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ONLINE FAN BLADE MONITORING USING WIRELESS INSTRUMENTATION

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A project report submitted
in fulfillment of the requirements for the degree of
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DECLARATION

I declare that this project entitled "Online Fan Blade Monitoring Using Wireless Instrumentation" is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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APPROVAL

I hereby declare that I have checked this thesis, and, in my opinion, this thesis is adequate in terms of scope and quality for the award of the Bachelor of Mechanical Engineering Technology with Honours.

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Date : 11 JANUARY 2023

DEDICATION

I dedicate the thesis report to my whole family, project supervisor, and fellow friends. The eternal gratitude is formed for the project supervisor, Ts Dr Nor Azazi bin Ngatiman for his guidance and unlimited teachings for the software and the monitoring session throughout the process of completing the thesis report. The thesis report is believed to become complete due to my most beloved friends to the kindest words and endless support in either physical support or emotional support.

ABSTRACT

Vibration is quite known in the machinery industry where it is unavoidable. The magnitude of the vibration does increase over quite some time and has become disadvantages to the machinery. The difficulty of monitoring the vibration level to ensure its safety to continue working has led to the purpose of this project. The project is meant to measure the vibration conditions of the fan blade wirelessly and to analyze the fan blade faults vibration by using time domain graph and frequency domain graph. With those, this project is also to validate all the analyzed data by using the coefficient of determination. The blade is being monitored by using wireless instrumentation of Erbessd Instruments where the data will be processed in the designated software named DigiVibeMX11. The result will then be analyzed in DigiVibeMX11 with the other specific details as the discussion will be made based on the details on the graph produced in the software by using FFT (Fast Fourier Transform) analysis including time-domain graph and frequency domain graph. In conclusion, vibration is very common in machinery, however, there are some patterns that need to be observed where it will differentiate between normal vibration or fault vibration.

ABSTRAK

Getaran cukup dikenali dalam industri jentera di mana ia tidak dapat dielakkan. Magnitud getaran meningkat sejak sekian lama dan telah menjadi kelemahan kepada jentera. Kesukaran memantau tahap getaran untuk memastikan keselamatannya untuk terus bekerja telah membawa kepada tujuan projek ini. Projek ini bertujuan untuk mengukur keadaan getaran bilah kipas secara wayarles dan menganalisis getaran kerosakan bilah kipas dengan menggunakan graf domain masa dan graf domain frekuensi. Dengan itu, projek ini juga untuk mengesahkan semua data yang dianalisis dengan menggunakan pekali penentuan. Bilah sedang dipantau dengan menggunakan instrumentasi tanpa wayar Instrumen Erbessd di mana data akan diproses dalam perisian yang ditetapkan bernama DigiVibeMX11. Hasilnya kemudiannya akan dianalisis dalam DigiVibeMX11 dengan butiran khusus yang lain kerana perbincangan akan dibuat berdasarkan butiran mengenai graf yang dihasilkan dalam perisian. Kesimpulannya, getaran sangat biasa dalam jentera, bagaimanapun, terdapat beberapa corak yang perlu diperhatikan di mana ia akan membezakan antara getaran normal atau getaran kerosakan.

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LIST OF SYMBOLS AND ABBREVIATIONS

D,d	-	Diameter
Hz	-	Hertz
CPM	-	Cycles Per Minute
RPM	-	Revolution Per Minute
RMS	-	Root Mean Square
FFT	-	Fast Fourier Transfrom
DAQ	-	Data Acquisition
mm/s	-	milimeter per second
mm	-	milimeter
mm^2/s	-	milimeter squared per second
in	-	inch
g	-	gram
m	-	meter
MATLAB	-	Matrix Laboratory
EMD	-	Empirical Mode Decomposition
AE	-	Acoustic Emission
WSN	-	Wireless Sensor Networks
SK	-	Spectral Kurtosis
SERP	-	Strain Energy Release Approach
STFT	-	Short Time Fourier Transform
WT	-	Wavelet Transform
HHT	-	Hilbert-Huang Transform
WVD	-	Winger-Ville Distribution
FE	-	Finite Element
IBH	-	inboard horizontal
OBH	-	outboard horizontal
IBV	-	inboard vertical
OBV	-	outboard vertical

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CHAPTER 1

INTRODUCTION

1.1 Background

Vibration is the mechanical oscillations of an object about an equilibrium point. The oscillations may be regular such as the motion of a pendulum or random movement such as tire on the gravel road (Canadian Centre for Occupational Health and Safety, 1997). The movements of vibrating object in different directions can be seen in slow motion. Any vibration has two measurable quantities. How far (amplitude or intensity), and how fast (frequency) the object moves helps determine its vibrational characteristics. This movement is described using the terms frequency, amplitude, and acceleration. Frequency is known as the number of cycles that a vibrating object completes in one second. A vibrating object moves back and forth from its normal stationary position and a complete cycle of vibration occurs when the object moves from one extreme position to the other extreme, and back again. The unit of frequency is hertz (Hz) which equals to one cycle per second. The distance from the stationary position to the extreme position on either side is measured in metres (m). A vibrating object moves to a certain maximum distance on either side of its stationary position is also known as amplitude. The intensity of the vibration depends on its amplitude. The speed of a vibrating object varies from zero to a maximum during each cycle of vibration as it moves fastest when it passes through the natural stationary position to an extreme position. The vibrating object will slow down as it approaches the extreme where it stops and moves in the opposite direction through the stationary position toward the other extreme. The speed of the vibration is expressed in metres per second (m/s). Acceleration is the rate at which the speed changes over time. The magnitude of acceleration changes from zero to a maximum during each cycle of vibration where it increases as the vibrating object moves further away from its normal stationary position. The acceleration is measured in metres per second squared (m/s^2) (Canadian Centre for Occupational Health and Safety, 1997).

1.2 Problem Statement

Blade is mainly used in the machinery industry where it experiences damage periodically. The damage occurs due to the constant repetitive perpetual motion cycle throughout the operation of the machine. However, the fan blade machinery is harder to monitor 24 hours/7 days manually. The increase in vibration magnitude level has made the machinery experience poor performance. The damage will eventually lead the machine to have a complete failure or breakdown. For an optimum machine performance and long lifespan of the machinery, the blade should undergo the analysis and monitoring process to reduce the vibration magnitude levels and eliminate the potential vibration that cause the machinery undergo difficulties.

Thus, this project aimed at an online vibration monitoring where it can be monitored 24 hours/ 7 days wirelessly which means it can be monitored from everywhere and at any time. Furthermore, there will be notifications that send immediate notification which leads to immediate damage control if reading shows higher vibration level data.

1.3 Research Objectives

The main aim of this monitoring and diagnostic is to

- to measure the vibration conditions of fan blade wirelessly,
- to analyze the fan blade fault vibration data by using Fast Fourier Transform,

- to validate the analyzed data by using coefficient of determination.

1.4 Scope of Research

The project is focused on the measurement of the vibrations of the blade. The vibration ofthe blade is measured under the normal and with fault diagnosis. The data is analyzed via various methods of Vibrational Statistical Analysis. The report is aimed to verify the analysis that has been done by the various analysis methods throughout the machine learning techniques.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Vibration monitoring is a technique for identifying frequency peaks and valleys in machine components that uses vibration sensors and cloud-based software. Measurements of vibration frequently reveal common faults or potential downtime. We can track the severity of these four common faults over time. Severity codes arebased on data taken and analyzed from hundreds of thousands of machines by vibration experts for decades. To that end, professional knowledge and experience are incorporated into rule-based algorithms and a baseline database. This proven method works is effective on standard rotating machines, such as motors, pumps, fans, compressors, blowers, and single-shaft spindles. (Varguez, 2022).

Performing vibration monitoring is complex. Handheld vibration meters or testers are often used for scheduled routes. Furthermore, users frequently require specialized training or the services of third-party experts. Vibration analysis may be too costly for most assets. It is a condition monitoring method that is more flexible with continuous remote, wireless sensors. Monitoring assets with remote sensors is a low-cost, scalable way to increase coverage. For instance, assets in difficult-to-reachor hazardous locations are ideal for condition monitoring.

Finally, vibration monitoring is not an alternative to diagnosing which makes it merely a way to identify that a problem exists and needs diagnosis. Reliability engineers,maintenance managers, and maintenance technicians mostly use vibration sensors topreserve asset health. Installing the vibration sensor on asset allows you to spend less time taking the manual measurement. In addition, there will be more time to address the problems that could lead to downtime or equipment failure (TWI Global, 2023).

Vibration monitoring identifies issues resulting from imbalance, looseness, misalignment, and late stage bearing wear. Therefore, the goal is to collect and analyze the cloud-based vibration data, to find and correct the failures much earlier, to avoid any unexpected downtime, to collect historical data to justify maintenance speed, and to democratize vibration expertise for the non-experts which providing the easy-to-interpret data (Ghazali & Wan, 2021).

2.2 Previous study in machine diagnostics

As the demand for improved performance, safety, and reliability mechanical components develops, machine failure diagnostics is becoming increasingly relevant in the field of monitoring system. Mechanical systems such as wind turbines, planes, bullet trains, and machine tools have emerged as a consequence of scientific and technological advancements. Experts, on the other hand, must devise ways of ensuring the performance of this system in order for them to fulfil the required functions under specific conditions for a specified period of time. These functions include observing machine operating conditions, evaluating if a machine or component is encountering a malfunction or failure,determining the source of the unhealthy condition or failure, analyzing its severity, and detecting abnormalities. Forecasting the condition's continued usable life or tendencies (Pierre Tchakoua, et al., 2014) .

Diagnosing machine failures is an important technique for continuous maintenance as it helps prevent the progression of abnormal events, reduces downtime, predicts remaining life, and reduces productivity losses. is. Therefore, you can avoid major system failures and catastrophes (CHEN, WANG, QIAO, & CHEN, 2018) .

2.3 Mechanism of fault

The foundation of mechanical failure analysis is an understanding of the mechanism of problem technology and propagation. Model-primarily based completely methods frequently appoint physics-specific and express mathematical models of the machines beneath observation. The majority of model-primarily based totally techniques use input- output and statespace fashions to symbolize the system`s general mass, stiffness, and damping matrices, with mechanical faults done via way of means of introducing outside forces into equations. To perform fault analysis on a wide range of rotating machines and composite structures, including gearboxes, bearings, blades, and reducing tools, a number of model-based totally diagnostic techniques, including the analytical method, the finite element (FE) method, and the combined analytical—FE method, are now used (McEvily, 1976) .

2.3.1 Rotating Mechanical

Rotating machines are important in economic and industrial development, and their complexity has grown as manufacturing has progressed. Particularly, the reliability and durability of rotating machines have greatly improved. However, rare failure events regularly cause unexpected shutdowns and substantial financial damage. Model-based approaches to blade complexities consider the model of a custom-built machine, which includes blade, bearing, gear, and foundation sub- models. Furthermore, component-level defect identification is crucial (CHEN, WANG, QIAO, & CHEN, 2018).

In industrial rotation and transport machinery applications, the three basic rotating parts (bearing, gear, and blade) are critical. These components, on the other hand, are prone to failure. Rotating machinery bearings are most common and frequently damaged mechanical parts. Bearing flaws are indicators of other possible weaknesses in mechanical components. Bearing defects can occur as a result of inaccuracy or imbalance, for example. The dynamic modelling of rolling element bearings helps to comprehend the process of vibration formation in a problematic rolling element bearing, and to improve the efficacy of vibration-based monitoring systems and fault diagnostics. The vibration of a faulty bearing is complicated by the time-varying and infrequent dynamic response of bearing elements under high-speed and other complex operational requirements. As a result of these complications, vibration- based diagnosis techniques become more difficult to implement. A dynamic analysis that collectively accounts for intermittent and time-varying movements of bearing components is badly needed to forecast the dynamic response of defective rolling element bearings. Over the last three decades, several researchers have focused on the diagnostic test of blade crack formation in rotating machines. The excellent review papers by Dimarogonas, Wauer, and Gasch cover many aspects of this topic and provide valuable information and knowledge in this field. As guest editors, Bachschmid and Pennacchi edited a crack blades issue of Mechanical Systems and Signal Processing in 2008. One of the most serious issues in this field is the difficulty in designing a crack (N. Bachschmid & Pennacchi, 2008). Many authors have studied the dynamic behaviour of blades with transverse cracks in relation to this. (N. Bachschmid & Pennacchi, 2008) proposed a frequency domain model-based transverse crack identification method to investigate the dynamic behaviour of cracked horizontal blades, which they validated using experimental results obtained on a large test rig. Papadopoulos discussed the strain energy release approach (SERP) for modelling cracks in blades, as well as some of its extensions and limitations. They discovered that when a structure has multiple cracks, the dynamic response becomes more complicated based on the relative positions and depths of these cracks. Sekhar summarised the various studies on double/multi-cracks and mentioned the methods for identifying them in vibration structures such as beams, blades, and pipes. Gasch investigated the dynamics of the Laval blade with a transverse crack. Despite these studies, explicit mathematical modelling for complex systems (CHEN, WANG, QIAO, & CHEN, 2018).