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Fault Identification of Vibration-Based Condition Monitoring of Motor Using Minitab and Matlab: A Case Study on Francis Turbine

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Abstract- This paper discusses the identification of faults in a Francis turbine using vibration-based condition monitoring with Minitab and MATLAB. The vibration signals are analyzed to detect faults in the motor components of the turbine. Statistical analysis uses Minitab to identify trends, while MATLAB carries out advanced signal processing, including Fast Fourier Transform (FFT) and wavelet analysis, to extract fault features. The combined approach effectively diagnoses issues like misalignment and bearing defects, showing its value in predictive maintenance for improved turbine performance.

Index Terms- fault detection, diagnosis; vibration-based condition monitoring; neural networks

I. INTRODUCTION

Francis turbines are essential to hydroelectric power generation, making reliability and performance critical to success in operation. With time, turbines suffer from different mechanical faults like misalignment, imbalance, and bearing defects that can decrease efficiency and downtime. Vibration-based condition monitoring has emerged as a powerful tool for diagnosing such issues with early fault detection and predictive maintenance. Operators can identify potential problems, minimize disruptions, and extend the life of the equipment by analyzing vibration signals.

This paper analyzes vibration data to identify faults in a Francis turbine using Minitab and MATLAB. For analysis, Minitab will help analyze statistical significance to trend patterns and anomalies that are apparent from the data; while MATLAB facilitates powerful signal processing methodologies such as Fast Fourier Transform and wavelet analysis for fault critical features extraction. These together establish a very powerful condition monitoring platform with systematic diagnoses of faults towards effective reliability.

II. LITERATURE SURVEY

B. K. Pavan Kumar, Yadavalli Basavaraj, N. Keerthi Kumar, and M. J. Sandeep

(1) “Optimization of Vibration-Based Condition Monitoring of Motor Drive End Using Taguchi Technique: A Case Study on Milling Machine”. This paper focuses on the novel aspect of predictive maintenance using signal processing techniques. Mainly, data are collected from the rotating machines using a vibrometer, and obtained spectrums are analyzed for process control using Taguchi for optimization and signal processing techniques for defining clearly the severity level of vibration in a component.

Y. Koch, S. Sendlbeck, M. Otto, K. Stahl, E Kirchner “A review on the use of angle measurements in gear condition monitoring and fault detection”. This review provides insights into current methods of angle-based condition monitoring for gear transmissions – from sensors, data acquisition, and algorithms to condition evaluations. It shows how current research applies measurement principles with various resolutions and sampling frequencies at stationary and dynamic operating conditions. It includes one or multiple angle measurements (instantaneous angle, instantaneous angular speed, instantaneous angular acceleration, or transmission error), electric current measurements, or the combination with acceleration measurements.

B. K. Pavan Kumar, Yadavalli Basavaraj, Santosh V. Janamatti, Sameer Algburi, Hasan Sh. Majdi, Salah J. Mohammed, Madeva Nagaral, Fazil Nalband, Nagaraj Namdev, and V. Auradi “Performance Analysis of Motor Vibration Based Condition Monitoring Using R-curve”. This study is focused on knowledge acquired from vibration analysis and applied to condition monitoring techniques. Results showed a 99.87% accuracy level of vibration that improves the performance of the motor.

Zepeng Liu, Zi-Qiang Langb, Yufei Gui, Yun-Peng Zhu, Hatim Laalej “Digital twin-based anomaly detection for real-time tool condition monitoring in machining". The present study exploits these potential advantages of digital twins and proposes a new digital twin-based anomaly detection framework for real-time

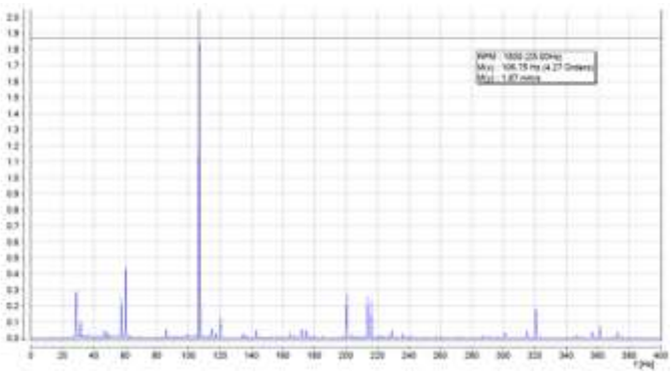
TCM in machining. The framework of the digital twin consists of three parts: the physical product, the virtual product, and data flow connections. Within this digital twin framework, the ‘‘physical product'' represents the machining processes.

III. FAULT DETECTION

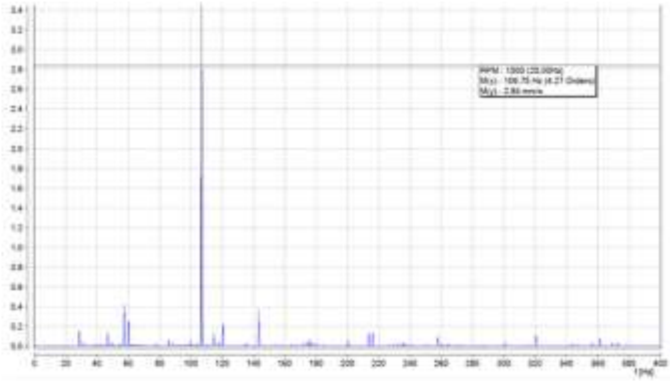
Fault detection by a vibrometer is a process of monitoring and analyzing vibrations in machinery or structures to detect potential defects such as imbalance, misalignment, bearing faults, or cracks. Laser Doppler vibrometers are the most common type of vibrometer because they measure vibrations without touching the object with high precision and sensitivity. Generally, these processes are recorded as vibration signals, with features such as an amplitude shift or shift in frequency within the signal domain and processed. This approach often finds applications involving predictive maintenance of structures, and assessment of aerospace system health, where early faults allow for failure-risk reduction by lowering the potential possibility of shocks.

Fig (1): Motor

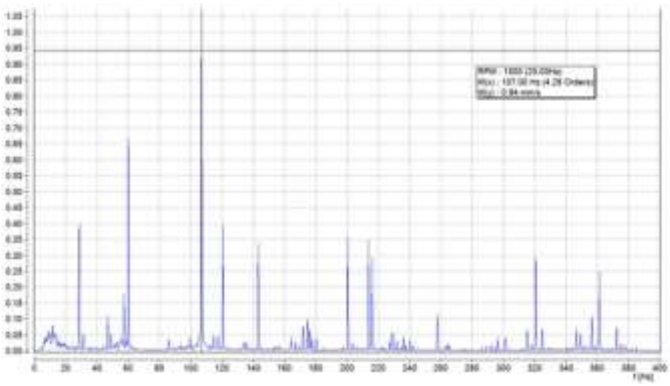
1. Frequency Spectrums of NDE
Horizontal



Vertical



Axial



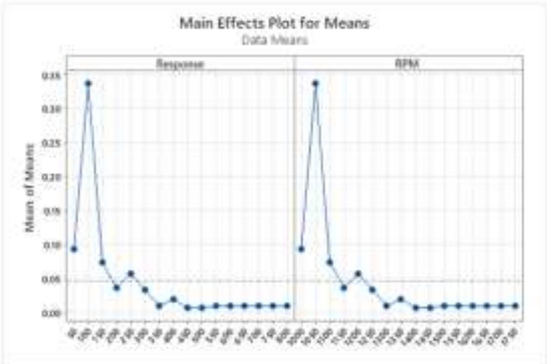
IV. MINITAB AND MATLAB FOR PERFORMANCE VALIDATION

1. MINITAB
Minitab is a statistical software widely used in data analysis and quality improvement. It can be effectively paired with a vibrometer to analyze vibration data. A vibrometer measures the vibration characteristics of a structure or machinery and provides precise data on parameters such as amplitude, frequency, and acceleration.

The data can be imported into Minitab for detailed statistical analysis, including descriptive statistics, regression analysis, and time series analysis. The strong capabilities of Minitab allow engineers to check the performance of machines, detect patterns, and identify potential issues such as imbalance or misalignment.

Moreover, through the application of control charts and capability analysis, Minitab can be used to monitor vibration trends over time, thus ensuring the reliability and longevity of equipment. That's where vibrometer measurement and Minitab analysis come in very handy is especially true for manufacturing, automotive, and aerospace industries where accuracy and equipment maintenance are vital.

2. Result



3. MATLAB

A vibrometer is a device that measures the vibration of a surface or structure. MATLAB, with its powerful data acquisition and signal processing capabilities, is often used in conjunction with vibrometers to analyze and visualize vibration data.

Using MATLAB, one can interface with a vibrometer via compatible hardware, such as data acquisition (DAQ) devices, to collect real- time vibration signals. MATLAB's built-in functions allow noise filtering, performing Fourier transforms, and even computation of frequency response plots to make assessment of vibration characteristics like amplitude, frequency, and phase relatively straightforward.

These are built-in features in MATLAB that can also be applied for complex analysis purposes such as modal analysis or machine condition monitoring. Furthermore, integration with Simulink allows for the simulation and design of control systems based on vibration data. This combination is particularly valuable in fields like mechanical engineering, structural health monitoring, and product testing.

Methods

Neural Network

A neural network in MATLAB is a computational model that has been inspired by the way a human brain function. It has been developed to solve some complex problems like classification, regression, pattern recognition, and time-series forecasting. The Neural Network Toolbox, which MATLAB provides, gives one a very powerful and flexible environment for the creation, training, and simulation of neural networks with the Deep Learning Toolbox. This toolbox offers inbuilt functions for designing shallow networks, such as feedforward and radial basis networks, as well as deep networks, including convolutional and recurrent networks. The interface is user- friendly and enables researchers and engineers to easily configure network architectures, visualize training progress, and evaluate model performance.

Pattern Recognition

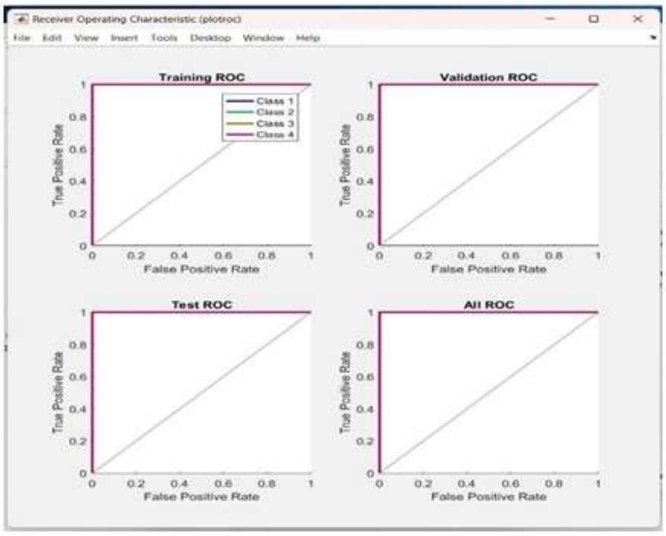
Pattern recognition in MATLAB is based on machine learning and neural networks where data is classified based on its patterns or features. MATLAB provides functions and applications in the Deep Learning Toolbox, which helps users design, train, and validate models for pattern recognition applications. The commonly used algorithms include feedforward neural networks, k-nearest neighbors, and support vector machines. The toolbox eases data pre-processing, feature extraction, and model evaluation; hence, classifying complex data sets efficiently with applications in fields such as image analysis, signal processing, and bioinformatics.

4. Result

Plot Confusion

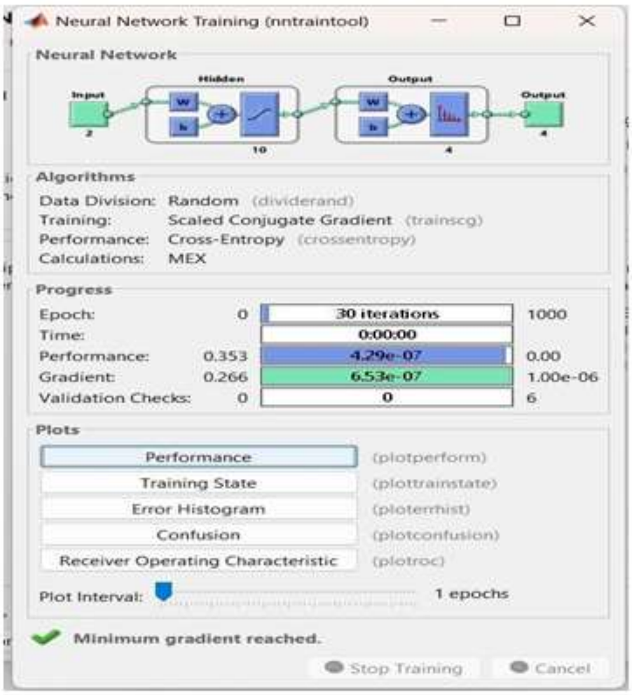
These matrices show the counts of correct and incorrect predictions for each class. The diagnosis cells represent correct predictions. While off-diagonal cells represent misclassification's

Plot ROC



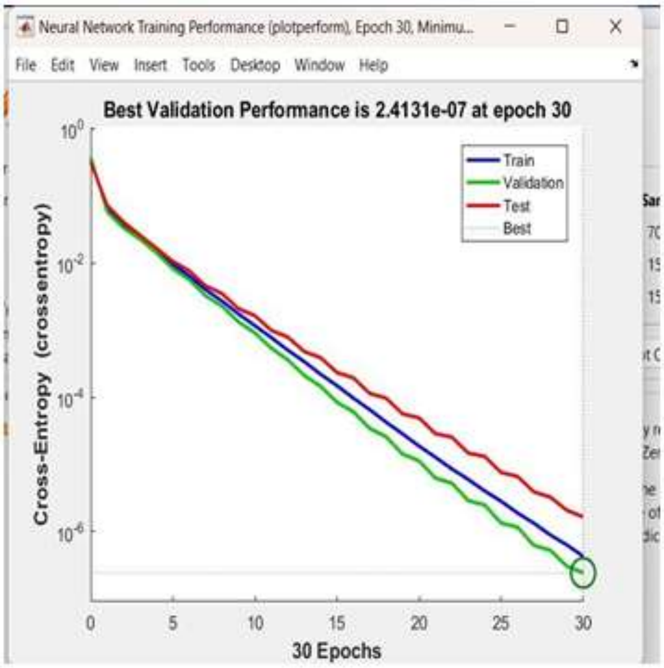
Plot ROC illustrates the true positive rate (TPR) versus the false positive rate(FPR) for different thresholds

Performance Validation



Performance validation access the model's performance on training, validation, and test data sets. The NN, trained using the scaled conjugate gradient algorithm with cross-entropy as the metric

Epoch



Epoch plot show a consistent decree in cross entropy loss over 30 epochs. The best validation performance occurred at epoch 30 with a cross-entropy loss of 2.4131e-07. Indicating optimal model performance.

V. CONCLUSION

The fault identification of vibration-based condition monitoring of motors using Minitab and MATLAB demonstrates a reliable approach to implementing early fault detection and predictive maintenance. MATLAB's signal processing capability incorporated with Minitab's statistical analysis effectively identified various faults of motor conditions such as unbalance, misalignment, and bearing defects. Applying regression and ANOVA, some significant relationships between characteristics of vibration and the severity of faults are identified and further lead to better predictions using machine learning models. This integrated methodology improves motor reliability, reduces downtime, and supports the development of effective predictive maintenance strategies.

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