EXPERIMENTAL MODAL ANALYSIS ON WIRA CAR CHASSIS

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ABSTRACT

One of the problem exist in automobile industry is vibration on the chassis. Resonance exists when excitation forces coincide with one of the natural frequency of the structure. So it is important to study the dynamic characteristic of the structure. Dynamic characteristic can be determined using Experimental Modal Analysis (EMA) method or Modal Testing. Dynamic characteristic or modal parameters are divided into three which are natural frequency, damping factor and mode shape. Structure used for this project is wira car chassis. Used Proton Wira needs to be dismantled, the purpose of dismantling the Proton Wira is because the modal testing is performed only on the chassis structure. Two methods from modal testing is performed on the chassis, there are roving impact hammer test and shaker test. Data collected from the hammer and shaker test is converted and imported to MÊ' Scope VES, then chassis is simulated. Result obtain from both methods, is compared on each axis (x, y and z axis). However there is a small discrepancy in terms of natural frequency, which the discrepancy does not exceed then 5%.

ABSTRAK

Salah satu masalah yang dihadapi oleh indutri pemotoran adalah getaran terhadap struktur kereta. Resonans wujud apabila frekuensi getaran menyerupai salah satu frekuensi asli struktur tersebut. Bentuk getaran, frekuensi tabii dan faktor pengurangan getaran dapat diperolehi dengan melakukan analisis terhadap struktur kereta wira. Ketiga-tiga sifat getaran tersebut boleh diperolehi dengan melaksanakan eksperimen analisis modal terhadap struktur kereta wira. Komponen perlu dipisahkan daripada Proton Wira, ini adalah kerana hanya strutur kereta wira sahaja yang akan dianalisis. Dua kaedah akan digunakan untuk mendapatkan ketiga-tiga sifat getaran, iaitu ujian hentakan penukul dan ujian getaran rambang mengunaka alat penggetar. Data yang diperolehi daripada eksperimen ditukarkan format dan dan dipindahkan ke perisian ME' Scope VES. Selepas itu struktur kereta beserta data tersebut disimulasi. Keputusan yang diperolehi oleh kedua-dua kaedah di bandingkan pada setiap paksi (paksi x, y dan z). Walaubagaimanapun, kerana peratus perbezaan di antara kedua-dua kaedah tidak melebihi daripada 5%.

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LIST OF SYMBOLS

f	-	Frequency
t	-	Time
ω	-	Angular velocity
m	-	Mass
k	-	Spring Constant
H (ω)	-	Frequency Response Function (FRF)
f (t)	-	Input force in time domain
x (t)	-	Output response in time domain

CHAPTER 1

INTRODUCTION

1.1 Introduction

In the modern days, both man and women commute to work. Children attending colleges also commute in their own time and routes. It is very common that the savvy and affluence in any community has more than one car has shown the importance of it. The application of car is wide, whatever the use of car is, the main function of a car is to make human's life easier to maneuver from one place to another in a short period of time.

Originally structures or frames of an automobile were made of wood. Later on, about in 1900 steel and aluminum was introduced to the development of automotive construction technology where the type of material used is metal sheet body on a wooden frame. In 1915, H.J. Hayes invented a body with structural functionality where it reduces the cost and reduction of noise and vibration. Still in year of 1915, Edward G. Budd introduced a car made of nearly 100% of steel. Lancia Lambda was a revolution in the development of automotive construction in the year of 1922 created by Vincenza Lancia, where Lambda's were fully made of steel. The improvement of the material type of the automobile structure is important in automobile industry as it improves and benefits people in terms of stiffness, torsion and reduction of vibration. By 1930s, steel ladder frame become common in development of automobile structure.

One of the problem exist in automobile industry is vibration on the chassis. There two types of vibration which are forced and resonant vibration. Both combinations of forced and resonant vibrations are called vibrations. The factors that bring to forced vibration are external loads, internally generated forces and many more. Resonant vibration can be due to one or more resonance of vibrations. Resonance can be determined by the material properties (mass, stiffness and damping properties) and the boundary conditions of a chassis or structure [4].

1.1.1 Project Background

Car chassis is the main component in a vehicle system. Most of structures in this entire world vibrate and car chassis is included in the structures that vibrate [2]. Vibration of chassis can be formed due to dynamic forces such as the engines, unsmooth road and many more [9]. Even though chassis of a car looks very solid and strong, the structure might be collapsed when resonance occurs. Therefore, to prevent structure collapse due to resonance, it is important to analyze the structure of a chassis to determine the modal parameters. Modal parameters of a chassis can be determined by Experimental Modal Analysis.

Experimental modal analysis has been used since early 1940's to solve the problem of flutter to predict accurately by measuring the modal parameters [3]. This method is widely used among engineers to analyze desired structure such as aircraft wing, automotive structures and bridge structures. By 1970's experimental modal analysis has grown steadily with the beginning of the digital FFT spectrum analyzer. Nowadays impact testing has been widely used because it is fast and economical in finding the modes of vibration of a structure [4].

Experimental Modal analysis is a process to describe wira car chassis/structure in terms of modal parameters or characteristics. In other word Experimental Modal Analysis can also be called as Modal Testing or Modal Analysis. Modal analysis is a process to determine the dynamic characteristic of wira car chassis. Types of dynamic characteristics are natural frequency, damping ratio and mode shape. These characteristics are also known as modal parameters. There are 2 method is used to analyze the structure of used Proton Wira. Those 2 methods are likely to be shaker test and impact hammer test and the chassis of wira is to be analyzed under free-free boundary condition.

1.2 Problem Statement

Since 1930, car has been fully made of steel. Have you ever think about the car that you use daily is actually safe? People usually think that chassis of a car is strong enough, but most of them do not know the effects of noise and vibration can create resonance on the chassis.

Most structures vibrate. To be specific chassis of wira will definitely vibrate. Damages could occur to the structures if resonance occurs. Problems due to resonance occur while natural frequency of external forces coincides with the natural frequency of structures. The modal behaviour of a wira car chassis is indispensable information for the dynamic analysis on the structure. Modal analysis is used to investigate the vibration behaviour of the chassis.

Wira car chassis will undergo torsion or bending deflection due to the passenger load and automotive parts (engine, tire, absorber and etc) attach to the chassis. In order to determine the modal parameters that caused by deflection, a study and analysis must be carried through out the wira car chassis. In order o determine the modal parameters, roving impact hammer and shaker test are performed on the chassis.

1.3 Project Objectives

There are several objectives regarding the title of Experimental Modal Analysis on wira car chassis, which are:-

i. To analyze the structure of wira car chassis.
ii. To compare the natural frequency of experimental value between impact hammer test and shaker test.

1.4 Project Scopes

By starting this project based only on the objectives is not recommended as is too large or too wide to cover, and it is important to create a scope of this project. Scopes of Experimental Modal Analysis on Wira Car Chassis are:-

i. Dismantle the used Proton Wira and the purpose of dismantle is because the analysis will only be performed on the wira car chassis.
ii. Draw the 3D model of wira car chassis using ME' Scope software.
iii. Analyse the structure of Wira by using experimental modal analysis by using two methods which are impact hammer test and shaker test.
iv. To analyze using specific boundary condition, which is free-free boundary condition.
v. To compare the natural frequency of experimental value between impact hammer and shaker test in each direction. There are three direction which are X, Y and Z directions.

1.5 Outline

Chapter 1 describes the purpose of experimental modal analysis on wira car chassis, the objectives and scopes of the modal testing. This chapter also defines the problem and desired method to solve the problems.

Chapter 2 explains the fundamental of Modal Testing and to collect information regarding the Experimental Modal Analysis. It is important to study on the basic concept of modal testing and the methods use previously by other researcher.

Chapter 3 describes the procedure or the method used before, during and after the modal testing, the type of software used to complete the experimental modal analysis and the other relevant method due to experimental modal analysis. The apparatus used for analysis the chassis are listed.

Chapter 4 provides the result of the analysis. Comparison between Impact hammer test and shaker test is displayed and discussed. The suitable way of selecting the desired data and the relationship between the setup and result are also been discussed.

Summary of this project is explained in chapter 5, where it contains summary of the entire project. There are also some recommendations for future research on wira car chassis.

1.6 Gantt Chart

The purpose of gantt chart is to display the time and duration together with work implementation. For that reason, gantt chart for Final Year Project 1 and 2 is created. Chart for final year project 1 and 2 can be referred to Appendix A and Appendix B

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter is to explain the fundamental of Modal Testing and to collect information regarding the Experimental Modal Analysis. It is important to study on the basic concept of modal testing and the methods use previously by other researcher.

2.2 Experimental Modal Analysis

Experimental modal analysis is also known as modal testing or modal analysis. It is a process to determine and identify the vibration characteristics of a system. Those characteristic are divided into three parameters which are frequency, mode shape and damping ratio. These characteristics can be defined as modal parameters or dynamic characteristic.

For a better understanding of modal analysis, example of a freely supported flat plate is used shown in Figure 2.1. Force which is constant is applied to the plate. Normally people will think that the freely supported flat plate will bend (static deformation), but to explain in another way is force that varies in sinusoidal fashion is applied to the plate. To begin, Frequency of oscillation of the constant force is fixed. The rate of oscillation of the frequency is adjustable but the peak force remains in the same value (rate of oscillation of the input force is adjustable). Response of the plate is measured by using accelerometer attached to the corner of a plate. Notice that the amplitude changes as the rate of oscillation of the input is adjustable or changed is shown in Figure 2.2.

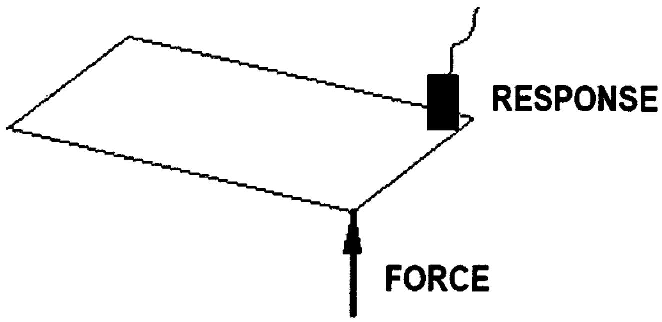

Figure 2.1: Flat plate
(Source: Avitable, 1998)

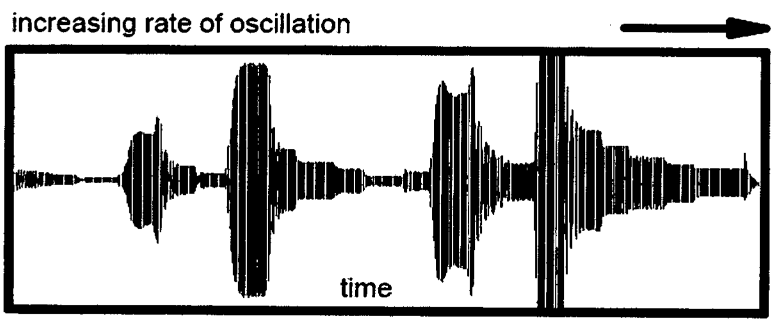

Figure 2.2: Measured response of flat plate
(Source: Avitable, 1998)

Shown that the amplitude vary depending on the rate of oscillation of the input force as the force remains constant. (Peak is remain constant while rate of oscillation is adjustable)

Once force is applied to the structure with a rate of oscillation, the response amplifies gets closer and closer to the natural frequency (resonant frequency), and the rate of oscillation is maximum when reaches the natural frequency of the system.

Response of the structure that has been test will be in time domain data and transform the time domain to the frequency domain using the Fast Fourier Transform (FFT). Thus, either time trace or frequency response function (FRF) can be use to determine the natural frequency of a system.

There are varieties of different shapes depending on the frequency used for excitation force. Each natural frequency has own deformation pattern. Deformation patterns is a mode shapes of system. By mode shapes, the deformation pattern of a structure can be determined.

2.3 Frequency Response Function (FRF)

It is important to know what is frequency response function (FRF) and purpose of FRF. It is a measurement to isolates the inherent dynamic properties of structures and simply is the ratio of output response of a structure due to an applied force (input). FRF can also be measured not only by force but by displacement, velocity and acceleration. In this case FRF is measured by applied force. The purpose of this frequency response function is to obtain modal parameters of a structure excited [4]. Frequency response function (FRF) is shown in Figure 2.3.

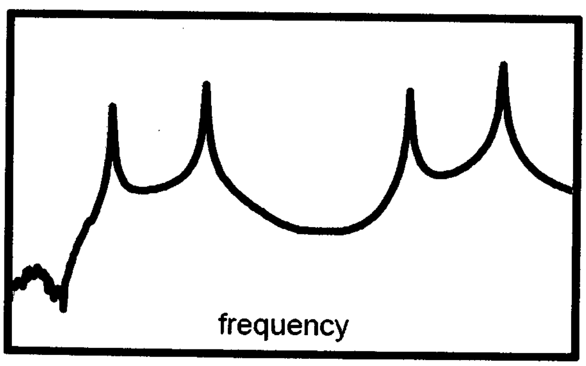

Figure 2.3 : Frequency response function (FRF)
(Source: Avitable, 1998)

FRF is a transformation response from the time data. Multi channel FFT analyzer is a device to collect time data to make FRF measurement between the apply force as an input with the output degree of freedom (DOF) of the structure [4]. Time data (time domain) is transform into frequency response function (frequency domain) using Fast Fourier Transform (FFT).

Either time data or frequency response function can be used to determine dynamic characteristics. This is because the frequency of the time trace to reach maximum is similar with frequency of the frequency response to reach maximum [1]. This is proved when time data is overlay with the frequency response as shown in Figure 2.4.

Figure 2.4 : Time overlay with frequency response
(Source: Avitable, 1998)

Frequency Response Function is more preferred then time data because of FRF is easier to evaluate.

By transforming the time data to frequency response function, the FRF is transforming into complex valued numbers. In other word it can be explain as the functions contain real and imaginary magnitude and phase components to describe the structure [1].

2.4 Mode Shape

What is mode? Modes are inherent properties of a system/structure and modes do not depend on forces acting on it. Each mode can be represented as single degree of freedom (SDOF) [2]. By knowing the material properties and boundary condition of the structure mode can be determined. Mode of the structure can be change if either the material properties or the boundary condition of a structure change. For example, if mass is added to a structure, structure will vibrate differently because of the mode has changed. Mode is defined by the modal parameters [4].

There are varieties of deformation pattern of the structure depending on the frequency used for the excitation force. Each of the natural frequency show us deformation pattern of the structure. Deformation pattern can be defined as a mode shape of the structure. Figure 2.5 shows deformation pattern that exist in the structure and show the result of mode shape when the excitation is coincides with the one of the natural frequencies of the structure. First natural frequency of a system (mode 1) shows the pattern of bending deformation. Mode 2 represent twisting deformation pattern, when dwell at third and fourth frequencies, mode 3 represent the second bending and mode 4 shows second pattern of twisting deformation. So, there are two types of pattern will occur in mode shape which are bending and twisting deformation. Another word for twisting is torsion. Natural frequencies and mode shapes occur in most structures that vibrate [2].

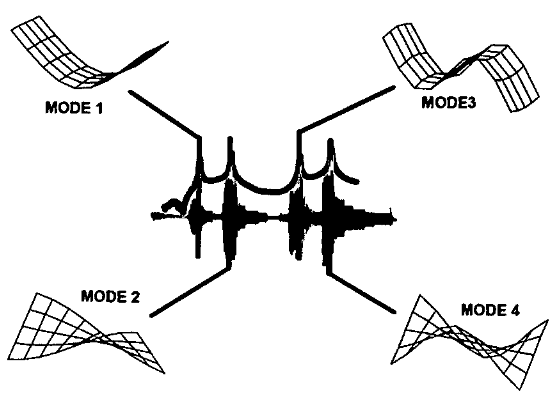

Figure 2.5 : Modes on each natural frequency
(Source: Avitable, 1998)

Mode shapes are continuous functions, which in modal testing, are sampled as "spatial resolution" depending on the number of degree of freedom (DOFs) used. Mode shape cannot be measured directly, but it can be obtain and determine from FRF measurements [2].

Modes are divided into 2 classes, which are Normal Modes and Complex modes. Normal modes are characterized that all parts of the structure are moving either in phase or out of 180° with each other. Normal mode shapes are considered to be a fixed node line of the standing waves. Figure 2.6 shows a Normal mode shapes.

Complex modes are characterized that it can have any relationship between parts of the structures. Complex mode shapes are thought of as propagating waves with no stationary node line. This is shown in Figure 2.7.

To differentiate the two classes of mode, the existence of damper in a structure determines either the mode is in normal or complex class. The difference of the 2 classes is shown in Figure 2.6 and Figure 2.7. Structures which have very light or no damper in it can be defined as normal modes. Structures with much localized damping have complex modes. An example of structure that have complex mode is automobile body with a spot wells and shock absorbers. Complex modes can occur in structures where normal should exist because of the mode shape are derived from poor measurement [2]. Basically mode shapes or deformation patterns and natural frequency existence depend on the weight and stiffness of the structure [1].

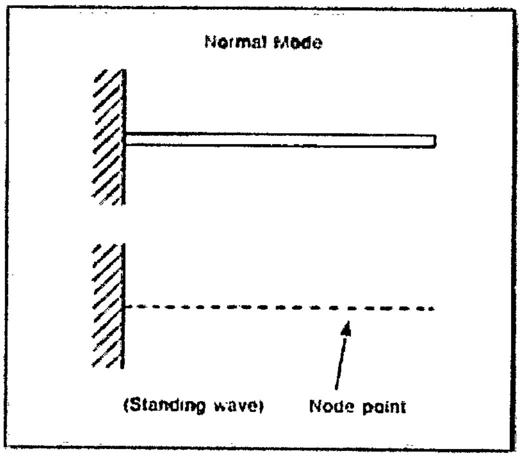

Figure 2.6 : Normal mode
(Source: Dossing, 1988)

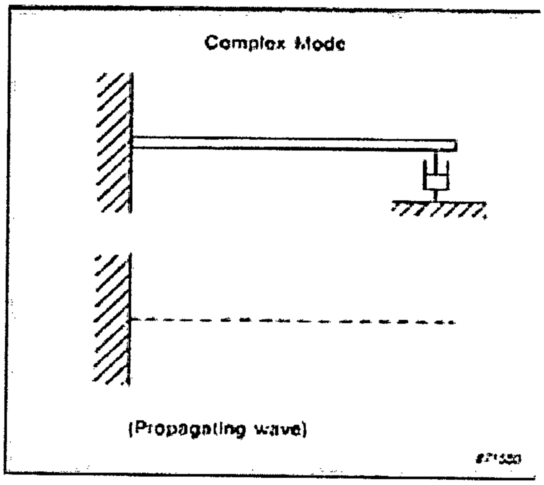

Figure 2.7 : Complex mode
(Source: Dossing, 1988)

How many mode shapes is depend on the person in charge, based of the research done some may have set to three mode shapes and some may assume four mode shapes.