UNIVERSITI TEKNIKAL MALAYSIA MELAKA

PERFORMANCE COMPARISON OF MULTI PIEZO-BASED SENSORS ON INTERNAL COMBUSTION ENGINE FOR CONDITION MONITORING

This report is submitted in accordance with the requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor of Mechanical Engineering Technology (Maintenance Technology) with Honours.

By

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ABSTRAK

Pemantauan keadaan adalah kaedah untuk menganalisis pengesanan kerosakan enjin, digunakan secara meluas dalam kereta dan perindustrian. Pemantauan keadaan ini pada dasarnya terdiri daripada rakaman dan pengukuran nilai keseluruhan getaran dan parameter biasa. Ia membolehkan diagnosis keadaan mesin umum. Pemantauan keadaan juga memberi manfaat dalam penyelenggaraan pencegahan meminimumkan kos pembaikan. Kajian ini membentangkan Perbandingan Prestasi Piezo Berbilang Sensor Berbasis Pada Enjin Pembakaran Dalaman untuk Memantau Keadaan. Sensor pelbagai yang digunakan adalah pecutan, komposit makro serat dan sensor filem piezoelektrik. Hasilnya menunjukkan bahawa, parameter yang digunakan boleh dioptimumkan dengan menggunakan analisis isyarat, dan menganalisis menggunakan analisis statistik dan kaedah perisian Matlab dan Labview. Ia boleh membuktikan ketepatan parameter yang sedang dikaji oleh pengeluaran data.

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ABSTRACT

The condition monitoring is a method to analyse the fault detection of the engine, is widely used in automobile and industrial. This condition monitoring essentially comprises the recording and measurement of the typical overall value of vibration and parameter. It allows the diagnosis of the condition for a general machine. The condition monitoring also benefits in preventive maintenance as minimizing the cost of repair. This study presents about Performance Comparison of Piezo-based Multi Sensors On Internal Combustion Engine for Monitoring Condition. The multi-sensors used is accelerometer, macro-fiber composite and piezoelectric film sensor. The result demonstrates that the parameters used can be optimized by using signal analysis and analyze using statistical analysis and Matlab and Labview software method. It can prove the parameter accuracy that is being studied by the production of the data.

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DEDICATION

The dedication I want to thanks to all people that hard to help me in complete my thesis. Special appreciation to my beloved father and mother Saffiee Bin Dris and Norida Binti Yusop and my family, that always gives moral support. Also, thanks to my supervisor Mr Irman Bin Ramli and Mr Azazi Ngatiman always help me in giving an idea and supervised me in conducting the project. Not to forget to thanks, my fellow friend.

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LIST OF ABBREVIATIONS

DoF	Design of Freedom
EMS	Engine Monitoring System
VSA	Vibration Statistical Analysis
HEV	Hybrid Electric Vehicles
ICE	Internal Combustion Engine
IC	Internal Combustion
CCD	Charge Couple Devices
PSD	Position Sensitive Detector
DC	Direct Current
AC	Alternating Current
ACC ENV	Accelerometer Envelope
HFD	High Frequency Demodulation
SEE	Spectral Emitted Energy
ICP	Integrated Circuit Piezoelectric
CF	Crest Factor
CBM	Condition Based Maintenance
LPF	Low Pass Filter
HPF	High Pass Filter
Abs	Absolute

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FFT	Fast Fourier Transform
Log	Logarithm
IFFT	Inverse Fast Fourier Transform
RMS	Root Mean Square
MSE	Mean Square Error
MAPE	Mean Absolute Percentage Error
RMSE	Root Mean Square Error
APE	Absolute Percentage Error
AI	Artificial Intelligent
ES	Skill System
SVM	Support Vector Machine
BN	Bayesian Network
TCM	Texture Curing Machine
KMC	K-means Clustering
SA	Statistical Analysis
PCA	Principle Component Analysis
PLSR	Partial Least Squares Regression
SPE	Square Prediction Error
DAQ	Data Acquisition

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CHAPTER 1

INTRODUCTION

1.1 Overview

Firstly, this project is about performance comparison of multi-sensor on internal combustion engine for condition monitoring. The project will conduct by using signal analysis to identify the fault in the engine by using a piezoelectric film sensor, accelerometer and macro-fiber composite as a detector of the faults. Other than that, statistical analysis is implement in this project to determine the reliability and performance of multi-sensors that could be applied in condition monitoring for fault detection and diagnosis of abnormal engine condition in practice. This is an understanding of the wear processes occurring during a laboratory engine test in order to determine the application of various condition monitoring will be applying.

As the goal that represented in the project, this study is to determine the performance of the multi piezo-based sensors and to monitor the condition of internal combustion engine. The analysing are required to obtain the signal in providing valuable information. This project involves two main procedures include the collecting data as well as analyse the data. The sensor is attached at the running engine, and the signal will transfer to the data acquisition. Data acquisition will convert the data and filter it and perform the data into fast furrier transform as to identify the best method were used.

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1.2 Background Study

In a mechanical system, vibration is a very commonly happen. There was example of vibration which is the vibration of the varying speed of a vehicle engine and vibration of the rotor due to unbalance mass. In understanding the fundamental and advanced concepts of mechanical vibration for engineering and designer, there are required to study of a dedicated course. However, this is a basic course level. As focusing at the engine, the fundamental of vibration was introduce free and forced, damped and undamped vibration, the vibration of single Degree of Freedom (DoF) system, 2-DoF and multi-DoF system and also the theory of absorbers vibration and instrument of vibration.

The engine is a designated motor that converting energy to useful mechanical motion which is electrical energy converted to mechanical motions. Gasoline engine is also known as petrol engine and also internal combustion engine with ignition spark. This engine was designated to run on the petrol and similar volatile fuel. Before compressing the fuel, there are pre-mixed the fuel and air in most of petrol engine. The pre-mixed were done in electronically fuel injection now, but before this, it was formerly done in carburettor. In between gasoline engine and diesel, gasoline can run at higher speed compared to diesel. Partially, due to their light piston connecting rod and crankshaft also fast burning petrol compare to diesel.

Nowadays, fault diagnosis is broadly used in real life. It was used in many areas where investigated and applying such as electrical motor, dynamic system and an analogue system. There are specific tools used in approaching to develop the intelligent fault diagnosis. As an example, a statistical method is applying in analysis fault diagnosis. Due to its efficiency and information in the uncertain fuse, the evidence theory is used in broadly in many real systems instead of investigation. As an example reliability analysis,

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uncertainty measure, and failure mode evaluation. Moreover, evidence theory has a limitation for conflicting evidence sometimes as the application of evidence theory. There a specific method is proposed to handle the conflicting evidence.

The engine monitoring system (EMS) is an advanced acoustic emission based monitoring system and cylinder pressure. The flywheel is pickups of ultimate quality and accuracy where the system is incorporating sensors. It was designated for all type of engine two or four-stroke at the slow speed, medium and high-speed engine even V-type engines. The engine monitoring system (EMS) is allowing real-time engine measurement and tuning which has turned any computer into a gasoline engine combustion analyzer. This monitoring system can be used in a monitor as many petrol engines that may exist on board vessels.

In this project, the statistical method being introduced where it can be used in all kind of research problem. There is a role that playing in the summarizing and describing observed variables and relationship between variables as a focus in statistical concepts a technique. Besides, to generalizing the results as well as for a larger group that an observation group. The third theme pertains used various statistical techniques to analyse and observed the data. In consideration of using a standard method which to deal with an above stated question, there is some best practice statistical method will be introduced.

1.3 Problem Statement

The various type of sensor has been developed nowadays, it has a different type of use. In vibration analysis, the sensor is important in detecting a fault for a vibration analysis where the data would be transfer to signal process. The sensor has a lot of types where the user of it is specifically to the method are used in the project. The characteristic

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of the sensor is the part of the selection of a sensor to use. In the vibration sensor, there has a few types of sensor that related to the vibration. Therefore, the multi-sensor of vibration sensor is developed to study the effectiveness or sensitivity toward any resistance beside to make a comparison with another sensor as the most effective to detect the fault through the vibration of the engine.

1.4 Objective

The objective of this project is:

1. To measure the vibration of the engine by using multi-sensor such as piezoelectric film, accelerometer, and macro fiber composite.
2. To analyse collected data by using vibration statistical analysis (VSA).
3. To identify the best sensor to be used as a transducer for engine combustion processes.

1.5 Scope

A coordinated scope of work needs to be done in order to develop a fault diagnostic using multi-sensor. By determining the scope of this project, it believes that the objectives can be achieved. Below is the scope of work in this project:

1. To study the difference of structure-borne and airborne in noise analysis.
2. Analysing the effectiveness of the multi-sensor as a fault monitoring.
3. The analysis will be carried by varying the purpose of fault diagnostic of the engine in order to obtain the experiment results.

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1.6 Significant Study

The results of the study will be of great benefit to the following:

1. To study the best sensor will apply to monitor the faults of gasoline engine condition.
2. To study the comparison between the multi-sensor regarding price, space saving, heat resistance and more characteristics of the sensor.
3. To study the analysis of the sensor through the result of the multi-sensor as the best multi-sensor will be applied to detecting faults of gasoline engines.

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CHAPTER 2

LITERATURE REVIEW

2.1 Literature Overview

Literature review needs to be done at the start before proceeding to the project. Having a current knowledge for extensive for this project is important. In other word, it is the reading of the work before connection and proceeds to the project. Wider knowledge will have a better understanding if the literature review is properly made about the project. Literature can be found from the sources that categories as primary sources and secondary sources. As an example of the sources is books, magazine, journal, thesis and some more reference has been proved. This chapter will study some project that related to Hybrid Electric Vehicles (HEV) of Internal Combustion Engines (ICE) fault diagnostic using multi-sensor.

2.2 Internal Combustion Engine

Internal combustion engine (ICE) is a device in part of the reactants of combustion (oxidizer and fuel and produced from the working fluid of the engine. The oxidizer-fuel mixture happens due to non-reacted working fluid as an engine increased its energy from heat released during the combustion. Internal-Combustion (IC) causes from work generated acting on the moving surface of the engine and the hot gaseous produced of combustion. As an example, the face of the piston, a turbine blade or a nozzle a part of moving surface of the engines that generate of combustion. The

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