CONDITION-BASED MONITORING AND MAINTENANCE SYSTEM OF TUNNEL BOOSTER FAN THROUGH VIBRATION ANALYSIS

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Abstract: This paper presents a Condition-Based Monitoring and Maintenance System for tunnel booster fans, focusing on vibration analysis as a key diagnostic tool. As critical components in tunnel ventilation, booster fans must operate efficiently to ensure safety and air quality.

This system utilizes real-time vibration data to assess fan performance and detect potential mechanical issues before they escalate into failures. By employing advanced signal processing techniques and machine learning algorithms, the system identifies patterns indicative of wear, imbalance, or misalignment.

The implementation of this proactive maintenance approach not only reduces downtime and maintenance costs but also enhances the reliability and lifespan of tunnel ventilation systems, ultimately contributing to safer transportation environments. Advanced techniques, including vibration signature analysis, allow for the identification of specific fault patterns, enabling targeted maintenance strategies. The integration of deep learning methods with vibration analysis enhances the accuracy of fault detection and predictive maintenance, streamlining the monitoring process.

Index Terms - Condition-Based Monitoring, Tunnel Booster Fans, Machine Learning, Predictive Maintenance, Failure Detection, Data Analytics
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I. INTRODUCTION

In modern infrastructure, the efficient operation of tunnel systems is crucial for transportation and safety. Tunnel booster fans play a vital role in maintaining airflow, ensuring adequate ventilation, and controlling air quality within tunnels. As these fans are subject to continuous operation and environmental challenges, implementing a robust monitoring and maintenance strategy is essential for maximizing their performance and lifespan.

Condition-based monitoring (CBM) has emerged as an effective approach to maintain industrial equipment, allowing for timely interventions based on the actual condition of the machinery rather than relying on scheduled maintenance. Among various monitoring techniques, vibration analysis has proven to be a powerful tool for assessing the health of rotating machinery, including tunnel booster fans. By measuring and analyzing vibration patterns, potential issues such as imbalance, misalignment, or bearing wear can be detected early, reducing the risk of unexpected failures and minimizing downtime and also saving man power.

This introduction outlines the significance of a CBM system specifically tailored for tunnel booster fans, highlighting the advantages of integrating vibration analysis. The deployment of such a system not only enhances operational efficiency but also contributes to cost savings and improved safety in tunnel environments. Through continuous monitoring and data-driven maintenance strategies, organizations can ensure the reliability and effectiveness of tunnel ventilation systems, ultimately supporting the safe passage of vehicles and personnel in these critical infrastructures.
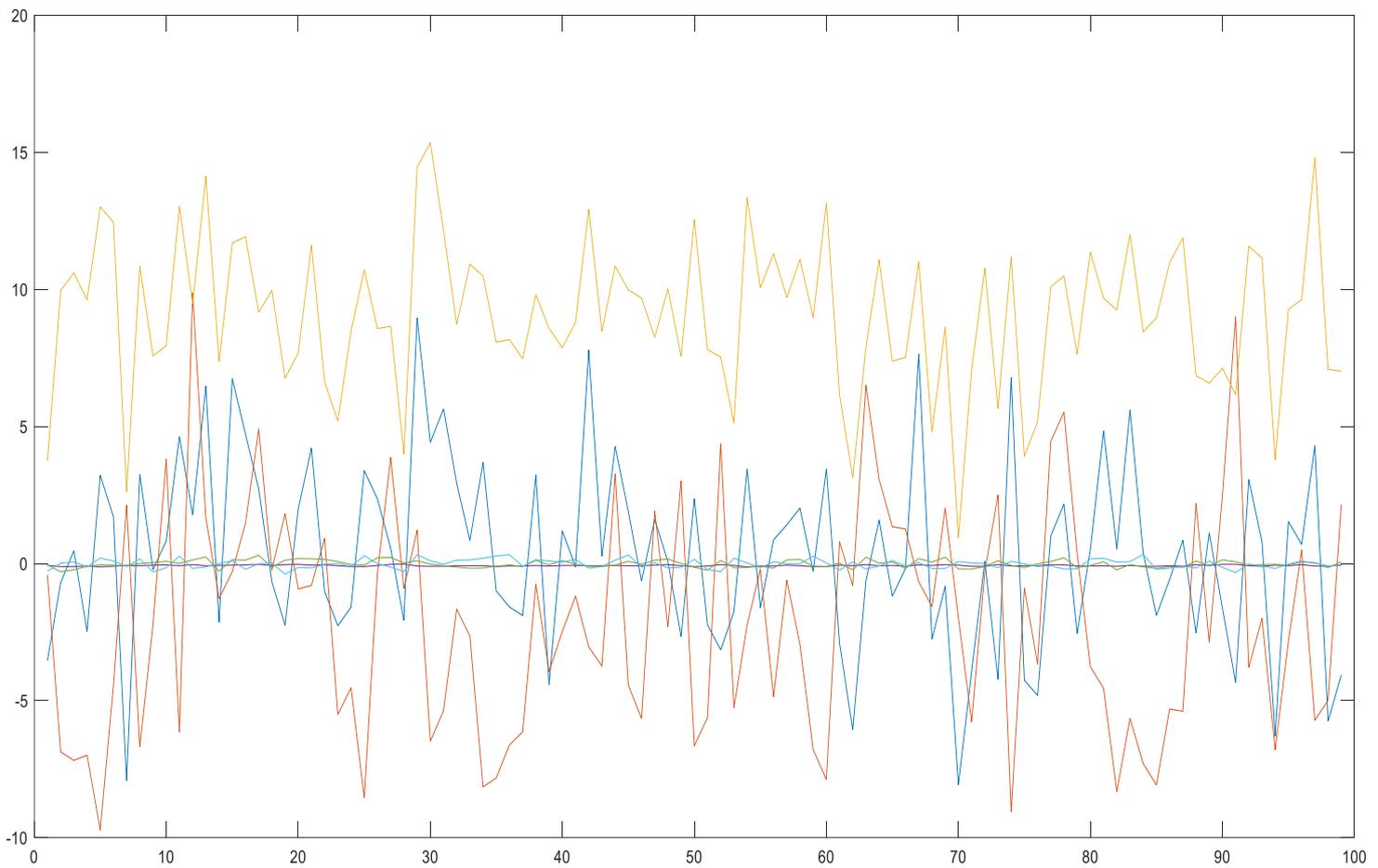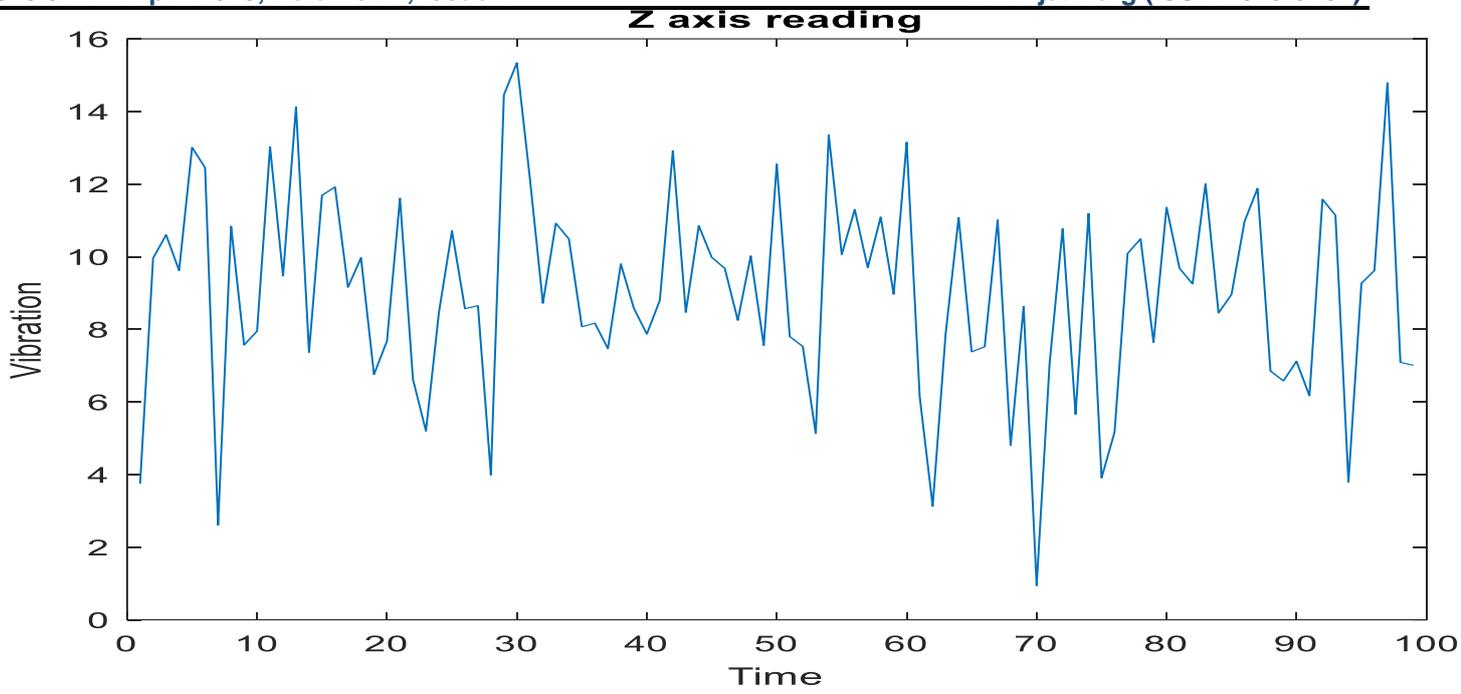
II. METHODOLOGY

•**Vibration Signature Analysis**: Vibration signature analysis is a critical tool for monitoring the condition of rotating elements in tunnel booster fans. By utilizing accelerometers to capture vibration signals, the analysis can identify specific fault patterns, enabling predictive maintenance strategies.
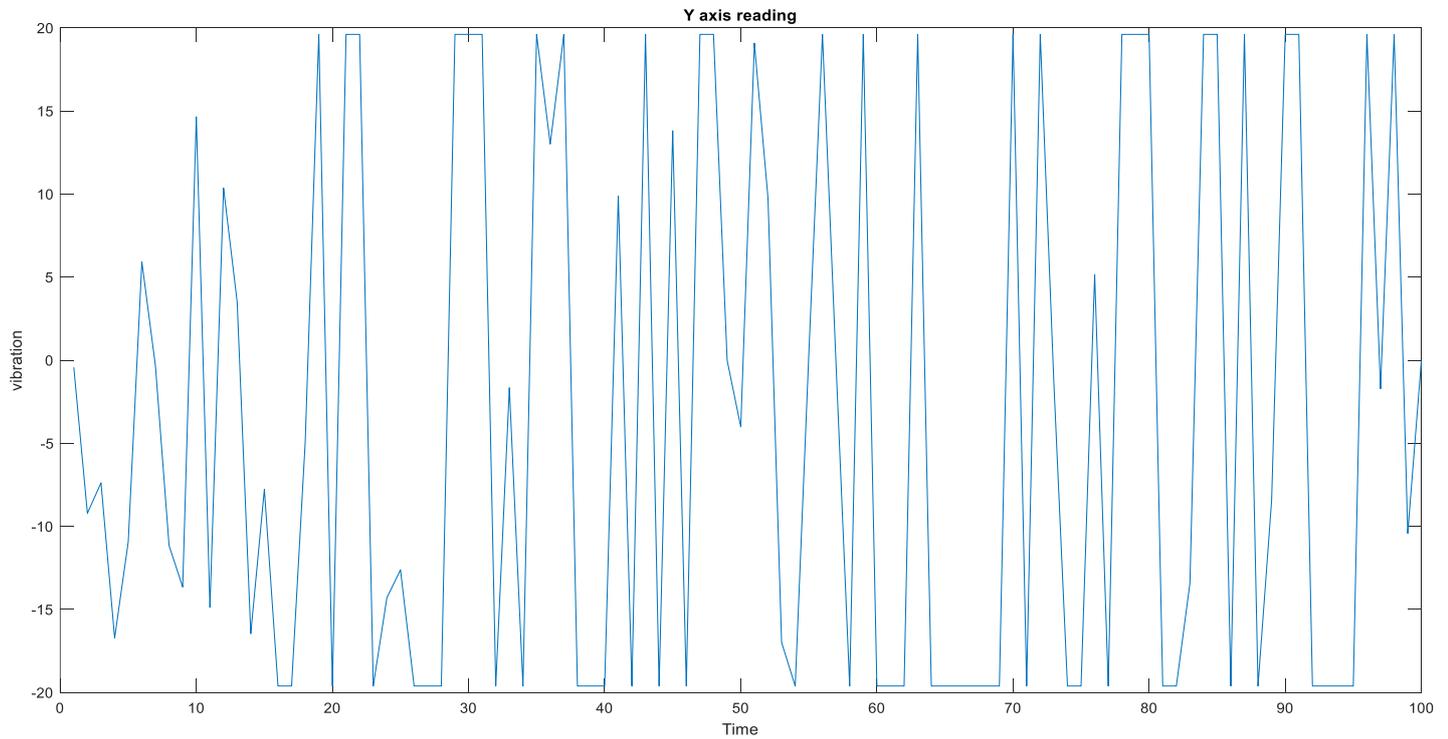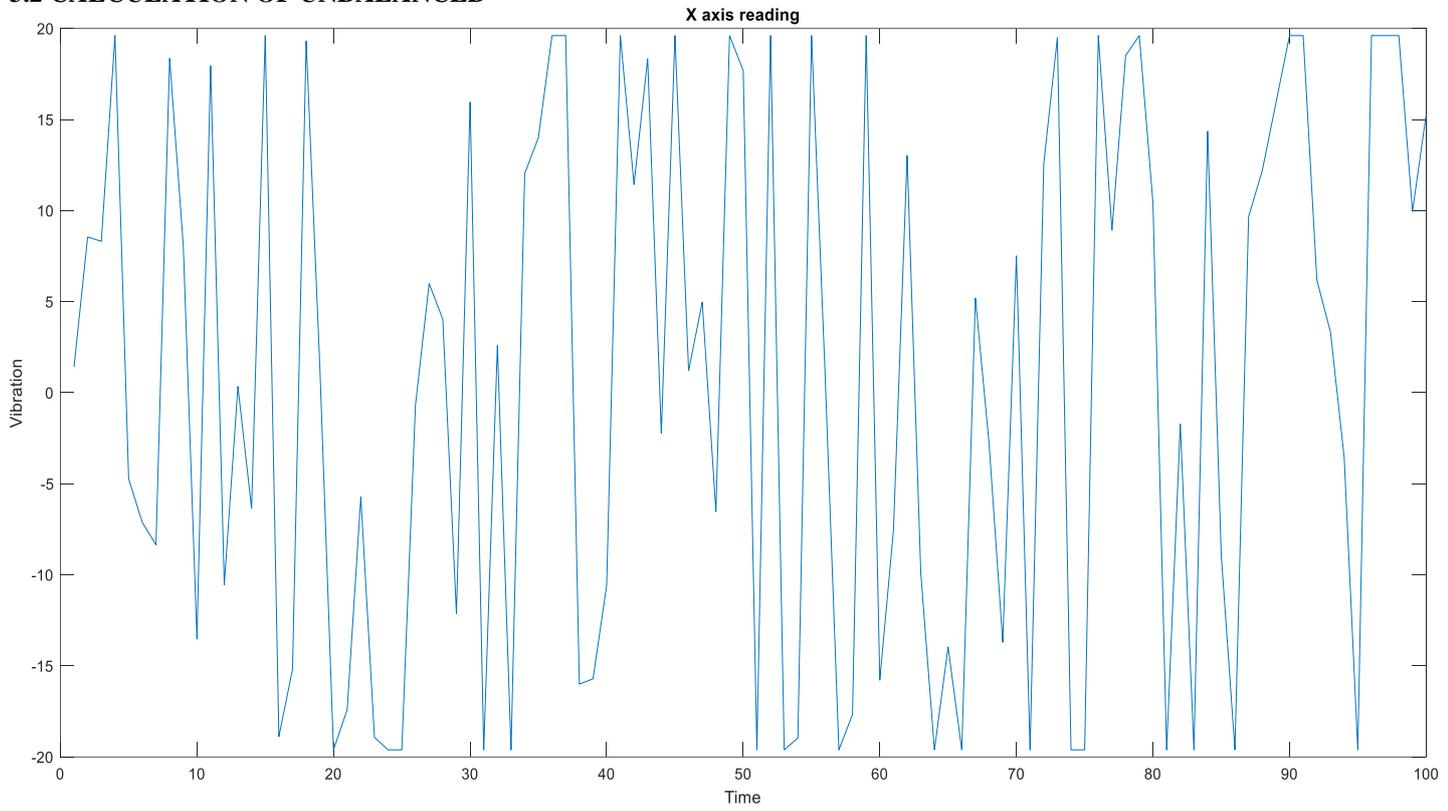
III.

3.1. CALCULATION OF BALANCED
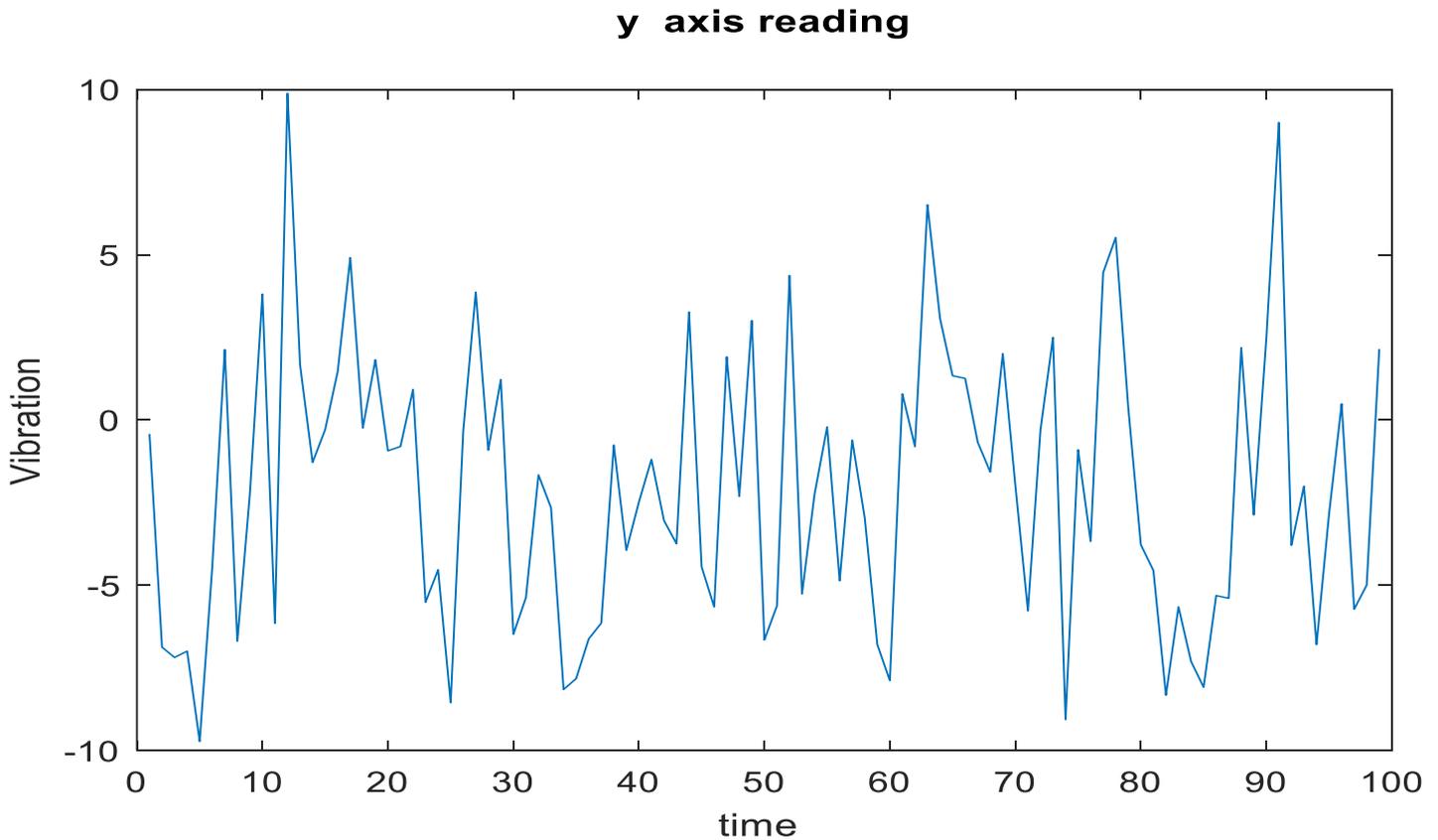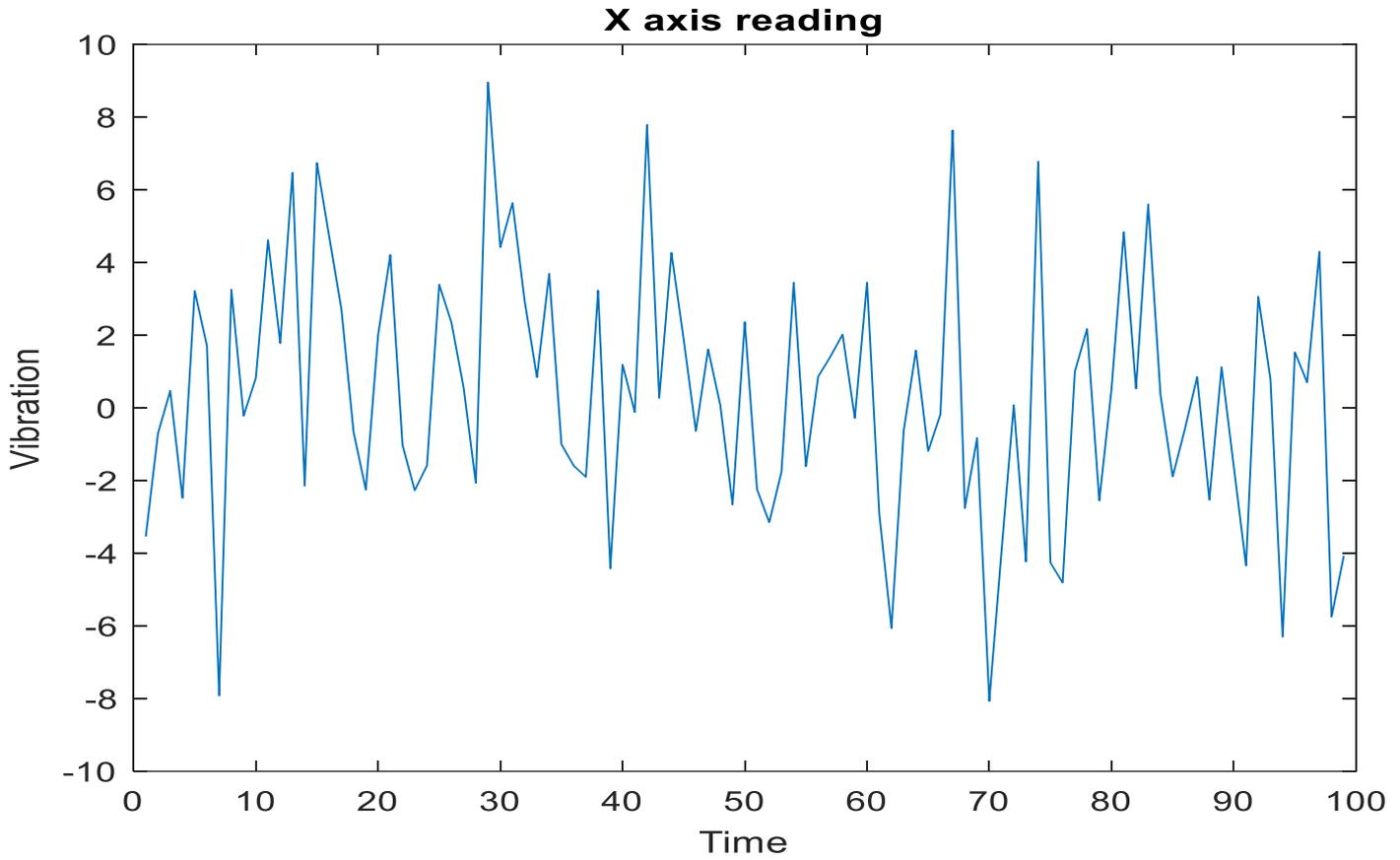
3.2 CALCULATION OF UNBALANCED

X axis reading

Y axis reading
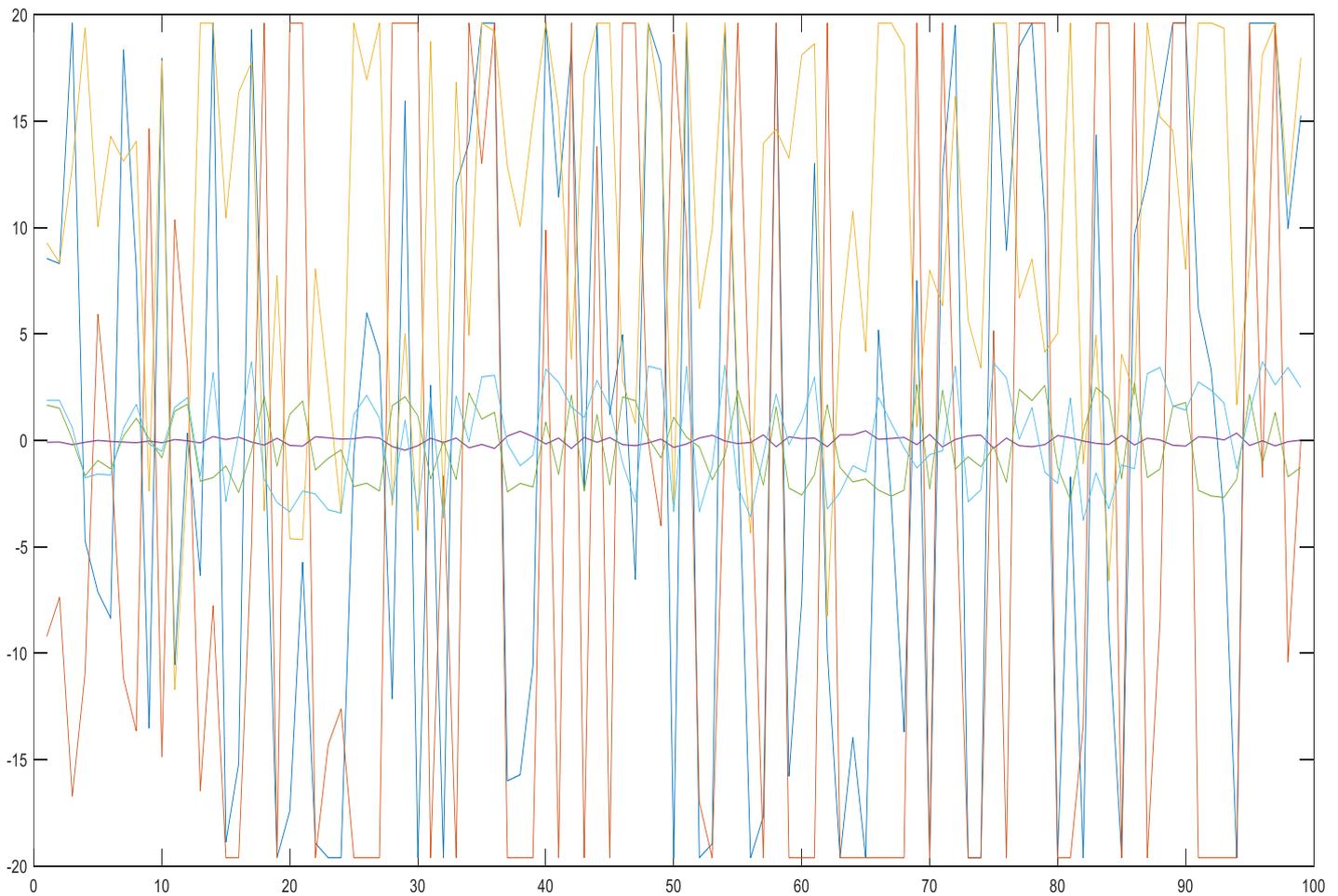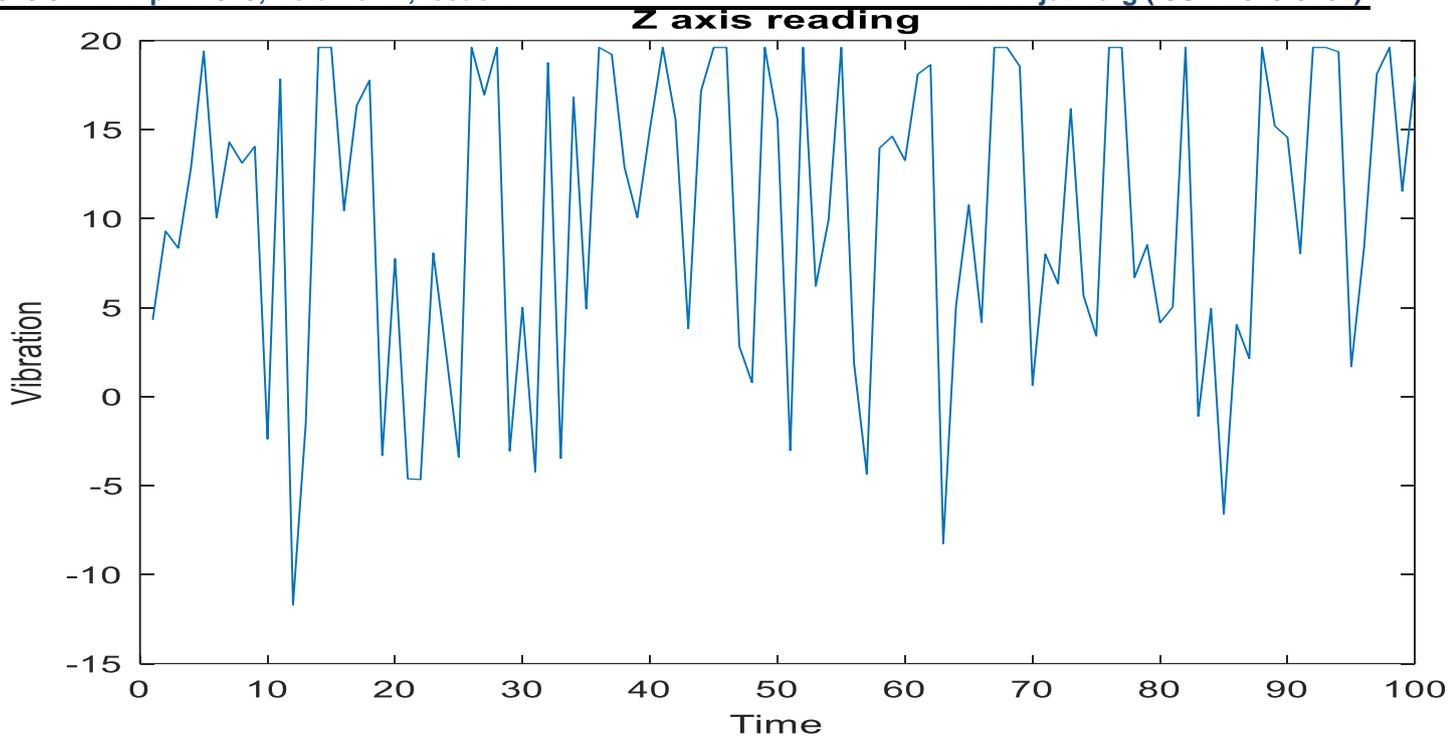
• **Sensor-Dependent Data**: Acquisition Implementing a system of multiple sensors allows for comprehensive data collection on fan performance. Techniques such as short-time Fourier transform (STFT) can be employed to analyze vibration data, facilitating the identification of faults like blade cracks.

•**Data-Driven Prognosis**: Data-driven methods, including principal component analysis (PCA) and partial least squares (PLS), can effectively detect abnormal behaviors in fan operation. These methodologies utilize historical vibration data to predict maintenance needs and optimize operational reliability.

•**Monitoring Systems**: Thresholds Advanced monitoring systems can automatically compare real-time vibration data against established thresholds. If vibration levels exceed these thresholds, warning signals are generated, enhancing the accuracy of fault detection.
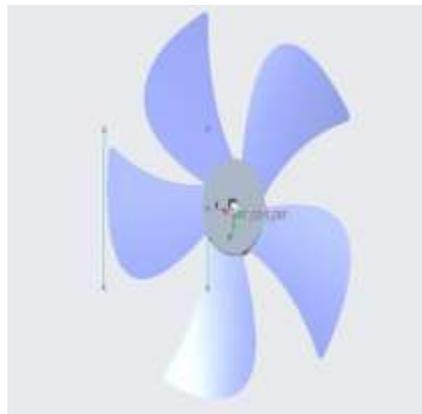
IV. Project dimension-

Length: 17-inch   Diameter: front-14.5 inch, back-11.75 inch

Drawing No.1

Drawing No.2
Dimension-   Dimension- 12 inches
Length- 17 inch
Diameter- (Front)- 14.5 inch, (Back)- 11.75 inch

V. Prototype

Project Image back View-

Fig. No. 1.1

(Condition Monitoring Process diagram with hexagons: Select Appropriate Maintenance Strategy, Select Monitoring Method, Condition Monitoring Process, Data Acquisition And Analysis, Determine Maintenance Action, ...efit...is)

Project Image Front View:

Fig. No. 1.2

VI. Selection Criteria of our Project

1. We are doing this condition monitoring to overcome the schedule maintenance process.

2. With the help of this process we will save man power, save traffic disruption and reduce downtime inside tunnel.

3. Condition monitoring process will help us to save the maintenance cost and we increase the machine life Spain.

4. Data analysis will be done through the data acquisition method.

5. This all analysis will be done on MATLAB software.

VII. TECHNICAL APPROACH

- Modelling of working prototype using CAD software

- The fabrication of experimental setup

- Data acquisition and analysis using MATLAB software.

- Vibration based analysis

- Pre- found fault Analysis and rectification

VIII. System Components

1. Vibration Sensors: Accelerometers or velocity sensors installed on the fan's motor, gearbox, and bearings to collect vibration data.
2. Data Acquisition Unit: Collects and transmits vibration data to a central processing unit.
3. Signal Processing Software: Analysis vibration data using algorithms such as Fast Fourier Transform (FFT) and wavelet analysis.
4. Machine Learning Model: Trained on historical data to predict potential failures based on vibration patterns.
5. User Interface: Displays real-time vibration data, alerts, and maintenance recommendations.

IX. Vibration Analysis Techniques

1. Frequency Analysis: Identifies specific frequency components associated with fan operation.
2. Time-Frequency Analysis: Analysis changes in vibration patterns over time.
3. Wavelet Analysis: Detects transient events and anomalies in vibration signals.
4. Machine Learning Algorithms: Classifies vibration patterns as normal or abnormal

X. Benefits

1. Reduced Downtime: Proactive maintenance reduces unexpected failures and associated downtime.
2. Energy Efficiency: Optimized fan performance leads to reduced energy consumption.
3. Increased Safety: Predictive maintenance ensures the tunnel ventilation system operates within safe limits.
4. Extended Equipment Life: Regular maintenance and monitoring extend the lifespan of the fan and its components.

XI. Conclusion

The CBM system using vibration analysis provides a proactive approach to maintenance, enabling tunnel operators to optimize fan performance, reduce downtime, and increase safety. The system's ability to predict potential failures and recommend maintenance actions makes it an essential tool for efficient tunnel ventilation system management.

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