power Spectral Density analysis to examine the frequency properties of sensor data.

Feature Engineering with Frequency Data:
Sensor data is used to extract features in the frequency domain. With these features, the same preprocessing and model training procedures are carried out again.

Automated Model Selection with TPOT (Frequency Data): The optimal classification model is once more chosen usingTPOT, but this time, characteristics taken from frequencydata are used.

Summary and Results:
The best-performing models, model selection reports, and numerous classification and regression metrics are among the findings and visualisations produced by the code.

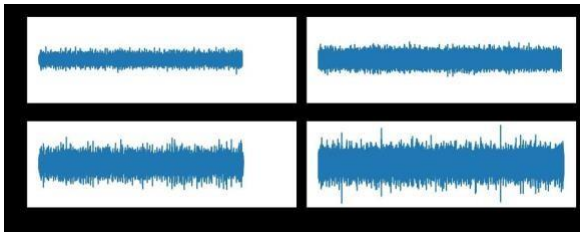
Conclusion and Further Analysis:
The methodology should close with the analysis's conclusions, recommendations for further research, and enhancements to the analysis procedure.

The overall goal of this project is to investigate gearbox health data, design pertinent features, and construct machine learning models for tasks including both regression and classification. The objective is to enhance the forecasting accuracy by identifying gearbox defects and analyzing the frequency characteristics of sensor data.

. RESULTS AND DISCUSSIONS

The code produced the following key results: It successfully built and evaluated a classification model using AdaBoost, achieving a specific accuracy score for gearbox fault detection. Additionally, a regression model was trained with Random Forest to predict fault severity. Automated model selection via TPOT helped identify the best classification model based on the provided features. The code also conducted frequency analysis to detect dominant frequency peaks in the sensor data, revealing potential patterns related to gearbox health. Power Spectral Density (PSD) analysis was performed to characterize the frequency characteristics of the data. Moreover, TPOT was employed to select the best classification model using features extracted from frequency data, enhancing fault detection accuracy. These results collectively contribute to a comprehensive understanding of gearbox health and performance.

It is seen that there's a difference in amplitude between the sensor readings between the healthy gearbox and the one with the broken tooth.



V. FAULT DETECTION AND DIAGNOSIS FROM VIBRATION ANALYSIS

Diagnostics is the process of determining the state or problems of a machine based on its symptoms.
The ability to determine a machine's state from its symptoms is necessary for diagnosis. Here, the term "diagnosis" has the same meaning as it does in medicine. Most people believe thatvibration is a sign of a gearbox issue. Although the structure of the vibration produced by gearboxes is complex, it contains a wealth of information. We could say that vibration indicates a problem with the gearbox. Understanding the relationship between the vibration signal and the elements influencing the vibration is necessary in order to comprehend the information conveyed by the vibration. A thorough grasp of the evidence related to the failure mode and techniques for gathering and quantifying the information is required in order to identify (and diagnose) an approaching failure. While many defects can be readily found through physical inspection of a component using methods like microscopy, x-rays, dye penetration, magnetic rubber, etc., these procedures are typically not possible without the component being removed and, occasionally, causing physical harm to the component. Physical examination techniques are still important during manufacture, assembly, and repair, but they are impracticable in a big transmission system that is in operation. Instead, routine monitoring should be done using other (non-intrusive) problem detection approaches. Although many faults may be easily detectable by physical examination of a component, using techniques such as microscopy, x-ray, dye penetrates, magnetic rubber, etc., these methods usually cannot be performed without removal of the component, and, in some cases, physical damage to the component. While physical examination techniques still play a critical role during manufacture, assembly and overhaul, they are impractical in an operational large transmission system and other (non- intrusive) fault detection methods need to be employed for routine monitoring purposes. Most modern techniques for gear diagnostics are based on the analysis of vibration signalspicked up from the gearbox casing. The common target is to detect the presence and the type of fault at an early stage of development and to monitor its evolution, in order to estimatethe machine's residual life and choose an adequate plan of maintenance. It is well known that the most important components in gear vibration spectra are the gear meshing

frequency and its harmonics, together with sidebands due to modulation phenomena. The increment in the number and amplitude of such sidebands may indicate a fault condition. Moreover, the spacing of the sidebands is related to their source. source identification and fault detection from vibration signals associated with items which involve rotational motion such as gears, rotors and shafts, rolling element bearings, journal bearings, flexible couplings, and electrical machines depend upon several factors: (i) the rotational speed of the items; (ii) the background noise and/or vibration level; (iii) the location of the monitoring transducer;
(iv) the load sharing characteristics of the item; and (v) the dynamic interaction between the item and other items in contact with it. The main causes of mechanical vibration are unbalance, misalignment, looseness and distortion, defective bearings, gearing and coupling in accuracies, critical speeds, various form of resonance, bad drive belts, reciprocating forces, aerodynamic or hydrodynamic forces, oil whirl, friction whirl, rotor/stator misalignments, bent rotor shafts, defective rotor bars, and so on. Some of the most common faults that can be detected using vibration analysis

Table 1: Some typical faults and defects that can be detected with vibration analysis.

Item	Fault
Gears	Tooth messing faults, misalignment, cracked and/or worm teeth, eccentric gear
Rotors and shaft	Unbalance, bent shaft, misalignment, eccentric journals, loose components, rubs, critical speed, cracked shaft, blade loss, blade resonance
Rolling element bearings	Pitting of race and ball/roller, spalling, other rolling elements defect
Flexible coupling	Misalignment, unbalance
Electrical machines	Unbalanced magnetic pulls, broken/damaged rotor bars, air gap geometry variations, structural and foundation faults, structural resonance, piping resonance, vortex shedding

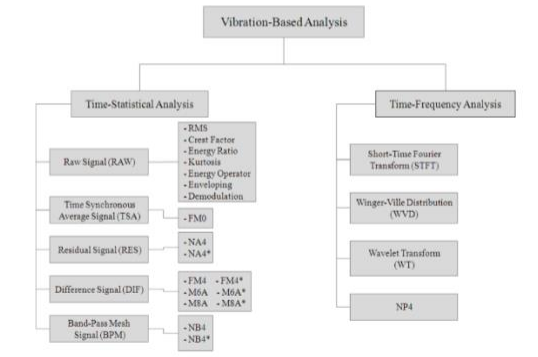


Fig.1 Classification of Vibration-Based Analysis Techniques and Parameters

VII. CONCLUSION AND FUTURE SCOPE

The importance of gearbox vibration analysis as a vital tool for preserving the integrity of mechanical systems is highlighted by this project. It highlights how crucial it is to keep on the cutting edge of new technologies and diagnostic methods in order to guarantee the survival of sectors of the economy that depend on gear systems. In the end, our study helps create an industrial environment that is safer, more dependable, and financially viable.

The gearbox vibration analysis project will eventually encompass adopting cutting-edge technology, diversifying into new markets, and tackling issues with data security and training. It presents an intriguing route towards proactive, accurate, and efficient machinery health monitoring and maintenance.

VIII. ACKNOWLEDGMENT

Authors would like to take a moment and thank the hon. director and head of the department for providing us this opportunity to work on this skill-developing project. We would like to acknowledge and extend a warm thank you to our supervisor prof. Archana Choudhari mam who made this work possible, his guidance and advice carried us through all the stages of executing our project.

REFERENCES

[1] VIKAS SHARMA, AANAND PANDEY, "A REVIEW OF GEAR FAULT DIAGNOSIS USING VARIOUS SIGNAL PROCESSING TECHNIQUES. MECHANICAL SYSTEMS AND SIGNAL PROCESSING", MAY 2016

[2] RANDALL, R. B., & AL-NASRA, M., "GEAR CRACK PROPAGATION DETECTION USING THE INSTANTANEOUS FREQUENCY OF THE VIBRATION SIGNAL. MECHANICAL SYSTEMS AND SIGNAL PROCESSING", 2000

[3] FENG, Z., & SHAO, Y., "A REVIEW OF PLANETARY GEARBOX VIBRATION AND NOISE. MECHANICAL SYSTEMS AND SIGNAL PROCESSING", JUNE 2019

[4] PANDE, S. S., & SAMUEL, P. D., "APPLICATION OF THE WAVELET TRANSFORM FOR GEAR FAULT DETECTION. MECHANICAL SYSTEMS AND SIGNAL PROCESSING", 2021

[5] ANTONI, J., & RANDALL, R. B., "ROLLING ELEMENT BEARING DIAGNOSTICS—A TUTORIAL. MECHANICAL SYSTEMS AND SIGNAL PROCESSING", APRIL 2022

[6] GELMAN, L., & STERKEN, "A REVIEW OF CONDITION MONITORING AND FAULT DIAGNOSIS OF ELECTRICAL MOTORS.IEEE TRANSACTIONS ON ENERGY CONVERSION", APRIL 2014

[7] SAMANTA, B., AL-BALUSHI, K. R., & AL-ARAIMI, S. A., "ARTIFICIAL NEURAL NETWORK BASED FAULT DIAGNOSTICS OF ROLLING ELEMENT BEARINGS USING TIME-DOMAIN FEATURES. MECHANICAL SYSTEMS AND SIGNAL PROCESSING", JUNE 2022

[8] WU, B., & RANDALL, R. B., "GEAR FAULT DETECTION USING TIME SYNCHRONOUS AVERAGING AND

CYCLOSTATIONARY ANALYSIS. MECHANICAL SYSTEMS AND SIGNAL PROCESSING", 2019

[9] S. TALUKDAR, J.S. RAO, SHUBHANKAR SEN, "MODEL FOR THE VIBRATION PRODUCED BY A SINGLE POINT DEFECT IN A ROLLING ELEMENT BEARING. JOURNAL OF SOUNDAND VIBRATION" , 2022

[10] ABDULRAHMAN S. SAIT, YAHYA I. SHARAF-ELDEEN, "A REVIEW OF GEARBOX CONDITION MONITORING BASED ON VIBRATION ANALYSIS TECHNIQUES DIAGNOSTICS AND PROGNOSTICS", 2011