ONLINE MACHINE VIBRATION MONITORING SYSTEM USING WIRELESS INSTRUMENTATION

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B091910047

BACHELOR OF MECHANICAL ENGINEERING TECHNOLOGY WITH HONOURS

2023

Faculty of Mechanical and Manufacturing Engineering Technology

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Bachelor of Mechanical Engineering Technology with Honours

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A project report submitted
in fulfillment of the requirements for the degree of
Bachelor of Mechanical Engineering Technology (BMMV) with Honours

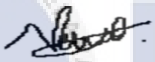
Faculty of Mechanical and Manufacturing Engineering Technology

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2023

DECLARATION

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

Signature : 

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APPROVAL

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

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Supervisor Name : TS. DR. NOR AZAZI BIN NGATIMAN

Date : 06/01/2023

DEDICATION

I dedicate my project to my parents, project supervisor and my friends. A special gratitude to my father, Raja Mohan A/L Gopal and my mother, Ariyamallai A/P Suppiah for both of their support and love for me in completing this research. My eternal thanks goes to my project supervisor Ts. Dr. Nor Azazi Bin Ngatiman for his guidance and teachings throughout the process of completing this project sucessfully. Finally, my heartfelt appreciation goes to my friends who gave me their support, guidance and kind words throughout the process of completing this project.

ABSTRACT

Vibration is something that is unavoidable and will occur in machinery. At any particular time, vibration can be induced by one or more variables, the most prevalent of which are imbalance, misalignment, wear and looseness. To remedy this, vibration signal analysis can be done as it is an effective vibration monitoring system. This project is about monitoring the vibration of rotor machine using wireless instrumentations. Vibration monitoring process was conducted using different types vibration analysis techniques. The blade on the rotor machine was set up in different condition which is normal and fault condition. The fault condition was divided into three which are static imbalance, coupled imbalance and dynamic imbalance. Each of these blade conditions was tested with load and run at five different rotating speeds. The vibration data of the rotor was analyzed and compared, to identify the difference between static imbalance, coupled imbalance and dynamic imbalance. Monitoring the machine's vibration levels allows one to determine the health and condition of the running machine. This project was also conducted to measure the effectiveness of wireless instrumentations compared to wired instruments. Researchers around the world are continuously conducting studies on rotor machine vibrations to improve or propose a solution to problems that arise due to the rotor machine vibrations.

ABSTRAK

Getaran adalah sesuatu yang tidak dapat dielakkan dan akan berlaku dalam jentera. Pada bila-bila masa tertentu, getaran boleh disebabkan oleh satu atau lebih pembolehubah, yang paling lazim adalah ketidakseimbangan, salah jajaran, haus dan kelonggaran. Untuk membetulkannya, analisis isyarat getaran boleh dilakukan kerana ia merupakan teknik pemantauan getaran yang berkesan. Projek ini adalah mengenai pemantauan getaran mesin rotor menggunakan instrumentasi tanpa wayar. Proses pemantauan getaran dijalankan menggunakan teknik analisis getaran yang berbeza. Bilah pada mesin pemutar dipasang dalam keadaan berbeza iaitu keadaan normal dan keadaan yang tidak seimbang. Keadaan tidak seimbang atau rosak telah dibahagikan kepada tiga ketagori iaitu ketidakseimbangan statik, ketidakseimbangan berganding dan ketidakseimbangan dinamik. Setiap keadaan bilah ini dijalankan pada lima kelajuan putaran yang berbeza. Data getaran pemutar telah dianalisis dan dibandingkan, untuk mengenal pasti perbezaan antara ketidakseimbangan statik, ketidakseimbangan gandingan dan ketidakseimbangan dinamik. Memantau tahap getaran mesin membolehkan seseorang menentukan jangka hayat dan keadaan mesin yang sedang berjalan. Projek ini juga dijalankan untuk mengukur keberkesanan instrumentasi tanpa wayar. Penyelidik di seluruh dunia secara berterusan menjalankan kajian tentang getaran mesin rotor untuk menambah baik atau mencadangkan penyelesaian kepada masalah yang timbul akibat getaran mesin rotor.

ACKNOWLEDGEMENTS

In the name of God, the Almighty, the Most Merciful and the Most Gracious

First and foremost, I want to express my gratitude and thanks to my Almighty God, my Creator and Sustainer, for all I have received since the beginning of my existence. I'd like to express my gratitude to Universiti Teknikal Malaysia Melaka (UTeM) for making this research platform available to me.

My utmost appreciation and gratitude goes to my supervisor, Ts.Dr. Nor Azazi Bin Ngatiman, Faculty of Mechanical and Manufacturing Engineering Technology, Universiti Teknikal Malaysia Melaka (UTeM) for all his support, advice and teachings. His unwavering patience in mentoring me and offering invaluable insights and knowledge during the completion of my project will be remembered for the rest of my life.

Last but not least, I wanted to express my deepest gratitude and appreciation to our instructors for their assistance and advice during this degree. I am grateful to University Technical Malaysia Melaka for enabling me to use the laboratory's facilities for the successful completion of my project.

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LIST OF SYMBOLS AND ABBREVIATIONS

R^2	-	R-squared
CM	-	Condition Monitoring
DAQ	-	Data Acquisition
FFT	-	Fast Fourier Transform
FRA	-	Frequency Response Analysis
FBG	-	Fiber Bragg grating strain sensor
WT	-	Wavelet Transform
HHT	-	Hilbert-Huang Transform
WVD	-	Winger-Ville Distribution
STFT	-	Short Time Fourier Transform
Hz	-	Hertz
CPM	-	Cycles Per Minute
RPM	-	Revolution Per Minute
FDD	-	Fault Detection and Diagnostics

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CHAPTER 1

INTRODUCTION

1.1 Background

Excessive vibrations on rotating machines such as turbines, pumps, gearboxes and compressors indicate that the equipment is malfunctioning. Excessive vibrations indicate that the machines will not last as long as it should and this situation can result in unplanned downtime or unsafe situations. As a result, it is critical to determine the source of vibrations by detecting and analyzing vibration data.

Condition monitoring (CM) is a preventative maintenance method that combines machine sensor data that detects vibration and other factors (in real-time) with cutting-edge machine monitoring software to anticipate machine health and safety. This method allows plant maintenance workers to remotely monitor the health of each individual piece of machinery while also providing a holistic view of mechanical operations across the entire facility. When a change in machine health is noticed, condition monitoring software generates an alert, allowing maintenance professionals to quickly examine the problem and determine whether or not corrective action is required. Condition monitoring system that used for this project is online monitoring which is easy to use, save time and more effective compared to off-line monitoring (Benker & Zaeh, 2022).

Machine unbalance results in vibration when the center of gravity of a rotating object is not exactly in the center line. A machine could be damaged including its foundation,

pipelines, and other components if the machine is unbalanced. Static unbalance, coupled unbalance and dynamic unbalance are the three types of unbalance.

A point mass at a given radius from the center of rotation causes static unbalance, which causes an eccentricity in the centre of gravity of a rotor. Static unbalance is classified as single-plane unbalance, which means it is represented by a single vector quantity and rectified by a single correction mass applied in the axial plane of the rotor's mass centre, opposite the unbalance point. If adding (or removing) mass in the same plane as the unbalance is not possible, the correction might be split into two equal adjustments at the rotor's ends to accomplish the same results.

A rotor with a diameter less than seven to ten times its breadth may have a few of unbalances. In the case of a cylinder, two identical masses can be symmetrically positioned around the centre of gravity, but at 180° from each other. The rotor is in static balance (the centre of gravity is not eccentric), but as the rotor rotates, the two masses create a change in the inertia axis, causing it to become misaligned with the rotation axis, resulting in significant vibrations.

The most prevalent type of unbalance observed in rotors is dynamic unbalance, which is a combination of static and pair unbalance. To address dynamic unbalance, vibration measurements must be taken while the machine is working and balancing masses must be added in two planes. Dynamic imbalance is similar to coupled unbalance in that it can only be measured while the portion is rotating. When the central principle axis of inertia is neither parallel to nor meets the shaft axis at the center of mass, dynamic imbalance exists. Only in two or more planes can this be fixed. The typical case of a mix of static and pair unbalance is dynamic unbalance.

1.2 Problem Statement

Rotor is the machine's rotating component. It's attached to a shaft with a key at the end that acts as a lock. Defects can occur in the design of equipment and apparatus such as rotor, during the production process or during the marketing stage, implying that the product does not come with adequate warnings or instructions on how to use it safely. Sometimes, a piece of equipment or machinery will have a number of flaws.

Machine failure causes high maintenance costs. Machinery's performance is poor as a result of the increased magnitude of vibration. This issue could eventually causes the machine to break down or fail completely. This project is mainly focused on how the rotor works and the vibration monitoring of rotor machine in different conditions. Different conditions means that during the vibration monitoring process, the machine blade was set up into few different condition, rotating speed of the machine was changed with constant belt torque applied.

The research aims to analyze the vibration levels of the rotor through machine monitoring and different types of vibration analysis techniques thus enabling better decision making concerning the rotor use and lifespan. This research was done using online monitoring system and wireless instrumentations which are more effective. Vibration analysis data was taken under few types of rotor machine conditions which are using normal blade and fault blade. The fault blade can be divided into static imbalance, coupled imbalance and dynamic imbalance. So, totally four types of conditions were monitored with load under five different rotating speeds which are 400rpm, 800rpm, 1200rpm,1600rpm and 2000rpm.

The research also aimed to prove that wireless vibration sensors are more effective and easy to use then the wired sensors by comparing the results taken. The data from wired sensors are not real time measurement data.

1.3 Research Objective

The main aim of this research is to monitor vibration of rotor machine. Specifically, the objectives are as follows:

a) To analyze the vibration signals of different rotor conditions which are normal condition, static imbalance condition, coupled imbalance condition and dynamic imbalance condition.

b) To measure the vibration of rotor machine with different type of vibration analysis techniques using Industrial Revolution 4.0 online monitoring.

c) To find out the effectiveness and advantages of wireless vibration signal sensors.

1.4 Scope of Research

The scope of this research are as follows:

- Monitor the vibration of rotor machine using different types of vibration analysis techniques. Rotor was set up in different conditions by changing the amount of load on rotor, changing the rotating speed of rotor with constant belt torque.
- Analyze and compare the vibration signals of the rotor to identify the difference between static imbalance, coupled imbalance and dynamic imbalance.
- Measure the effectiveness of wireless sensors for vibration measurements.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The theory and information that needed which is related to the scope of the projects will be discussed in this chapter. Other than that, discussion regarding the information and methods used in earlier research is also revised. In this chapter, the equipment and software related to the project that is Vibration Analysis on rotor machine are explained in this chapter. Various researchers have designed this analysis system. The literature review is perusing of the works of other before initiating on examination work to acquire significant data and information and comparable projects done by others. The sources are taken from previous thesis, journal, conference paper, books and also the Internet. All the related topics were collected and is discussed in this chapter. The pattern of energy used can be clearly seen and explained.

2.2 DigivibeMX Version 11

DigivibeMX is a versatile, multi-functional software capable of analyzing machine vibration in real time, performing traditional route data collection and balancing single-plane or two-plane rotors in-situ or on Soft Bearing Suspension balancing machines. The software features offered to the user are determined by the DigivibeMX model purchased. DigivibeMX combines comprehensive machine health monitoring capabilities with simple features and visual interfaces that are easy to understand. For unskilled users, the software delivers quick capabilities, while for expert users needing a full range of analysis skills, the software provides more advanced tools

2.3 Needs for Vibration Analysis On Rotor Machine

The modern lifestyle that is practice has become the requirement for the modern tools meet the demand the current modern lifestyle. Subsequently, the vibration analysis system on rotor machine has become a challenge to society in industrial sector. This system is a very new to the industry and not many of the company uses this system for their industries. Therefore, this vibration analysis system on rotor machine can help save time and energy (Kulac, 2019). This can be achieved by using this vibration analysis system on rotor machine will help to observe the real time data from the machine at anytime and anywhere. Furthermore, this system gives a very detailed and precise data.

2.4 Vibrations in a Machinery

Naturally machinery tends to vibrate, even the ones which are optimally working. Each machine has a vibration level that can be considered typical. However, the machine vibration level might sometimes increase or become excessive. The most common cause is mechanical failure. Unbalance, misalignment, worn gears or bearings and other factors can cause excessive vibration. With the use of sensors, the machine's vibration level can be detected. The most common application of accelerometers is vibration analysis. Data capture, feature extraction and problem identification are the steps involved in rotating machine failure diagnostics

Due to these minuscule problems, the vibrations that are produced can be inferred as expected vibrations or innate vibrations. Only when these vibration levels increase that problems arise as well. As mentioned before, vibration’s magnitude can increase due to several factors such as cracks, misalignment, unbalance, excessive loads, high temperature and along with others. Vibrations have a drastic effect on the performance of a machine, equipment or system where it can cause parts to become undone or loose, loose efficiency

and may lead to noise pollution. Vibrations also effects the comfort of oneself as the vibrations may be heard or felt outside by a person if it is in excessive amount. Unacceptable vibration levels and stress are generated due to rotating unbalance in individual and support structures.

2.5 Rotating Electrical Machine

A stator, rotor and the air gap between them make up a rotating electrical machine. Windings are found on the stator and rotor. The stem connects to the motor and any other loads after the rotor is attached. The electrical current that generates magnetic fields for the electrical load is carried via the windings. Machinery fault simulator(MFS) which is a machine used for diagnosis of rotating machinery.

2.5.1 Machinery Fault Simulator (MFS)

The Machinery Fault Simulator (MFS) is an innovative tool developed to examine the signs of typical machinery problems without jeopardising production schedules or profits. Unbalance, alignment, resonance, bearing, rotor dynamics, crack shaft, gearbox, belt drive, reciprocating mechanism, mechanical rub, induction motor, pump, compressor and fan are all examples of frequent machinery faults. The MFS is the finest tool for learning machinery diagnostics since various faults can be introduced individually or in groups in a completely controlled environment. Cocked Rotor (CR), Left Eccentric Rotor (LER), and Right Eccentric Rotor (RER) are the three types of rotor faults in MFS.

2.5.1.1 Rotor

A rotor is an important part of almost every mechanical system. A rotor unit is a shaft with a flange, disc or gear running down its axis that is supported by bearings. Many discs or other things could be attached on the shaft. Because nearly all machine systems entail motion transfer from linear to rotary or vice versa, a rotating shaft (a rotor) might be