UNIVERSITI TEKNIKAL MALAYSIA MELAKA

HYBRID VEHICLE (HV) ENGINE VIBRATION SOURCES DETECTION AND IDENTIFICATION USING TIME-FREQUENCY ANALYSIS

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor's Degree in Mechanical Engineering Technology (Automotive Technology) (Hons.)

By

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APPROVAL

This report is submitted to the Faculty of Engineering Technology of UTeM as a partial fulfilment of the requirements for the Degree of Bachelor's in Mechanical Engineering Technology (Automotive Technology) (Hons). The member of the supervisory is as follow:

……

Muhammad Nur Bin Othman

(Project supervisor)

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ABSTRAK

Dalam industri automobil, getaran dijana dalam enjin pembakaran dalaman memberi kesan kepada prestasi kenderaan dan kualiti keselesaan semasa menaiki kenderaan. Setiap komponen mekanikal dalam sesebuah kenderaan akan menghasilkan gerakan atau getaran apabila kenderaan itu mula berjalan. Objektif kajian ini adalah untuk mengukur getaran isyarat dari enjin dan menganalisisnya dengan menggunakan perisian Matlab. Tujuan lain kajian ini adalah untuk melaksanakan syarat pemantauan enjin hibrid dengan menggunakan meter pecutan. Matlamat Tujuan kajian ini adalah untuk membandingkan perubahan getaran isyarat pada lokasi yang berbeza dan pada pelbagai kelajuan. Dalam kajian ini, sensor accelerometer digunakan untuk mengukur isyarat getaran enjin hibrid kereta Toyota Prius. Getaran diukur dalam keadaan kereta tidak bergerak dengan kelajuan enjin yang berbeza. Kelajuan enjin berada dalam keadaan biasa iaitu 1000 rpm dan kemudian enjin tersebut telah direv sehingga 1500 rpm dan 2500 rpm. Sensor accelerometer tersebut telah dipasang di empat silinder enjin selaras. Kemudian isyarat tersebut dipantau dengan menggunakan kaedah penapisan. Hasil graf isyarat getaran empat saluran yang mewakili empat silinder dalam enjin pembakaran telah dianalisis dengan menggunakan perisian Matlab yang mempunyai algorithm “Fast Fourier Transform” (FFT) di dalam nya. Penggunaan koding dilakukan termasuklah kod untuk penapisan dan perubahan isyarat daripada domain masa ke domain frekuensi. Keseluruhan keputusan menunjukkan bahawa puncak graf iaitu amplitud pecutan maksimum bertambah dengan peningkatan kelajuan enjin.

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ABSTRACT

In automobile industry, the vibrations generated in the internal combustion engine affects the performance of the vehicle and quality comfort while ride the vehicle. Each mechanical component in a vehicle will produced a motion or a vibration when the vehicle started to run. The objective of this study is to measure the signal vibration from the engine and analyse it by using Matlab software. The other purpose of this study is to perform the hybrid engine condition monitoring by using the accelerometer. The aim goal of this study is to compare the change of the signal vibration on different location while at various speed. In this study, the accelerometer was used to measure the vibration signal of the Toyota Prius hybrid engine. The vibration were measured in the condition of the car in stationary with different engine speed. The engine speed were at idle which is 1000 rpm and then were revved until 1500 rpm and 2500 rpm. The accelerometer were mounted in line at the four cylinder of the engine. Then the signal were subjected to condition monitoring operation by using filtering. The vibration signal graph result of the four channel which represent the four cylinder in the combustion engine were analysed by using Matlab software including Fast Fourier Transform. The coding done including the coding for filtering and transformation of the signal from time domain to frequency domain. The overall results indicated that the peak of the graph which is maximum acceleration amplitude increase with the increasing of engine speed.

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DEDICATION

Every challenging work needs self-efforts as well as the guidance from the elders. Those who have lending their hand to help me, such as my friends, along with all hardworking and respected lectures especially my supervisor, former supervisor and co-supervisor. Not to forget, my humble effort I dedicate to my sweet, loving and supportive father and mother for their support, love, encouragement and prayers of day and night until I am able to get such a success and honour.

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LIST OF ABBREVIATIONS AND SYMBOLS

IC	-	Internal combustion
FFT	-	Fast Fourier Transform
HV	-	Hybrid vehicle
EV	-	Electric vehicle
Rpm	-	Revolution per minute
TFA	-	Time-Frequency Analysis
AC	-	Alternating current
DC	-	Direct current
Hz	-	Hertz
kHz	-	kilo Hertz
m/s^2	-	meter per second square

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CHAPTER 1

INTRODUCTION

1.0 Introduction

This chapter discusses the background, problem statements, objectives and scope of the study. The background states about the engine vibration that occur in the hybrid vehicle (HV).

1.1 Background of study

An engine is the most important component in automobile industry. The engine is a machine that converts heat energy into mechanical energy. The heat from burning a fuel produces power which move the vehicle. The process is burning a fuel to create heat which then creates power. In automotive system, there are use internal combustion (IC) engines as the fuel that runs them is burned internally or inside the engines. The explosion that is come from the high pressure in the combustion chamber resulting power produced in the engine. The impact of the excitations resulting to the engine vibration.

The different sensor or transducer have their different sensitivity. By using a sensor while measuring the engine vibration at various speed, we can see the pattern of the signal generated from the graph. From the result of the measurement, which is the raw signal data, it will go to the next process which is signal processing. In the signal processing, a software script/coding used to perform the vibration analysis. The raw data which is in time domain will be

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converted into spectrum which is in frequency domain. The result in frequency domain will give more understanding about the vibration profile.

The idea of this project is to study about the vibration that occur in engine system of hybrid vehicle (HV). A vehicle would produce a vibratory motion when the engine is running. The vibration of the engine will be measured by using an accelerometer sensor at different location of the engine and different engine speed. From the result of the measurement, which is the graph of time domain, it will go to the next process that is signal processing. This signal processing uses the Fast Fourier Transform (FFT) script/coding that will be create in Matlab software. The converted data which is the graph of frequency domain will make us easier to read the graph. Finally, the result will be compared to see their vibration signal generate by the sensor at different tapping location and different engine speed.

1.2 Problem statement

The automotive industry in the recent past has paid more attention on the internal combustion engine vibration as it is the main problem that is faced by every vehicle. The engine is a core component of a vehicle that has a great influence in the performance of a vehicle. Due to the complex structure and running conditions of the engine, their faults rate always be the main problem compared to the other vehicle components. An internal combustion engine produces power in the form of controlled explosion. These explosions produces powerful energy that cause the engine to vibrate in response. In addition, the rapid rate of pressure rise and it will excite the resonance in the gas inside combustion chamber cavity resulting to engine vibration. So, a sensors used to detect the vibration of the engine. Besides that, a condition monitoring was used to monitor a parameter of condition in the machinery (vibration).

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1.3 Objectives

An objective is defined as the purposes or target that will be obtain after finishing the project.

1. To measure the signal vibration from the engine and analyse it by using Matlab software.
2. To perform the hybrid engine condition monitoring by using the accelerometer.
3. To compare the change of the signal vibration on different location while at various speed.

1.4 Work scope

This project is focuses on analysis of an engine vibration of a hybrid vehicle (HV). This project starts with the measurement of the vibration of the engine hybrid vehicle. The vehicle used in this project is Toyota Prius. The accelerometer sensor is used as the measurement equipment. Then the project continues with the signal processing using the Matlab software to analyze the vibration caused by the engine on a stationary vehicle with different engine speed. From the result, the signal vibration on different location at various speed will be compared.

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CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

In order to complete the literature review, a relevant written documents should be search. It could be found in books, journal articles, newspaper articles, historical records, government reports, theses, project papers and any kind of sources. This study and research information are based on some major component and topics that related to this project. From that, every theory and information about it is compared among it and summarise it as well as critically analysed these documents. The best and most suitable information will be selected to use in this project.

2.1 Fundamental of vibration

Naturally all things that have movement would produce a vibration. The usage for industrial had made the world need to build machines for it especially since motors have been used to power them. Vibration is a mechanical phenomenon where an oscillation occur about an equilibrium point or about reference point. For the simplest way, vibration is known as displacement over time. The vibration would produce a frequency from the thing that have vibration motion. The frequency is the number of times a complete motion cycle happen while the period of one second that measured in hertz (Hz). There are a few units for the vibration which are displacement, acceleration and velocity. The units would indicate about the frequencies of the vibration where the displacement is indicates the low frequency, the acceleration is indicates the higher frequency while the velocity is consistent across the larger range

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of frequency. The velocity analyse most of the vibration as the energy level is consistent throughout the frequency range. (Beards 1996)

In many case, vibration is undesirable, wasting energy and would creating unwanted sound. For example, the vibration could come from vibrational motion of engine, an electric motor and any mechanical devices. This could be happen because of the imbalance in rotating part, uneven friction, misalignment of couplings, bearings and gears, meshing of gear teeth, gear wear and looseness. Generally, engineers try to avoid vibration because vibration have many unpleasant effect. Cyclic motion implies cyclic forces that resulting damaging to materials. For a worse, even modest levels of vibration can cause extreme discomfort to the human. (Kjer 1982)

Vibrations also will lead to a loss of precision in controlling machinery. In term for a vehicle, the vibration means that something is out of balance. Things that rotates such as crankshafts, tires and axles have a certain resonance at a given speed. A resonance is a phenomenon that occur when vibrating system or external force drive another system to oscillate with greater amplitude at specific preferential frequency. Thus, the resonance is not good for the vehicles. Engineers will overcome this resonance by balancing the component by removing or adding weight at a strategic points. This helps to prevent a vibration at a given engine speed, rpm. (Kjer 1982)

2.1.1 Type of vibration

2.1.1.1 Free vibration

When no external force acts on body after giving it an initial displacement thus the body is said to be under free or natural vibration which is no external force and no damping. Free vibration is the vibration of a system in response to initial excitations, which is consisting of initial displacements or velocities. It will vibrate at one or more of its natural frequency which are properties of the dynamical system establish by its mass and stiffness distribution. (LDS 2003)

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2.1.1.2 Force vibration

The vibration that takes place under the excitation of external force is called the force vibration. This external force which acts on the system executes the vibration of the system. This may be harmonic and periodic, non-harmonic and periodic or non-periodic. When the excitation is oscillatory, the system is forced to vibrate at the excitation frequency. If the frequency of excitation coincides with one of the natural frequencies of the system, a condition of resonance is encountered and dangerously large oscillations may result. Examples of forced vibration are air compressors, IC engines, turbines and machine tools. (LDS 2003)

2.1.1.3 Torsional vibration

Torsional vibration is predominant whenever there is a large disc on relatively thin shafts. Numerous torsional vibration problems still occur in reciprocating and rotating machinery. This is because of the mating of equipment traditionally used in non-reciprocating applications like variable speed motors with reciprocating compressors. Furthermore, the lack of monitoring engine or compressor performance as well as improper application and maintenance of viscous dampers and elastomeric couplings.

2.2 Vehicle vibration

Vehicle vibration is a vibration that occur in a vehicle that will come out with the noise which is unwanted sound. This are caused by many factors which are come from the engine, tyres, brake, wrong engine firing, radiator fan, drive shaft, steering wheel and chassis. Engine problem might occur from not getting enough air, fuel or

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spark that the engine to run smoothly. Besides that, this can come from the tire's problem. This could be from uneven tire wear, tire have separated tread and the tires are out of balance. Furthermore, this also can come from a brake trouble. The brake disc become warped over a time. A rotor can get bent out of the shape due to heavy wear and tear. The brake pads and callipers which squeezes brake rotors to make a car stop cannot get enough grip to the road when the brake applied. (Griffiths 2012)

Engine firing also can be the causes to the vehicle vibration. This happen when one or more spark plugs in the cylinders is not firing correctly. In addition, the radiator fan might be broken. If this happen, it become very uneven. It still tries to turn, but it become wobbles. Next, the problem can come from the drive shaft. This happen if they hit the ground during an accident thus resulting a damage. The steering wheel vibrate is the most common vibration people deal with. If vibration occur at all the time while driving or when step on the brakes, it's probably to be a tire or tire balance problem. If the vibration only occur when the brakes is step, it would be the brakes problem. This does not meant that the brakes are fail but there are several things that affected which is the brake discs or brake drums have become out of round or warped.

2.2.1 Type of vehicle

2.2.1.1 Electric vehicle

All electric vehicles (EV) run on electricity only. There is no engine like in the conventional and hybrid car. They were propelled by one or more electric motors powered by rechargeable battery packs. According to (Chen & Shih 2015), the internal combustion engine vehicles have a motor that is same as the electric vehicles. However, instead of mechanical power derived from burning gasoline, the electric vehicle's power supply derived from battery-stored electricity.

Electric engine, a battery pack and controllers were took over the traditional gas or diesel motor and fuel tank. The controller powered

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