DEVELOPMENT OF ONLINE CONDITION MONITORING SYSTEM FOR INTEGRATED VIBRATION ASSESSMENT AT FACTORY

NIK MUHAMMAD KHAIRI BIN NIK KHALID
B091810471

BACHELOR OF MECHANICAL ENGINEERING TECHNOLOGY (MAINTENANCE TECHNOLOGY) WITH HONOURS

2021

Faculty of Mechanical and Manufacturing Engineering Technology

DEVELOPMENT OF ONLINE CONDITION MONITORING SYSTEM FOR INTEGRATED VIBRATION ASSESSMENT AT FACTORY

Nik Muhammad Khairi Bin Nik Khalid

Bachelor of Mechanical Engineering Technology (Maintenance Technology) with Honours

2021

DEVELOPMENT OF ONLINE CONDITION MONITORING SYSTEM FOR INTEGRATED VIBRATION ASSESSMENT AT FACTORY

NIK MUHAMMAD KHAIRI BIN NIK KHALID

A thesis submitted
in fulfillment of the requirements for the degree of
Bachelor of Mechanical Engineering Technology (Maintenance Technology) with Honours

Faculty of Mechanical and Manufacturing Engineering Technology

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2021

DECLARATION

I declare that this Choose an item.entitled " Development Of Online Condition Monitoring System For Integrated Vibration Assessment at Factory " is the result of my own research except as cited in the references. The Choose an item. has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature	:	
Name	:	Nik Muhammad Khairi Bin Nik Khalid
Date	:	17 January 2022

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 (Maintenance Technology) with Honours.

Signature : 

Supervisor Name : Ts. Dr. Ahmad Fuad Bin Ab Ghani

Date : 17 January 2022

DEDICATION

I dedicate my dissertation work to my family and all my friends. A special feeling of gratitude to my loving parents, Rohayati Binti Manap and Nik Khalid Bin Nik Pa whose words of encouragement and push for tenacity ring in my ears. They have never left my side and are very special. I also dedicate this dissertation to my supervisor and lecturer who have supported me throughout the process. I will always appreciate all they have done, for helping me develop my technology skills.

ABSTRACT

The continuity of machine operation is very important to ensure that the manufacturing sector remains intact. To maintain and preserve the manufacturing sector requires a well - functioning machine condition. the main problem in the industrial sector today is the unexpected failure of machine operation resulting in the machine not being able to be used optimally and forcing the industry to incur the cost of ongoing maintenance and repair of the machine. Significant changes in machine condition due to machine failures and malfunctions can be overcome with efficient machine condition monitoring. Efficient surveillance for condition monitoring and rapid detection of mechanical damage is an essential task. Vibration monitoring is an important technique among the various condition monitoring technique to predict the working condition of any machine. Identifying damage to the machine can be analyzed through early warning if the vibration analysis is done correctly. The reliability maintenance should also be emphasized in monitoring the condition of the machine depending on the accuracy of the measuring instrument. A malfunctioning machine condition can shorten the lifespan of the machine and result in major failures occurring, but the unique benefits of condition monitoring of the machine are able to overcome this problem. Some types of machine condition monitoring systems that are available and are on the market involve relatively high overall costs and are detrimental to the industry. Existing machine condition monitoring systems identified for vibration using piezoelectric acceleration. Therefore, research studies are needed to develop an inexpensive machine condition monitoring system. Through this study, to ensure lower power consumption and lower production costs can be achieved, micro electro mechanical system (MEMS) was identified to be used as a potential alternative to conventional systems. In addition to the cost can be reduced, this study was made to ensure that this monitoring system does not affect the accuracy and reliability of measurements.This online machine condition monitoring system for analyzing machine vibration has two parts. Where, the first part is the acquisition of temporary data. Data acquisition can be developed based on micro-electro-mechanical systems (MEMS). For the second part, the data obtained should be transmitted and diagnostic. Software that can be integrated with data acquisition will be developed based on the C ++ programming language. Functional prototypes are then tested at actual work locations where performance and accuracy assessments can be made.

ABSTRAK

Kelangsungan operasi mesin sangat penting untuk memastikan sektor pembuatan kekal utuh. Untuk mengekalkan dan memelihara sektor pembuatan memerlukan keadaan mesin yang berfungsi dengan baik. Masalah utama dalam sektor perindustrian hari ini adalah kegagalan operasi mesin yang tidak dijangka menyebabkan mesin tidak dapat digunakan secara optimum dan memaksa pihak industri menanggung kos penyelenggaraan dan pembaikan mesin secara berterusan. Perubahan ketara pada keadaan mesin disebabkan oleh getaran dan kerosakan mesin dapat diatasi dengan pemantauan keadaan mesin yang cekap. Pengawasan yang cekap untuk pemantauan keadaan mesin dan pengesanan kerosakan mekanikal yang cepat adalah tugas penting. Pemantauan getaran adalah teknik penting di antara pelbagai teknik pemantauan keadaan mesin untuk meramalkan keadaan pengeoperasian mesin. Mengenal pasti kerosakan pada mesin dapat dianalisis melalui amaran awal jika analisis getaran dilakukan dengan betul. Penyelenggaraan kebolehpercayaan juga harus dititikberatkan dalam memantau keadaan mesin bergantung pada ketepatan alat pengukur. Keadaan mesin yang tidak berfungsi dengan baik dapat memendekkan jangka hayat mesin dan mengakibatkan kegagalan besar berlaku dimasa hadapan, tetapi kelebihan unik pemantauan keadaan mesin dapat mengatasi masalah ini jika dilakukan. Beberapa jenis sistem pemantauan keadaan mesin yang tersedia dan berada di pasaran melibatkan kos keseluruhan yang agak tinggi dan merugikan pihak industri. Sistem pemantauan keadaan mesin sedia ada yang mengenal pasti getaran pada mesin adalah menggunakan pecutan piezoelektrik. Oleh itu, kajian penyelidikan diperlukan untuk mengembangkan sistem pemantauan keadaan mesin yang murah. Melalui kajian ini, untuk memastikan penggunaan tenaga yang lebih rendah dan kos pengeluaran yang lebih rendah dapat dicapai, sistem mekanik mikro elektro (MEMS) dikenal pasti digunakan sebagai alternatif yang berpotensi untuk menggantikan sistem konvensional sedia ada. Selain objektif utama untuk mengurangkan kos penyelenggaraan dan membaik pulih mesin, kajian ini dibuat untuk memastikan bahawa sistem pemantauan ini tidak mempengaruhi ketepatan dan kebolehpercayaan pengukuran. Sistem pemantauan dan menganalisis getaran mesin dalam talian ini mempunyai dua bahagian. Di mana, bahagian pertama adalah pemerolehan data sementara. Pemerolehan data dapat dikembangkan berdasarkan sistem mikro-elektro-mekanikal (MEMS). Untuk bahagian kedua, data yang diperoleh harus dihantar dan diagnostik. Perisian yang dapat diintegrasikan dengan pemerolehan data akan dikembangkan berdasarkan bahasa pengaturcaraan C ++. Prototaip yang dibangunkan kemudian diuji di lokasi kerja sebenar untuk memastikan penilaian prestasi dan ketepatan dapat dibuat.

ACKNOWLEDGEMENTS

In the Name of Allah, the Most Gracious, the Most Merciful

First and foremost, I would like to thank and praise Allah the Almighty, my Creator, my Sustainer, for everything I received since the beginning of my life. I would like to extend my appreciation to Universiti Teknikal Malaysia Melaka (UTeM) for providing the research platform. Thank you also to the Malaysian Ministry of Higher Education (MOHE) for the financial assistance.

My utmost appreciation goes to my main supervisor, Ts. Dr. Ahmad Fuad Bin Ab Ghani, Faculty of Mechanical and Manufacturing Engineering Technology, Universiti Teknikal Malaysia Melaka (UTeM) for all his support, advice and inspiration. His constant patience for guiding and providing priceless insights will forever be remembered. Also, to my co-supervisor, IR. Dr. Fudhail Bin Abdul Munir, Universiti Teknikal Malaysia Melaka (UTeM) who constantly supported my journey. My special thanks go to our partners for all the help and support I received from them.

Last but not least, from the bottom of my heart a gratitude to my beloved parent, Rohayati Binti Manap and Nik Khalid Bin Nik Pa, for their encouragements and who have been the pillar of strength in all my endeavors, for their endless support, love and prayers. Finally, thank you to all the individual(s) who had provided me the assistance, support and inspiration to embark on my study.

TABLE OF CONTENTS

		PAGE
DECLARATION		
APPROVAL		
DEDICATION		
ABSTRACT		**i**
ABSTRAK		**ii**
ACKNOWLEDGEMENTS		**iii**
TABLE OF CONTENTS		**iv**
LIST OF TABLES		**vi**
LIST OF FIGURES		**vii**
LIST OF SYMBOLS AND ABBREVIATIONS		**ix**
LIST OF APPENDICES		**x**
CHAPTER 1	**INTRODUCTION**	**11**
1.1	Background	11
1.3	Problem Statement	15
1.4	Research Objective	15
1.5	Scope of Research	16
1.6	Hypothesis / Research Question	16
CHAPTER 2	**LITERATURE REVIEW**	**18**
2.1	Introduction	18
2.2	Condition Monitoring System (CMS)	19
2.3	Vibration Analysis	23
2.4	Micro - Electro - Mechanical (MEMS)	27
2.5	Summary or Research Gap	31
CHAPTER 3	**METHODOLOGY**	**34**
3.1	Introduction	34
3.2	Research Design	37
3.3	Proposed Methodology	43
	3.3.1 Experimental Setup	45
3.4	Summary	52
CHAPTER 4	**SYSTEM DEVELOPMENT**	**53**
4.1	Introduction	53
4.2	Hardware Development : Online Vibration Monitoring Devices	54

4.2.1 Hibiscus Sense ESP32 Development Board 56
4.2.2 Power Supply for Hibiscus Sense ESP32 59
4.3 Software Development : Blynk Platform 66

CHAPTER 5 RESULTS AND DISCUSSION 67
5.1 Introduction 67
5.2 Designing Of Arduino Based On MPU6050 Accelerometer 68
5.2.1 Specification Of The System 69
5.2.2 Modelling Of The System 72
5.3 Result Analysis and Critical Design Review 73
5.3.1 Data Collection 73
5.3.2 Data Sending To Blynk 73
5.3.3 Experimental Data Collection 75
5.3.4 Comparing Data Analysis 81
5.4 Impact of this proposed model 84

CHAPTER 6 CONCLUSION AND RECOMMENDATIONS 85
6.1 Conclusion 85
6.2 Limitation and Future Improvement 87

REFERENCES 88

APPENDICES 91

LIST OF TABLES

TABLE	TITLE	PAGE
Table 2.1	Common parameters used as indicators of machine condition	25
Table 2.2	Summary of previous researcher findings	31
Table 3.1	Overall Research Plan	35
Table 3.2	Gantt Chart for PSM 1	41
Table 3.3	Gantt Chart for PSM 2	42
Table 4.1	Differentiation Between The Types of Accelerometers	55
Table 4.2	Technical Limit voltage of ESP32	61
Table 4.3	Technical limit of voltage regulator	61
Table 4.4	LiPo battery specification	62
Table 4.5	Data Analysis Acceleration and Frequency for Hibiscus Sense ESP32	76
Table 4.6	Data Analysis Acceleration and Frequency for Vibrometer	81
Table 4.7	Comparison Between Proposed and Existing Accelerometers	83

LIST OF FIGURES

FIGURE	TITLE	PAGE
Figure 3.1	Show the research design of this thesis	38
Figure 3.2	Waterfall Development Method	39
Figure 3.3	Block Diagram of the system	44
Figure 3.4	Overall system layout	45
Figure 3.5	Example of MEMS Sensor	46
Figure 3.6	Flowchart of Microcontroller Firmware	48
Figure 3.7	Flowchart of the desktop software	50
Figure 4.1	Online Vibration Monitoring devices	54
Figure 4.2	Hibiscus Sense ESP32	56
Figure 4.3	Hardware Overview	58
Figure 4.4	Pinout Diagram	58
Figure 4.5	ESP32 Voltage overview	60
Figure 4.6	LiPo Battery	62
Figure 4.7	3.7V to 5V Step-Up Boost Converter Module	63
Figure 4.8	TP4056 Battery Charger Module	64
Figure 4.9	Circuit diagram of power supply ESP32	65
Figure 4.10	Flowchart of Blynk Platform	66
Figure 4.11	Basic Sytem block diagram	69
Figure 4.12	Flow Chart for MPU6050 data sensing operation	70
Figure 4.13	Flowchart for Blynk Data Analysis Process	71
Figure 4.14	Flow chart for Blynk Data Analysis Process	72

Figure 4.15 MPU6050, ESP32 NodeMCU and Arduino in Hibiscus Sense ESP32 73

Figure 4.16 Blynk App on the mobile phone 74

Figure 4.17 Blynk App on the web dashboard 75

Figure 4.18 Experimental Result Graph Acceleration in X – axis versus time 77

Figure 4.19 Experimental Result Graph Acceleration in Y – axis versus time 77

Figure 4.20 Experimental Result Graph Acceleration in Z – axis versus time 78

Figure 4.21 Experimental Result Graph Frequency for X-axis versus magnitude 78

Figure 4.22 Experimental Result Graph Frequency for Y-axis versus magnitude 79

Figure 4.23 Graph Acceleration Acceleration versus time for Vibrometer 82

Figure 4.24 Graph Frequency for Vibrometer Y-axis versus magnitude 82

LIST OF SYMBOLS AND ABBREVIATIONS

a	-	Acceleration
v	-	Velocity
d	-	Displacement
MEMS	-	Micro - Electro - Mechanical System
f	-	Frequency
Ms^{-2}	-	Meter per second square

LIST OF APPENDICES

APPENDIX	TITLE	PAGE
APPENDIX A	Approval for Lab Experiment	91

CHAPTER 1

INTRODUCTION

1.1 Background

Reliability maintenance is one of the strategies in maintenance to ensure that each machine can operate properly on an ongoing basis and get rid of higher repair costs resulting in delayed manufacturing operations. The principle for reliability maintenance is to maintain the functioning of the machine system and to identify possible faults that may affect the functioning of the machine system. Reliability maintenance requires a process to identify the right maintenance with the right equipment at the right time before complete system failure.

One of the steps to ensure reliability maintenance can be achieved is to perform condition monitoring of the machine in real- time conditions to determine the maintenance that needs to be done. Maintenance can only be performed when these real-time indicators show deviations or signs of performance decline. The effectiveness and performance of the machine to the optimum level can be assisted by monitoring the condition of the machine.

For machine condition diagnostics using condition monitoring techniques. The analysis of signals or condition data required often focuses on vibration, torque, rotational speed, flow rate, voltage, current, temperature or humidity. It is important to maintain competitiveness in the manufacturing industry by performing predictions and prognosis of machine working conditions about its failure through online diagnosis. There have been various efforts as well as studies done continuously throughout this decade to improve monitoring techniques to detect machine failures early on.

Signal spectrum analysis has often been used previously for machine health diagnostics as one of the monitoring techniques. Machine condition monitoring can be used with vibration analysis method. Effective vibration signal extraction techniques play an important role in diagnosing machine function failures. Vibration analysis can be described as a process to measure the level of vibration frequency that occurs in the machine and the data obtained through the vibration is analyzed to determine the state of health of the machine and its components in operation.

Vibration signals and spectra as well as waveforms can change significantly if there is damage to the machine and some dynamic processes of the machine change such as rotating speed or workload although the vibration signal generated when the machine is operating properly is weak but consistent. In the past, Diagnosis of machine failure was usually based on recruitment time and laboratory training through relatively complicated data acquisition and analysis and inefficient computer techniques. Yet the vibration signal spectrum of the machine is capable of indicating the deterioration state of the machine immediately.

Vibration sample analysis on machines has been used for many years in traditional condition monitoring techniques that have been used in laboratories or factories to detect machine failures. However, this traditional machine condition monitoring technique cannot be operated remotely nor can the online network and the machine will not be able to be monitored continuously in the long run. Through traditional machine condition monitoring procedures, computers as well as specialized devices are used at pre -planned times to collect machine working condition data. The machine condition monitoring center will receive sample data to make further process. Then, the condition of the machine will be diagnosed to predict or determine the failure or damage that occurs to the machine. At the end of this traditional technique, maintenance work will be scheduled or determined according to the

condition of the machine that has been analyzed. Such traditional machine condition monitoring techniques can also be known as schedule -based diagnosis.

This is because, the technique is not very orderly, and the experience of the maintenance engineer is at stake in determining the diagnostic results of the machine fault and making preventive maintenance. Good diagnostic results cannot be generated and are unreliable due to traditionally outdated machine condition monitoring techniques through data samples. Approaches have been taken to ensure more efficient real -time and remote machine condition monitoring techniques to meet the relatively high demand from the industry in the face of global competition and technological developments.

Remote and advanced machine condition monitoring systems can be developed through the support of the latest advances in computer technology and internet. For example, through previous studies, (Jamil et al., 2014; Wahid et al., 2006) suggested vibrations generated using cables to analyze vibrations in machine condition monitoring systems. However, the cable is not suitable for use in monitoring the condition of the machine especially in remote and isolated conditions. Therefore, wireless data transmission media is becoming more popular in line with the ever -increasing pace of the industry. Various researcher using MEMS acceleration have successfully achieved results, among which two out of three different experiments have been performed by (Albarbar et al., 2008) to be applied in machine condition monitoring systems.

The proposed approach as well as research to improve the machine condition monitoring system shows great potential to increase production without any overall machine failure and even maintenance costs can be saved if compared to the machine condition monitoring system based on conventional schedule in maintenance strategy.

1.2 Significance of the study

This study was conducted mainly for those who are directly involved with the monitoring of the condition of machines in the manufacturing industry who are able to perform their duties effectively with a directed maintenance strategy. Meanwhile, for those who are indirectly involved with the program will be able to understand more about the importance of maintenance systems based on condition monitoring. For those who are interested in implementing maintenance programs, especially in condition monitoring, it is hoped that this study will be able to provide benefits. Condition monitoring studies are very important to ensure that you are able to handle the maintenance situation by monitoring the condition of the machine before more severe damage will occur and choosing an effective way to monitor the condition of the machine.

The life cycle of the machine, reducing the financing of damage costs and reducing the risk of harm to personnel and assets can be overcome with practice, applying maintenance procedures and good knowledge in the machine maintenance program. Through the expected results of the study and the conclusions that will be made, it is hoped that the maintenance program can be improved as well as obtain accurate data to make decisions in the selection of maintenance systems that can be applied in the factory.

1.3 Problem Statement

There are various measurement systems mainly for detecting and analyzing vibration. Vibration is often measured using piezoelectric sensor. Yet some have questioned the effectiveness and reliability of the development of an online monitoring system for machine vibration using MEMS sensors compared to piezoelectric sensor in providing results.To obtain high accuracy in low frequency and relatively large vibration amplitude, measurement of the vibration method using a piezoelectric sensor makes it possible but due to the high inertia, the waveform of the signal is distorted which makes high frequency measurement unworkable, small amplitude vibrations. The study focused to introduce a model of monitoring system for machine vibration using Micro - Electro - Mechanical (MEMS) sensor to justify the success. In developing online monitoring systems for machine vibration, problems in software capabilities used, programming languages, external circuits, outputs and types of experimental signals confirmation should be taken into consideration.

Conventional methods for analyzing machine vibrations that use piezoelectric acceleration usually involve high costs. However, due to use Micro - Electro - Mechanical (MEMS) sensor in online monitoring system, the development of this monitoring systems is seen as a potential alternative to conventional systems as it has lower power consumption, light weight and lower production costs. It is hoped that costs can be significantly reduced without affecting the accuracy and reliability of measurements.

1.4 Research Objective

There are several objectives to be achieved in this project and these objectives are defined as shown below:

i. To develop an online monitoring system for machine vibration that is based on Micro-Electro-Mechanical System (MEMS) sensor vibration measurement . The system should be able to easily acquire the signal, process the signal and display the signal from the output of the MEMS sensor for analysis using the same programming platform and highly accurate measurement through the online monitoring system.

ii. To fabricate and validate the working prototype a low cost online monitoring system for machine vibration analysis. The system must approach for minimizing cost & down time of the system breakdown.

iii. To evaluate working prototypes of online monitoring systems developed in actual workplaces and ensure assessments of performance and accuracy can be made without affecting the accuracy and reliability of measurements.

1.5 Scope of Research

The scope of this research are as follows:

i. Analyze vibration based on condition monitoring system

ii. Vibration based condition monitoring in real time condition

iii. The machine vibration state monitoring system was developed only by using Micro - Electro - Mechanical (MEMS) as the sensor.

1.6 Hypothesis / Research Question

Conventional real -time monitoring systems for vibration that use piezoelectric acceleration are expensive and bulky. Therefore, micro - electro - mechanical systems

(MEMS) are seen as a potential alternative to conventional systems as they have lower power consumption, light weight and lower production costs. It should that by using MEMS in online monitoring systems, costs can be significantly reduced without affecting the accuracy and reliability of measurements.

Research Questions :

i. How reliable is the MEMS sensor as compared to piezoelectric accelerometer in giving results for online monitoring system?

ii. Can the cost of the system be reduced significantly?

iii. Why measurement results should be relayed in real time dimension?

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this modern industrial era, current industrial demands require the evolution of mechanical systems, data acquisition and analysis techniques, and sensors, which need to be more accurate than previous eras. Exerted forces and motions are characteristics found in a mechanical system. To ensure the performance of these mechanical systems is increased, sensors are often used to compute measurements through data acquisition, motion analysis and mechanical forces (Koene et al., 2020). Understand the behavior of the machine especially the rotating machine, a condition monitoring system is essential. (Juan Carlos A et al.,2020). Making maintenance decisions requires accurate and relevant data to be properly collected and analyzed. Therefore, determination of the condition monitoring system, vibration analysis is still seen as the best and reliable technique among other measurement systems. The designed monitoring system must be robust and reliable. Besides, online condition monitoring is creating a new dimension in modern technology. Real -time measurements can be obtained at all times by monitoring sensors and software connected to the wireless internet. Then, the integrated software will analyze the obtained measurement data and for the storage of historical data sets. In this chapter, review the study of technological developments in machine condition monitoring.