EXPERIMENTAL DETERMINATION OF DAMPING PROPERTY OF STRUCTURE

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To my beloved wife and son

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ABSTRACT

The needs for reliable and accurate damping properties are necessary in order to produce a good simulation and improve a major source of uncertainty at the design stage. Thus, an experimental investigation was conducted to find damping property of structure. In this study, three different plates were used to determine their damping properties. Experimental modal analysis using impact hammer and accelerometer was performed to acquire the frequency response function (FRF) of test samples. Damping properties were extracted from FRF using polyreference least-squares complex frequency-domain method (PolyMAX) and polyreference least-squares complex exponential time-domain method (LSCE). The results reveal that for lightly damped structure, the damping ratio from LSCE and PolyMAX are comparable. However, for heavily damped structure, the damping ratio from LSCE is slightly higher than damping ratio from PolyMAX. The results also show that PolyMAX is better than LSCE in term of stabilisation diagram. Finally some improvements on the experimental method have been proposed in order to achieve accurate damping property.

ABSTRAK

Keperluan untuk mendapatkan sifat resapan yang persis dan jitu adalah mustahak untuk memperoleh simulasi yang tepat dan mengurangkan ketidakpastian dalam proses rekabentuk. Oleh itu, eksperimen telah dijalankan untuk menentukan sifat resapan struktur. Dalam ujikaji ini, tiga plat yang berbeza telah digunakan untuk menentukan sifat resapannya. Eksperimen ujikaji modal telah dijalankan untuk memperolehi data dalam bentuk fungsi tindak balas frekuensi (FRF). Sifat resapan diperolehi melalui FRF dengan menggunakan kaedah “polyreference least-squares complex frequency-domain method” (PolyMAX) dan “polyreference least-squares complex exponential time-domain method” (LSCE). Hasil keputusan menunjukkan bahawa untuk struktur yang rendah sifat resapan, nisbah resapan yand diperolehi melalui LSCE dan PolyMAX adalah setanding. Walau bagaimanapun, untuk struktur yang tinggi sifat resapan, nisbah resapan dari LSCE adalah sedikit lebih tinggi dari PolyMAX. Hasil keputusan juga menunjukkan bahawa PolyMAX lebih baik dari LSCE jika dibandingkan dari segi kestabilan. Akhir sekali, beberapa ubahsuaian kepada kaedah eksperimen telah dicadangkan bagi memperolehi sifat resapan yang lebih tepat.

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c	-	Damping coefficient
f	-	Force
k	-	Spring stiffness
m	-	Mass
C	-	Damping matrix
K	-	Stiffness matrix
M	-	Mass matrix
x	-	Displacement
$\dot{x}$	-	Velocity
$\ddot{x}$	-	Acceleration
ω	-	Angular frequency
ω_r^2	-	Eigenvalues
Φ	-	Eigenvectors
H_{jk}	-	Harmonic response in DOF *j* to a unit harmonic excitation applied in DOF *k*
X_j	-	Harmonic response in DOF *j*
F_k	-	Harmonic excitation applied in DOF *k*

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CHAPTER 1

INTRODUCTION

1.1 Introduction

The chapter begins by reviewing background of the problem before move into the problem statement. Then, the objective of the study and research question is stated clearly. Next, the scope and key assumptions used in this study is clearly defined. The importance of the study and the organization of this report are briefly explained before summarizing this chapter at the end.

1.2 Background of the Problem

Vibration analysis represents an important research topic in the context of structural and mechanical engineering. Most of the time, vibration is undesirable and it is important to reduce it by dissipation its energy or damping.

Damping can be defined as the phenomenon by which mechanical energy is dissipated in dynamic systems [1]. High energy dissipation will probably have low vibration amplitudes. Damping is mostly associated with the change of mechanical energy into thermal energy.

The recent developments in the fields of building structures have provided motivation towards developing newer and more efficient materials which have expedited the construction of lighter and more flexible buildings. These buildings are known to be highly responsive to dynamic loadings [2]. Therefore it has become more crucial to accurately determine dynamic properties which are the natural frequencies and damping.

Besides that, in automotive industry, ride comfort is gaining more prominence in recent years. Ride comfort can be defined as occupant's overall comfort and well-being during vehicle travel. Generally it involves all the vibration phenomena which act on the occupants of a vehicle. Since the sources of the vibration are outside of the passenger compartment, damping properties would help to hinder the transmission of these disturbances into the passenger compartment area [3].

In finite element analysis (FEA), the damping properties are important to simulate responses and resulting spectra. This has been clearly seen in the case of shock response spectrum where the amplitude is significantly affected by the damping of the response.

Since the damping property cannot be deduced from other structural or material properties, it becomes the most difficult dynamic property to predict at design stage. Therefore the damping can be measured only by conducting dynamic testing on a structure which is known as modal testing. The needs for reliable and accurate damping properties are necessary to have in order to produce a good simulation and improve a major source of uncertainty at the design stage.

1.3 Statement of the Problem

Since the damping properties are determined from modal parameter, the accuracy of the measured data is of paramount importance in experimental modal testing. The main challenge faced by many experiments in modal testing is the variations in modal test data which may be obtained by using different measurement techniques on a particular test structure [4]. Variations in modal test data have led to inconsistency in determining damping values.

Typically, the modal parameter obtained from experimental modal analysis may have low quality as a result of poor techniques and instrumentation used in the measurement. The main disadvantage using accelerometer to measure the response is due to mass loading effects. It is the mass relative to the effective mass of the structure where it is mounted play often an important role. An accelerometer weight at a very stiff location on a structure is different than that same accelerometer mounted on a thin lightweight panel in the same structure. Besides that, mass loading effects play a significant role when using a modal shaker [5].

The process of identifying modal parameters is commonly referred to as curve fitting. Therefore the accuracy of estimation damping values are also depends on which curve fitting technique is used. Part of this study involves in investigating the variation in damping values using different curve-fitting techniques.

1.4 Objective

The research objective of the study is to identify the damping properties of plates of several materials.

1.5 Research Question

The main research question is to determine which curve fitting algorithm is suitable for all type of material.

1.6 Scope and Key Assumptions

The scope of this study is limited to:

- Experimental approach using vibration technique.

- Aluminium plate, glass fibre composite plate and Kevlar fibre composite plate are used to identify the damping properties.
- The boundary condition of the test samples are set to be free - free condition.
- Two curve fitting methods are used: polyreference least-squares complex frequency-domain method (PolyMAX) and polyreference least-squares complex exponential time-domain method (LSCE).

1.7 Importance of the Project

The contribution of this study is obvious as the resulting outcomes can be capitalized as guidelines to achieve reliable and accurate damping properties which will help to simulate dynamic response of structures.

1.8 Organization of the Report

This project report consists of six chapters; the first chapter gives an overview of the subject by giving a background on the research subject and then followed by a statement of the problem. The second chapter provides a detailed review on the subject matter providing early literature to the very recent developments in the research area. The third chapter explains the related theory related to damping and modal analysis. Chapter four provides the methodology which this research is conducted upon. Experimental results and discussion are detailed in chapter five. Finally, chapter six concludes the study and provides recommendation for future research.

1.9 Summary

One of the most effective ways to reduce vibration problem is to have damping mechanism. The aim of the study is to determine reliable and accurate damping properties.

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