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Prediction of Gearbox Fault Using Machine Learning Techniques

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Abstract

Gearbox fault diagnosis plays a crucial role in ensuring the reliable and efficient operation of machinery. Traditional fault diagnosis methods often rely on manual inspection and experience-based techniques, which can be time-consuming, subjective, and limited in their ability to detect subtle faults. In recent years, machine learning techniques have emerged as a promising approach for gearbox fault diagnosis, offering the potential for automated and accurate fault detection. Comprehensive review of the application of machine learning algorithms for gearbox fault diagnosis. Additionally, the paper discusses the challenges and considerations associated with gearbox fault diagnosis using machine learning. These challenges include data acquisition and preprocessing, feature selection, model training, and the interpretability of the results. Machine learning techniques offer significant potential for gearbox fault diagnosis, providing automated and accurate detection of faults. Further research and development in this area can contribute to the advancement of predictive maintenance strategies enhancing the efficiency of machinery in various industrial applications.

1. Introduction

Gearbox fault diagnosis is a critical process in the maintenance and reliability of machinery. Gearboxes play a crucial role in transmitting power and adjusting speed and torque in various industrial applications. However, due to factors such as wear, misalignment, and inadequate lubrication, gearboxes are prone to develop faults and failures over time. Identifying and diagnosing these faults at an early stage is essential to prevent costly breakdowns, minimize downtime, and ensure the safety and efficiency of the machinery. Traditional fault diagnosis methods for gearboxes often rely on manual inspections and experience-based techniques. These methods can be time-consuming, subjective, and limited in their ability to detect subtle or early-stage faults. With advancements in technology.

Fig 1: Steps for Predictive Analytics of Gearbox Fault Analysis

2. Literature Review

2.1 Fault diagnosis of automobile gearbox based on machine learning techniques.

Gearbox is an essential device employed in industries to vary speed and load conditions according to the requirements. More advancement in its design and operation leads to increase in industrial applications. The failure in any of the components of gearbox can lead to production loss and increase maintenance cost. The component failure has to be detected earlier to avoid unexpected breakdown. Vibration measurements are used to monitor the condition of the machine for predictive maintenance and to predict the gearbox faults successfully. This paper addresses the use of vibration signal for automated fault diagnosis of gearbox. In the experimental studies, good gears and face wear gears are used to collect vibration signals for good and faulty conditions of the gearbox. Each gear is tested with two different speeds and loading conditions. The statistical features are extracted from the acquired vibration signals. The extracted features are given as an input to the support vector machine (SVM) for fault identification. The Performance of the fault identification system using vibration signals are discussed and compared.

2.2 Predictive Modeling of a Two-Stage Gearbox towards Fault Detection

This paper presents a systematic approach to the modeling and analysis of a benchmark two-stage gearbox test bed to characterize gear fault signatures when processed with harmonic wavelet transform (HWT) analysis. The eventual goal of condition monitoring is to be able to interpret vibration signals from non stationary machinery in order to identify the type and severity of gear damage. To advance towards this goal, a lumped-parameter model that can be analyzed efficiently is developed which characterizes the gearbox vibratory response at the system level. The model parameters are identified through correlated numerical and experimental investigations. The model fidelity is validated first by spectrum analysis, using constant speed experimental data, and secondly by HWT analysis, using non stationary experimental data. Model prediction and experimental data are compared for healthy gear operation and a seeded fault gear with a missing tooth. The comparison confirms that both the frequency content and the predicted, relative response magnitudes match with physical measurements. The research demonstrates that the modeling method in combination with the HWT data analysis has the potential for facilitating successful fault detection and diagnosis for gearbox systems.

2.3 An investigation on gearbox fault detection using vibration analysis techniques:

Gears are critical element in a variety of industrial applications such as machine tool and gearboxes. An unexpected failure of the gear may cause significant economic losses. For that reason, fault diagnosis in gears has been the subject of intensive research. Vibration analysis has been used as a predictive maintenance procedure and as a support for machinery maintenance decisions. As a general rule, machines do not breakdown or fail without some form of warning, which is indicated by an increased vibration level. By measuring and analyzing the machine's vibration, it is possible to determine both the nature and severity of the defect, and hence predict the machine's failure. The vibration signal of a gearbox carries the signature of the fault in the gears, and early fault detection of the gearbox is possible by analyzing the vibration signal using different signal processing techniques. This paper presents a review of a variety of diagnosis techniques that have had demonstrated success when applied to rotating machinery, and highlights fault detection and identification techniques based mainly on vibration analysis approaches. The paper concludes with a brief description of a new approach to diagnosis using neural networks, fuzzy sets, expert system and fault diagnosis based on hybrid artificial intelligence techniques.

2.4 A Machine Learning Approach for Gearbox System Fault Diagnosis:

This study proposes a fully automated gearbox fault diagnosis approach that does not require

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knowledge about the specific gearbox construction and its load. The proposed approach is based on evaluating an adaptive filter's prediction error. The obtained prediction error's standard deviation is further processed with a support-vector machine to classify the gearbox's condition. The proposed method was cross-validated on a public dataset, segmented into 1760 test samples, against two other reference methods. The accuracy achieved by the proposed method was better than the accuracies of the reference methods. The accuracy of the proposed method was on average 9% higher compared to both reference methods for different support vector settings.

2.5 Fault Detection and Diagnosis of Gear Transmission System via Vibration Analysis

Vibration analysis for condition assessment and fault diagnosis has a long history of application to power and mechanical equipment. In the present work, vibration signals of a gearbox are acquired and analyzed with the help of vibration analysis techniques. In order to understand the basic principles of vibration condition monitoring, a test rig with common machine faults (i.e., rolling element bearing damage, gear failure and shaft misalignment), designed and constructed at Madhav Institute of Technology and Science, Gwalior, India, was used. The methods used for extracting and identifying the type of faults are described. It is shown that this experimental setup provides a good illustration of the practical applications of basic theory included in vibration analysis and condition monitoring.

3: Experimentation

3.1 Experimentation:

The gearbox is connected to two shafts one is input shaft and other is output shaft. The input shaft is connected to DC motor. The other end of output shaft is connected to magnetic brake. The four accelerometer sensors are used in deriving the acceleration values. The two accelerometer sensors are placed on the input and output shaft. The other pair of accelerometer sensors is placed on the casing of the gearbox. The sensors capture the vibration caused during the experimentation. The magnetic brake is used to stop the gearbox in case of the any emergency.

Now, the DC motor is started and the shaft rotates; now the gear also rotates. Now the vibrations produced are sensed by the accelerometer sensors. The values of the acceleration are now sent to the data acquisition. The experiment is kept on doing with the different type of the gears with the same dimensions. The load on the gearbox is increased using the Load simulator by 10KN on random basis of gear.

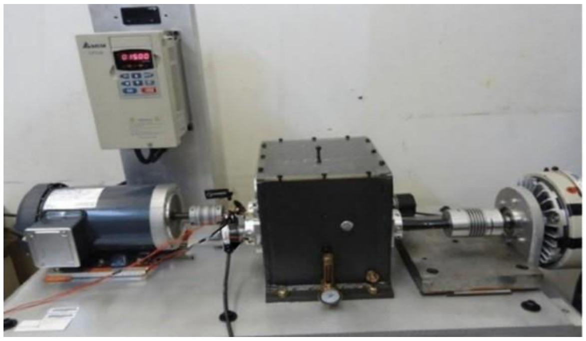

Fig: 3.1 Gear box diagnosis

3.2 Data collection: The data collection process for gearbox fault diagnosis involves the acquisition of relevant data from the gearbox, which provides valuable information about its condition and potential faults. The data collection process typically follows these steps:

1. ***Sensor Placement:*** Sensors are strategically placed at specific locations on the gearbox to capture relevant signals and measurements. The sensor placement depends on the type of data required for fault diagnosis. Common sensors used in gearbox fault diagnosis include vibration sensors, temperature sensors, acoustic emission sensors, oil analysis sensors, and torque sensors. The sensors may be installed on the gearbox housing, bearings, gears, or other critical components.

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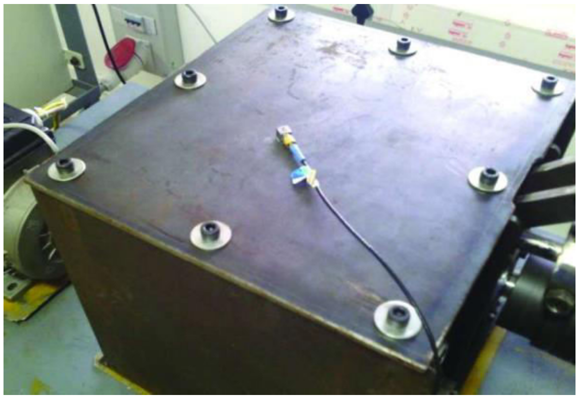

Fig 3.2 Accelerometer placed on gearbox casing

2. ***Data Acquisition:*** The sensors capture the desired signals, which are then converted into electrical signals or digital data. Data acquisition devices, such as data acquisition cards or modules, are used to interface with the sensors and collect the acquired data. These devices convert analog signals from the sensors into digital form for further processing.
3. ***Feature Extraction:*** Relevant features are extracted from the preprocessed data to capture specific characteristics or patterns related to gearbox faults. Feature extraction techniques can include time-domain analysis, frequency-domain analysis, statistical analysis, or wavelet analysis. These features serve as inputs for the diagnostic algorithms and models.
4. ***Transferring data:*** Data acquisition is the process of capturing and recording data from various sensors or sources in a measurable form for further analysis or storage. It involves the use of data acquisition systems or devices to collect data from physical or digital signals and convert them into a digital format that can be processed and analyzed by computers or other data processing systems. Now the data is transferred to an excel file and is divided into two datasets(healthy and broken tooth).

4.1 Predictive Analysis:

1. Statistical Analysis: Statistical analysis is a process of collecting, organizing, analyzing, interpreting, and presenting data to gain insights and draw meaningful conclusions. In Jupyter notebooks, statistical analysis can be performed using various libraries such as NumPy, Pandas, and SciPy.

2. Target Value analysis: Target value analysis refers to the examination and analysis of the target variable or dependent variable in a dataset. The target variable is the variable that you aim to predict or model based on the available features or independent variables

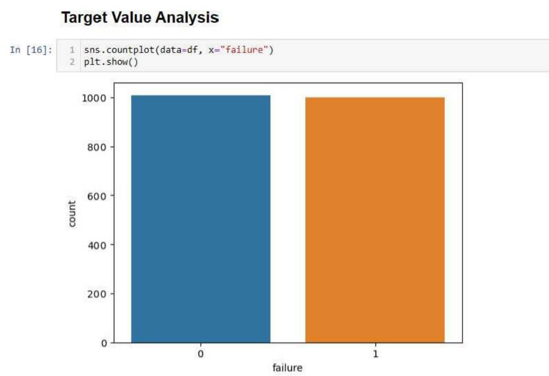

Fig 4.1 Target Value analysis

4.2 Correlation: Correlation is a statistical measure that quantifies the relationship between two variables. It indicates how changes in one variable are associated with changes in another variable. Correlation is often used to assess the strength and direction of the linear relationship between two continuous variables.

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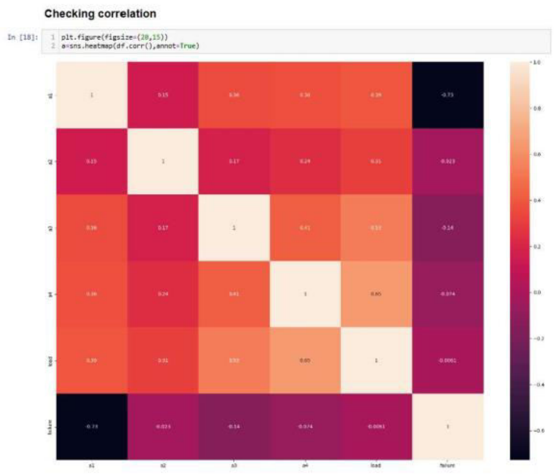

Fig:4.2 Correlation

4.3 Prediction Of Gearbox Fault:

Prediction refers to the process of using a trained model to make predictions or estimates on new, unseen data points. Once a model has been trained on a labeled dataset, it can be used to predict the target variable or class labels for new instances based on their features or attributes.

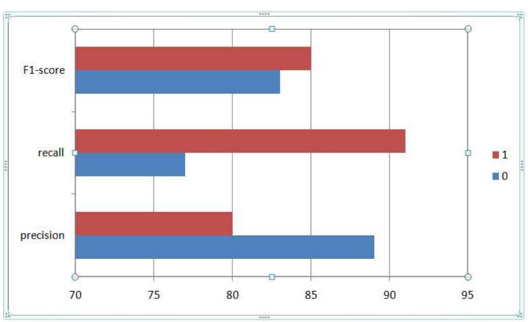

Fig 4.3 results of predictive analysis

5. Conclusion:

Gearbox fault diagnosis using predictive analysis is that it is an effective approach for identifying and diagnosing faults in gearboxes. By leveraging predictive analysis techniques and machine learning algorithms, it is possible to analyze sensor data from gearboxes and accurately predict potential faults or anomalies. The use of predictive analysis in gearbox fault diagnosis offers several advantages. It allows for proactive maintenance and reduces the risk of unexpected failures, resulting in improved reliability and reduced downtime. The accuracy is 84%. The f1-score of healthy tooth is 85% and broken is 83%. The recall of healthy tooth is 77% and broken is 91%.

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