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A Literature Review on Predicting and Analyzing of Bearing Faults using Machine Learning Approach

Nitheeshwaran R[1] and Thirumal P C[2]

Post Graduate Student, M. Tech Data Science, Department of Information Technology[1]

Professor, M.Tech Data Science, Department of Information Technology[2]

Kumaraguru College of Technology, Coimbatore, Tamil Nadu, India[1,2]

Abstract: *Bearing failure detection/diagnosis is heavily reliant on vibration signal analysis, and bearings frequently operate under rotational speed conditions that change over time. This paper includes a study based on vibration data obtained from bearings in various states of health and operating at different speeds. The bearing's condition ranges from good to bad, with the inside flaw and an exterior flaw. About the dataset's rotational speed operating parameters are accelerating rotational speed, deaccelerating rotational speed, speeding up and then slowing down, and slowing down and speeding up. The information gathered can be used to investigate the frequency response of bearings in various states of health under time-varying speed conditions. Through ML models for fault identification, the data can also be used to assess the effectiveness of any newly developed bearing defect diagnostic or condition monitoring technology in time-varying speed situations.*

Keywords*:* Rolling Element Bearing, Time-varying Rotational speed, Bearing failure detection, Vibration signal analysis, Defect diagnostic.

I. INTRODUCTION

The rolling element bearing is a critical component of rotating machinery (REB). The working REB is constantly subjected to pulling tension, compression stress, shear stress, and alternating thermal stress, which can easily lead to fatigue damage or machine failure. Early diagnosis of the presence and severity of the REB fault is critical for minimising economic losses and averting catastrophic casualties.Because of their widespread use and frequent cause of other failures, rolling element bearings, which support the shaft during rotation, have been of particular importance. In the wind turbine industry, for example, bearing problems are reported to account for 70 percent of gearbox failures and 21–70 percent of generator failures. Early detection and diagnosis of bearing defects is critical for avoiding such incidents. On this subject, a significant quantity of research has been done. There are numerous review papers available that discuss state-of-the-art algorithms from a variety of perspective.

Many researchers have lately published on a variety of fault detection methods, including statistical features, graph signal processing, and machine learning, and so on. They make significant contributions to the REB's fault diagnosis. Whenever a bearing failure experiences on either inward or outward race flaw, the vibration signal generates a series of impulses as a result of the bearing defect interacting with some other surface, and the impacts cause extreme frequency resonances than the other resonance frequencies in the bearing system, causing a modulating phenomenon.

The Mendeley datasets, which have been utilized as a standard reference in evaluating diagnostic algorithms and analytics purposes for to give a required solution.

Bearing Fault Prediction – Need for the Study

The need for the study arises from the limitations of traditional methods for bearing faultdiagnosis, which often rely on manual inspections or rudimentary techniques that may not be efficient or reliable. It also argues that machine learning approaches have the potential to overcome these limitations by leveraging the power of data-driven algorithms.By employing machine learning, it becomes possible to develop predictive models that can analyse large amounts of sensor data and identify patternsindicative of bearing faults. This enables timely and proactive maintenance interventions, minimizing downtime and improving overall operational efficiency.It also emphasize the importance of accurate fault analysis, as it provides valuable insights into the underlying causes and mechanisms of bearing failures. Machine learning techniques can aid in the interpretation of complex data patterns and contribute to a deeper understanding of the fault progression and its implications.Furthermore, the study aims to evaluate and compare different machine learning algorithms to identify the most effective approach for bearing fault prediction and analysis. This research would provide valuable guidance for practitioners and researchers in selecting the most appropriate machine learning techniques for their specific application scenarios.In summary, the need for the study lies in the limitations of traditional bearing fault diagnosis methods and the potential benefits of employing machine learning. The study seeks to address these needs by developing predictive models, enabling proactive maintenance, and advancing the understanding of bearing faults through data analysis.

II. LITERATURE REVIEW

Wang, H., Zheng, J., & Xiang, J. (2023),The paper focuses on the development of an online bearing fault diagnosis method that combines numerical simulation models with machine learning classifications. The objective is to enhance the accuracy and efficiency of bearing fault detection and diagnosis in industrial machinery. The proposed approach involves creating a numerical simulation model to generate vibration signals corresponding to various fault conditions in bearings. These simulated signals are then used to train machine learning classifiers, such as support vector machines and random forests. The trained classifiers are capable of accurately identifying different types of bearing faults, including outer race, inner race, and ball defects, based on real-time vibration signals acquired from the machinery. Experimental results demonstrate that the proposed method achieves high accuracy in diagnosing bearing faults, outperforming traditional fault diagnosis techniques. The combination of numerical simulation models and machine learning classifications provides a robust and effective approach for online bearing fault diagnosis, enabling early detection of faults and proactive maintenance strategies in industrial systems. [1]

Yoo, Y., Jo, H., & Ban, S. W. (2023),This paper presents a lightweight and efficient deep learning model for bearing fault diagnosis using the CWRU dataset. The model is designed to accurately identify bearing faults while minimizing computational complexity. It utilizes a reduced-layer convolutional neural network architecture. Experimental results show that the proposed model achieves high accuracy in classifying bearing faults and outperforms traditional machine learning algorithms. Moreover, the model has fast inference time and low memory requirements, making it suitable for real-time fault diagnosis applications. The study demonstrates the potential of employing lightweight deep learning models for efficient and accurate bearing fault diagnosis inindustrial systems. [2]

Kumar, H. S., & Upadhyaya, G. (2023), This paper focuses on the fault diagnosis of rolling element bearings using the continuous wavelet transform (CWT) and the K-nearest neighbor (KNN) algorithm. The CWT is employed to extract features from vibration signals, which are then used as input to the KNN classifier for fault classification. Experimental results demonstrate that the proposed method achieves high accuracy in diagnosing different types of bearing faults, such as outer race, inner race, and ball defects. The combination of CWT and KNN provides an effective approach for bearing fault diagnosis, enabling early detection and maintenance. The study highlights the potential of utilizing signal processing techniques and machine learning algorithms for efficient bearing fault diagnosis. [3]

Mian, T., Choudhary, A., & Fatima, S. (2023),This paper presents a method for multiple fault diagnosis of bearings using a combination of vibration analysis and infrared thermography, with the aid of deep learning techniques. Vibration signals and thermographic images are collected from the bearings, and a deep learning model is developed to analyze and classify multiple types of faults, including outer race, inner race, and ball defects. The proposed approach achieves high accuracy in fault diagnosis, outperforming traditional methods. The integration of vibration and thermography data with deep learning provides a comprehensive and effective solution for bearing fault detection, enabling proactive maintenance strategies and enhancing the reliability of industrial machinery. [4]

Saha, D. K., Hoque, M. E., &Badihi, H. (2022),This paper presents the development of an intelligent fault diagnosis technique for rotary machine element bearings using a machine learning approach. Vibration signals from the bearings are analyzed to extract features, which are used to train machine learning models. These models successfully diagnose various bearing faults, including outer race, inner race, and ball defects. The proposed technique offers an efficient and accurate solution for fault diagnosis in rotary machine bearings, enabling proactive maintenance and improved reliability. [5]

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Wang, Z., Yang, J., & Guo, Y. (2022), This paper focuses on extracting unknown fault features from rolling bearings operating under variable speed conditions using statistical measures. The study aims to address the challenge of identifying fault characteristics that may vary with speed. Statistical measures, including mean, standard deviation, and kurtosis, are employed to capture the variations in vibration signals. Experimental results demonstrate the effectiveness of the proposed approach in accurately identifying unknown fault features in rolling bearings, regardless of speed changes. The study highlights the importance of statistical analysis for fault diagnosis in variable speed conditions, providing valuable insights for condition monitoring and maintenance of rolling bearings. [6]

Cui, B., Weng, Y., & Zhang, N. (2022), This paper presents a framework for bearing fault diagnosis that combines feature extraction techniques with machine learning. The proposed approach focuses on extracting informative features from vibration signals, such as statistical features, time-frequency features, and wavelet-based features. These features are then used as input to train machine learning models, including support vector machines and random forests. Experimental results demonstrate the effectiveness of the framework in accurately diagnosing bearing faults, achieving high accuracy rates. The study highlights the significance of feature extraction and machine learning in enhancing the fault diagnosis capabilities of bearing systems, enabling proactive maintenance and improved reliability.[7]

Salunkhe, V. G., &Desavale, R. G. (2021), This paper presents an intelligent prediction method for detecting bearing vibration characteristics using a machine learning model. The study focuses on utilizing a deep learning architecture, specifically a long short-term memory (LSTM) neural network, to analyze vibration signals and predict bearing fault conditions. The proposed method achieves high accuracy in detecting bearing faults, including inner race, outer race, and ball defects. Experimental results demonstrate the effectiveness of the intelligent prediction approach, highlighting the potential of machine learning models, such as LSTM, for accurate and efficient detection of bearing vibration characteristics, enabling proactive maintenance strategies in industrial applications. [8]

Irgat, E., Çinar, E., &Ünsal, A. (2021), This paper discusses the detection of bearing faults in induction motors by utilizing vibration signals and machine learning techniques. The study focuses on extracting relevant features from vibration signals, such as statistical features and wavelet-based features. These features are then used to train machine learning models, including support vector machines and artificial neural networks. Experimental results demonstrate the effectiveness of the approach in accurately detecting bearing faults, enabling early fault detection and maintenance of induction motors. The study emphasizes the significance of vibration analysis and machine learning in improving the reliability and performance of induction motor systems. [9]

He, M., & He, D. (2020),This paper introduces a new hybrid deep signal processing approach for bearing fault diagnosis using vibration signals. The proposed method combines deep learning techniques with signal processing algorithms to enhance the accuracy and efficiency of fault diagnosis. The approach involves pre-processing the vibration signals, extracting informative features using a deep convolutional neural network, and then utilizing a long short-term memory network for fault classification. Experimental results demonstrate the effectiveness of the hybrid approach in accurately diagnosing bearing faults, outperforming traditional methods. The study highlights the potential of integrating deep learning and signal processing for advanced and reliable bearing fault diagnosis in industrial applications. [10]

Udmale, S. S., Singh, S. K., &Bhirud, S. G. (2019), This paper presents a bearing data analysis approach that combines kurtogram analysis and deep learning sequence models. The study focuses on using the kurtogram, a statistical tool, to extract fault-related information from vibration signals. These features are then utilized to train deep learning sequence models, such as long short-term memory networks and convolutional neural networks. Experimental results demonstrate the effectiveness of the proposed approach in accurately diagnosing bearing faults, achieving high classification accuracy. The study highlights the potential of combining kurtogram analysis with deep learning sequence models for robust and reliable bearing fault diagnosis, enabling proactive maintenance strategies in industrial systems. [11]

Zhao, D., Li, J., Cheng, W., & Wen, W. (2016), This paper presents a method for detecting compound faults in rolling element bearings under time-varying rotational speed conditions using the generalized demodulation algorithm. The study focuses on effectively analyzing vibration signals to identify multiple faults simultaneously. The proposed method successfully captures and separates the fault-related components from the signals, enabling accurate diagnosis of compound faults. Experimental results demonstrate the effectiveness of the approach in detecting and classifying various types of bearing faults, even in the presence of time-varying rotational speed. The study highlights the significance of the

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generalized demodulation algorithm for robust compound fault detection in rolling element bearings, facilitating proactive maintenance strategies. [12]

Wang, T., Liang, M., Li, J., & Cheng, W. (2014), This paper introduces a method for diagnosing faults in rolling element bearings using Fault Characteristic Order (FCO) analysis. The study focuses on extracting fault features from vibration signals based on the order information of the fault frequencies. The proposed approach effectively separates the fault-related components from the signals and accurately identifies different types of bearing faults. Experimental results demonstrate the effectiveness of the FCO analysis method in diagnosing bearing faults, providing a reliable tool for proactive maintenance and improved reliability of rolling element bearings in industrial applications. [13]

Kankar, P. K., Sharma, S. C., & Harsha, S. P. (2011),This paper presents a fault diagnosis approach for ball bearings using machine learning methods. The study focuses on utilizing machine learning algorithms, such as support vector machines and random forests, to classify different types of bearing faults based on vibration signals. Features extracted from the signals, including statistical features and frequency domain features, are used as input to the models. Experimental results demonstrate the effectiveness of the machine learning approach in accurately diagnosing bearing faults, highlighting its potential for proactive maintenance and improved reliability of ball bearings in industrial applications. [14]

Amarnath, M., Shrinidhi, R., Ramachandra, A., &Kandagal, S. B. (2004),This paper presents a fault diagnosis approach for ball bearings using machine learning methods. The study focuses on utilizing machine learning algorithms, such as support vector machines and random forests, to classify different types of bearing faults based on vibration signals. Features extracted from the signals, including statistical features and frequency domain features, are used as input to the models. Experimental results demonstrate the effectiveness of the machine learning approach in accurately diagnosing bearing faults, highlighting its potential for proactive maintenance and improved reliability of ball bearings in industrial applications.[15]

III. CONCLUSION

The conclusion of the paper highlights the importance of feature extraction and data segmentation in the success of machine learning (ML) models for fault diagnosis in rotating machinery. The authors emphasize that techniques to reduce the dimensionality of input features have been suggested and demonstrated to be viable for development. By making the input features smaller, the models can be more efficient and effective in identifying faults. Furthermore, the researchers propose a novel approach of compressing the raw signal to a smaller size before utilizing it in ML models for fault identification. This compression technique offers potential benefits such as reduced storage requirements and improved computational efficiency while maintaining the essential information needed for accurate diagnosis.The study also emphasizes the significance of comparative research on various ML algorithms for forecasting bearing failures. By evaluating and comparing different algorithms, the researchers aim to identify the best-performing model with the highest level of accuracy. This research contributes to advancing the field of rotating machinery monitoring by leveraging ML techniques to enhance fault diagnosis capabilities.In summary, the paper concludes that the success of ML models in fault identification relies not only on the choice of algorithms but also on the feature extraction procedure and data segmentation. Techniques to reduce input feature dimensionality and compress the raw signal show promise in improving the efficiency and accuracy of fault diagnosis. Comparative research on ML algorithms helps to identify the most accurate model for bearing failure prediction. This work contributes to the advancement of rotating machinery monitoring through the application of ML techniques.

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