EXPERIMENTAL MODAL ANALYSIS ON FLEXIBLE PLATE STRUCTURE USING FORCED VIBRATION METHOD

AHMAD SYAFIQ BIN BAHARIN

This Report Is Submitted In
Partial Fullfillment of Requirements For the
Barchelor Degree of Mechanical Engineering (Structural & Material)

Fakulti Kejuruteraan Mekanikal
Universiti Teknikal Malaysia Melaka

APRIL 2009

VERIFICATION

“I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of degree of Bachelor Mechanical Engineering (Structure & Material)”

Signature	:…………………………………
Supervisor’s Name	: Puan Rainah Ismail
Date	: ………………………………...

SPECIALLY DEDICATED TO MY FATHER, MOTHER AND OTHER FAMILY MEMBERS….

DECLARATION

I hereby declare that this project report entitled

EXPERIMENTAL MODAL ANALYSIS ON FLEXIBLE PLATE STRUCTURE USING FORCED VIBRATION METHOD

is written by me and is my own effort except the ideas and summaries which I have clarified their sources.

Signature	:…………………………………
Author	: Ahmad Syafiq Baharin
Date	: ………………………………...

ACKNOWLEGEMENT

Thanks to Allah, for giving me permission to complete this project. In here I would like to record my graceful thank to all the support, encouragement and inspirations that I have received during completing this project.

I also would like to express greatest thankfulness and appreciation to my supervising lecturer, Pn. Rainah Ismail of which we had a good working relationship, and who had offered me a wonderful help and encouragement. She also gives me full of support and advice.

All the Lecturers and Technicians of Faculty of Mechanical Engineering, I would like to acknowledge and express my gratitude for giving me their cooperation and help in order to complete this project. Last but not least to my family and all my fellow friends, for their concern, encouragement and understanding.

ABSTRACT

Aircraft structure using the flexible structure as their main part of the body. The body must be safe to maintain their stiffness and increase the safety. This is very important because aircraft deal with human life. The study of experimental modal analysis is to get the modal parameter like frequency, damping and mode shape. The modal parameter will be analyzed to know the dynamic characteristic of structure. It very significant to know the dynamic characteristics of the structure because dynamic loads acting on an aircraft during flight will be encourages the onset of the structural damage such as fatigue crack. This structural damage is often the major cause of failure in aircraft system. This paper will discuss about the experimental modal analysis on flexible rectangular plate structure using forced vibration method. The forced vibration will apply at a flexible plate using the impact hammer. Then the data obtain will be compared with the finite element model that have be done by other researcher.

ABSTRAK

Kebiasaannya, struktur pesawat menggunakan struktur yang fleksibel sebagai rangka utama di dalam penghasilan rangka pesawat. Rangka pesawat hendaklah selamat untuk mengekalkan kekukuhan dan juga meningkatkan tahap keselamatan pesawat. Ini adalah amat penting kerana pesawat terlibat dengan keselamatan nyawa manusia. Tujuan eksperimen analisis modal adalah untuk mendapatkan parameter modal seperti frekuansi, redaman dan bentuk ragam. Parameter modal akan dianalisis untuk mengetahui cirri-ciri dinamik sesuatu struktur. Adalah amat penting untuk mengetahui ciri-ciri dinamik sesuatu struktur kerana daya dinamik yang bertindak ke atas pesawat akan menghasilkan kerosakkan keatas struktur badan pesawat seperti keretakkan. Kajian ini akan membincangkan tentang eksperimen analisis modal keatas struktur fleksibel dengan menggunakan kaedah getaran paksa. Kaedah getaran paksa dilakukan dengan mengenakan daya paksaan pada struktur fleksibel menggunakan tukul impak. Data yang diperolehi akan dibezakan dengan data dari *finite element model* yang telah dilakukan oleh pengkaji yang lain.

CONTENTS

CHAPTER 2 LITERATURE REVIEW

LIST OF TABLES

LIST OF FIGURES

LIST OF NOTATIONS

m	-	mass system
c	-	damping
k	-	stiffness
x	-	displacement
$\dot{x}$	-	velocity
$\ddot{x}$	-	acceleration
ω_n	-	natural frequency
ξ	-	damping ratio
$[\mathrm{m}]$	-	structural mass matrix
$[\mathrm{c}]$	-	structural damping matrix
$[\mathrm{k}]$	-	structural stiffness matrix
$\{\mathrm{X}\}$	-	the node displacement vector
$\{\dot{\mathrm{X}}\}$	-	the node velocity vector
$\{\mathrm{f(t)}\}$	-	the time function
$\mathrm{H}(\omega)$	-	input force function
$\mathrm{Y}(\omega)$	-	response function
f	-	frequency
T , t	-	time
ρ	-	pressure
h	-	volume density
Q_x, Q_y	-	dynamic shear force per unit length
$M_{x,} M_y$	-	moments per unit length
M_{xy}	-	twisting moment per unit length

E	-	modulus of elasticity
μ	-	Poisson ratio
G	-	shear modulus
D	-	flexural rigidity

LIST OF APPENDIX

CHAPTER 1

INTRODUCTION

1.1 Research Background

Modal analysis has become a major technology in the request for determining, improving and optimizing dynamic characteristics of engineering structure. Modal analysis has been used in mechanical and aeronautical engineering. Now days, modal analysis widely used in fundamental application for civil and building structure, biomechanical problems, space structure, acoustical instruments, transportation and nuclear plant. Contemporary design of complex mechanical, aeronautical or civil structure required them to become increasingly lighter, more flexible and strong. For example, the car manufactures have to achieve microscopic reductions of product body weight. Aerospace structure such as satellite antennas must have weight reduction of every possible gram to minimize their internal property during operation in space.

Another relevant fact in modern life is the increasing demands of safety and reliability upon contemporary structure defined by government regulations or by consumer. The demands have created the challenge to the scientific understanding of engineering structures. When the vibration of the structure being concern, the understanding lies on better understanding on its dynamic properties using analytical, numerical or experimental. The significance of the dynamic behavior of engineering structure becomes important to design with proper consideration of the dynamics characteristics.

1.2 Problem Statement

The current trends of space aircraft design are to use the large, thin and lightweight structures. This is due to the many factors such as cost, safety and mechanical parts. The vibrations are caused by the excitations. The excitations can come from external sources such as cross wind or foundation vibration, sources internal to the structure such as moving loads and engines. Heavy structure has small frequency than the lighter ones. The lightweight structure will produce higher frequency and this can lead to higher vibration. The higher vibration can cause crack, fatigue and failure of the structure. In this study, the frequency will be determine and analyzed.

1.3 Objective

The objectives of this study is to obtain frequency data for first three dominant modes by using forced vibration and to verify the results with the analytical finite element model that has been done by other researcher.

1.4 Research Scope

The scope of this study is:

1) To determine the frequency by using experimental modal analysis. The frequency is obtained from the Fast Fourier Transform (FFT) that will be computed by Dewesoft software used in this experiment. The flexible structure used in this study is Al-7001 that widely used in aircraft manufacturing.

2) To compare the experimental results with the simulation data (Nastran Patran software) and true value (Claseen and Thorne (1960)) data from other researcher. The data will be analyzed from error aspect such as experimental errors.

1.5 Research Methodology

Methodology of this study is summarized in the Figure 1.1 below

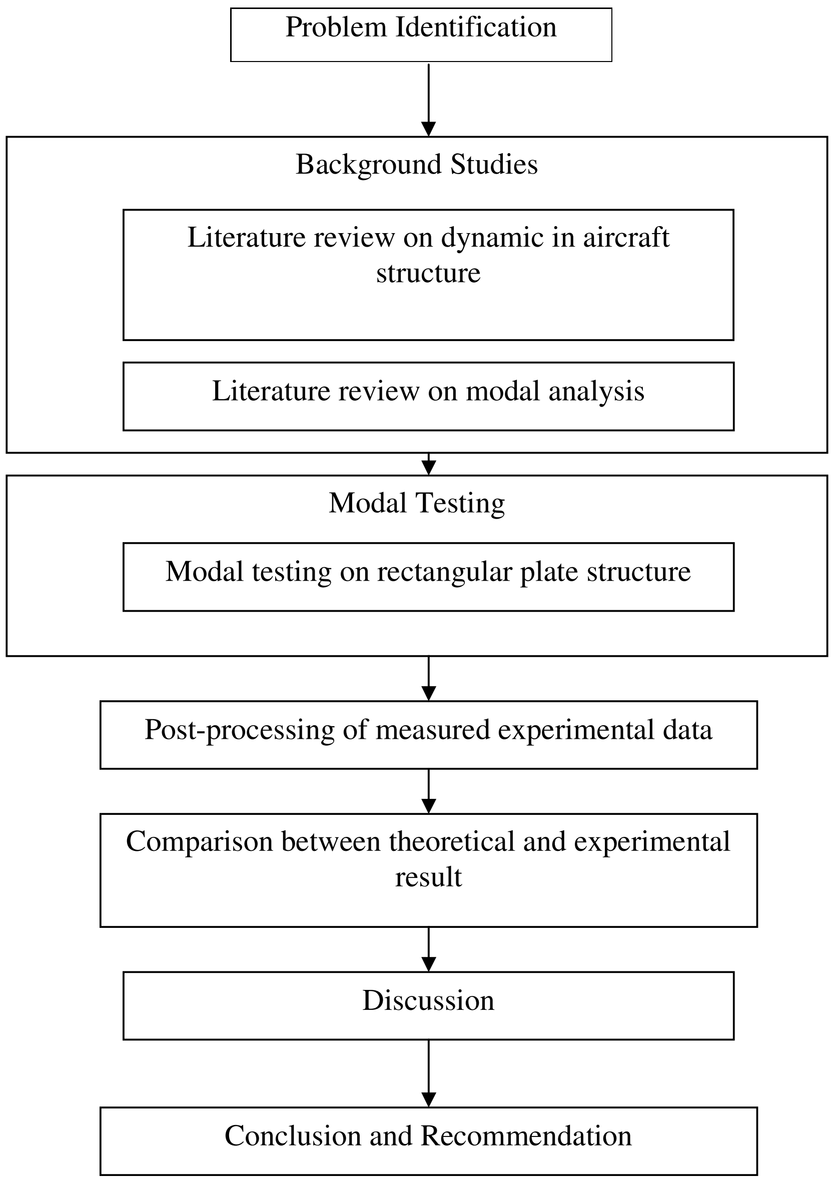

Figure 1.1: Methodology Flowchart

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The term vibration describes repetitive motion that can be measured and observed in a structure. Unwanted vibration can cause fatigue or degrade the performance of the structure. Therefore it is desirable to eliminate or reduce the effects of vibration. In other cases, vibration is unavoidable or even desirable. In this case, the goal may be to understand the effect on the structure, or to control or modify the vibration, or to isolate it from the structure and minimize structural response.

Modal analysis is the process of determining the inherent dynamic characteristic of a system in forms of natural frequencies, damping ratio and mode shapes. The formulated mathematical model is referred to the modal model of the system and the information for the characteristic is known as its modal data. Modal analysis is based on the fact that the vibration response of a linear time-invariant dynamic system can be expressed as the linear combination of a set of a simple harmonic motions called the natural modes of vibrations. Modal analysis embraces both theoretical and experimental technique.

2.2 Basic Vibration Theory

Vibration is the motion that repeats itself. The theory of vibration deals with the study of oscillatory motion of bodies and associated force. The phenomenon of vibrating involves an alternating interchange of potential energy to kinetic energy and vice-versa. Therefore any vibrating system must have a component that stores potential energy and a component that store kinetic energy. The components storing potential and kinetic energy are called a spring or elastic element and a mass or inertia element. In each cycle of motion the elastic element store potential energy and gives it up to the inertia element as kinetic energy and vice-versa.

Vibration also consider as the transfer between the kinetic energy and potential energy. It means the vibration systems has the storing and release both energy. Hartog and Den (1985) argued that vibration refers to mechanical oscillations about an equilibrium point. The oscillations may be periodic such as the motion of a pendulum or random such as the movement of a tire on a gravel road. Vibration is occasionally "desirable". For example the motion of a tuning fork, the reed in a woodwind instrument or harmonica, or the cone of a loudspeaker is desirable vibration, necessary for the correct functioning of the various devices.

2.2.1 Vibration Types

Vibrations can be classified into following type (Rao, 2004).

1. Undamped and Damped vibration

   If there is no less or dissipation of energy due to friction or other resistance during vibration of a system, the system said to be undamped. If there is a energy loss to the presence of damping, the system is called damped. Although system analysis is simpler when neglect damping, a consideration of damping become extremely important if a system operates near resonans.

2. Free and Forced vibrations

   If a system vibrations due to an initial disturbance (with no external force applied after time zero), the system said to undergo free vibrations. On other hand if the system vibrates due to the applications of external force, the system said to be under forced vibrations.

3. Linear and nonlinear vibrations

   If all the basic components of a vibrating system (i.e. the mass, the spring and the damper) behave linearly, the resulting vibrating is called linear vibration. However, if any of the basic components at a vibrating system behave nonlinearly, the resulting vibration is called nonlinear vibration.

2.2.2 Equation of Motion

A basic understanding of structural dynamic is necessary for successful modal testing. It is important to have a good grasp of the relationship between frequency response function and modal parameter. Knowing of the various forms and trends of frequency response functions will lead to more accuracy during measurement phase. During the analysis phase, knowing how equations relate to frequency response leads to more accurate estimation of modal parameters.

2.2.2.1 Single Degree of Freedom (SDOF)

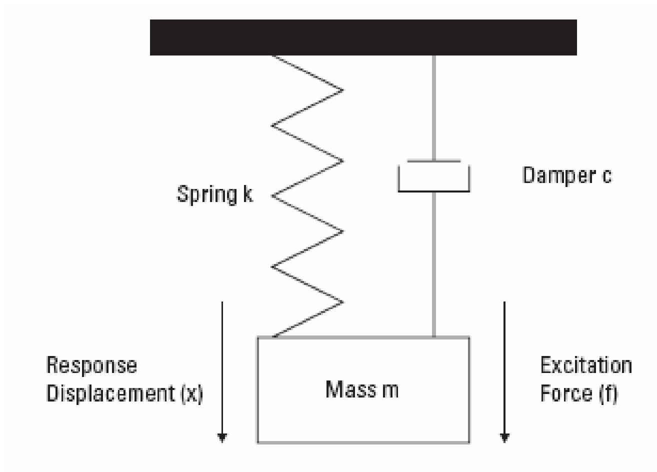

Figure 2.1: SDOF discrete parameter model

Although most physical structure is continuous, their behavior can usually represent by a discrete parameter model as illustrated in Figure 2.1. The idealization elements are called mass, spring, damper and excitation. The first three elements are described the physical system. Energy is stored by the system in the mass and the spring in the form of kinetic and potential energy. Energy enters the system through excitation and dissipated through damping.

$$m\ddot{x} + c\dot{x} + kx = f(t)$$

$$\omega_n^2 = \frac{k}{m}, \; 2\xi\omega_n = \frac{c}{m}, \; \xi = \frac{c}{\sqrt{2km}} \qquad (2.1)$$

The idealized elements of the physical system can be described by the equation of motion shown in (2.1). This equation relates the effect of the mass, stiffness and damping in a way that leads to the calculation of natural frequency and damping factors of the system.

This computation is often facilitated by the use of definition shown in (2.1) that leads directly to the natural frequency and damping factors. The natural frequency, ω, is in unit of radians per second (rad/s). The typical units displayed on a digital analyzer however are in Hertz (Hz). The damping factor can also represent as