UNIVERSITI TEKNOLOGI MARA

DYNAMIC CHARACTERISTICS OF
DAMAGE AND HEALTHY FOR FIBERGLASS
REINFORCED EPOXY USING
OPERATIONAL MODAL ANALYSIS

HAIZUAN BIN ABD. RAHMAN

Thesis submitted in fulfilment
of the requirements for the degree of
Master of Science

Faculty of Mechanical Engineering

April 2014
I declare that the work in this thesis was carried out in accordance with the regulations of Universiti Teknologi MARA. It is original and the results of my own work, unless otherwise indicated or acknowledged as referenced work. This topic has not been submitted to any other academic institution or non-academic institution for any degree or qualification.

I, hereby, acknowledge that I have been supplied with the Academic Rules and Regulations for Post Graduate, Universiti Teknologi MARA, regulating the conduct of my study and research.

Name of Student : Haizuan Bin Abd. Rahman
Student I.D No : 2009140903
Programme : Master of Science
Faculty : Faculty of Mechanical Engineering
Thesis Title : Dynamic Characteristics of Damage and Healthy for Fiberglass Reinforced Epoxy Using Operational Modal Analysis
Signature of Student : 
Date : March 2014
ABSTRACT

Composite materials with nonlinear properties are prone to subsurface damages. Even though vibration response as damage detection method is widely used in engineering applications, its usage is to nonlinear and nonhomogenous properties especially in composite materials is still limited. This study attempts to apply vibration using Operational Modal Analysis (OMA) on fiberglass reinforced epoxy plate. OMA is used on undamaged fiber glass reinforced epoxy plate to extract the modal parameters and after which the procedure is extended to damage fiberglass reinforced epoxy plate. Both healthy and damaged composite material are tested for different boundary conditions i.e. free-free on 4 edges, 1 edge clamped, 2 edges clamped, 3 edges clamped and 4 edges clamped condition. Then result of frequency from OMA was compared analytically with finite element method. Nastran software is employed in this study. Based on the results, it shows that a high deviation between OMA and finite element method can be observed. Result of frequency from OMA was then compared with Experimental Modal Analysis (EMA) to validate the effectiveness of OMA method. It is shown that results obtained from OMA are equivalent with results obtained from EMA. Results of modal parameters obtained OMA was then compared between healthy and degrees of damaged (1st degree, 2nd degree and 3rd degree of damaged specimen 1 and specimen 2) specimen plates to detect damage using changes of modal parameters. Based from this comparison, it was found that frequency, mode shape and damping can be used to detect damage in fiberglass reinforced epoxy.
ACKNOWLEDGEMENTS

First and foremost, all the graciousness to Al-mighty Allah, for His love, His merciful and His guidance, for giving me inspiration through the completion of this thesis. I would also like to express my sincere gratitude to every individual involved in helping me to get through this process.

I would like to express my appreciation to my supervisor Professor Madya Dr. Ahmad Azlan Bin Mat Isa for the continuous support of my master study and research, for his advice, patience, motivation and knowledge.

I would also like to acknowledge the University Technology MARA for the financial support given to this work and scholarship through Young Lecturer Scheme (Skim Tenaga Pengajar Muda) that have been given to me.

Besides that, I would like to thank my lecturers, lab technicians and colleagues for providing me valuable input in their advice and knowledge in the completion of this research.

Lastly, special thanks to my family members and friends for supporting me during the course of this work. Thank you very much.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>AUTHOR'S DECLARATION</td>
<td>ii</td>
</tr>
<tr>
<td>ABSTRACT</td>
<td>iii</td>
</tr>
<tr>
<td>ACKNOWLEDGEMENTS</td>
<td>iv</td>
</tr>
<tr>
<td>TABLES OF CONTENTS</td>
<td>v</td>
</tr>
<tr>
<td>LIST OF TABLES</td>
<td>viii</td>
</tr>
<tr>
<td>LIST OF FIGURES</td>
<td>xii</td>
</tr>
</tbody>
</table>

## CHAPTER ONE: INTRODUCTION

1.1 Background of the Study                                     1  
1.2 Problem Statement                                           2  
1.3 Objectives of the Study                                     3  
1.4 Scopes of the Study                                         4  
1.5 Significance of the Study                                   5  
1.6 Organization of the Thesis                                  5  

## CHAPTER TWO: LITERATURE REVIEW

2.1 Damage Detection Based Vibration                            7  
2.1.1 Introduction of Damage Detection Based Vibration          7  
2.1.2 Development of Damage Detection Based Vibration           11  
2.1.3 Non-linear and Non-homogeneous Properties In Composite Materials 12  
2.1.4 Methods of Vibration Based Damage Detection              18  
2.2 Operational Modal Analysis (OMA)                            24  
2.2.1 Development of OMA                                        25  
2.2.2 OMA's Modal Parameter Extraction Methods                 26  
2.3 Finite Element Method (FEM)                                 29  
2.3.1 Introduction and Development of FEM                      29