



**UNIVERSITI TEKNIKAL MALAYSIA MELAKA**

**STUDY MODE SHAPE CURVATURE IN ALUMINUM 6061 USING  
CUBIC POLYNOMIAL REGRESSION METHOD BASED ON  
SIMULATION DATA**

This report is submitted in accordance with the requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor of Mechanical and Manufacturing Engineering Technology (Maintenance) with Honours.

by

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## DECLARATION

I declare that this thesis entitled “Study Mode Shape Curvature in Aluminum 6061 Using Cubic Polynomial Regression Method Based on Simulation Data” is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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## **APPROVAL**

This report is submitted to the Faculty of Mechanical and Manufacturing Engineering Technology of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Mechanical Engineering Technology (Maintenance Technology) with Honours. The member of the supervisory is as follow:

.....

(Mohamad Afiq Amiruddin Bin Parnon)

## **ABSTRACT**

This project aim is to detect the damage detection on aluminum material by using centered finite difference method. The primary purpose of making this project is to detect the depth crack size from 0.5 mm, 1.0 mm and 2.5 mm on a specimen. There are consists of multiple steps that can be used to detect depth of crack size by calculating using damaged mode shape curvature, undamaged mode shape curvature, damage index and damage estimate reliability. Furthermore, Microsoft Excel and LabVIEW software are used to record the data, generate graph for damage estimate reliability and help with numerical simulation resolution.

## **ABSTRAK**

*Matlamat projek ini adalah untuk mengesan pengesanan kerosakan pada bahan aluminium dengan menggunakan kaedah perbezaan terhingga berpusat. Tujuan utama membuat projek ini adalah untuk mengesan kedalaman saiz retak dari 0.5 mm, 1.0 mm dan 2.5 mm kepada spesimen. Terdapat beberapa langkah yang boleh digunakan untuk mengesan saiz retak dengan mengira dengan menggunakan kelengkungan bentuk yang rosak, kelengkungan bentuk yang tidak rosak, indeks kerosakan dan kebolehpercayaan anggaran rosak. Di samping itu, perisian Microsoft Excel dan perisian Labview digunakan untuk merekod data, menghasilkan grap bagi kebolehpercayaan anggaran kerosakan dan membantu resolusi simulasi berangka.*

## **DEDICATION**

I dedicated this project and research work to my beloved family and friends for being my source of inspiration and for the endless support throughout my entire life.

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## TABLE OF CONTENTS

<b>DECLARATION .....</b>	<b>III</b>
<b>APPROVAL .....</b>	<b>IV</b>
<b>ABSTRACT .....</b>	<b>V</b>
<b>ABSTRAK.....</b>	<b>VI</b>
<b>DEDICATION .....</b>	<b>VII</b>
<b>ACKNOWLEDGEMENTS .....</b>	<b>VIII</b>
<b>LIST OF TABLES.....</b>	<b>XII</b>
<b>LIST OF FIGURES.....</b>	<b>XIII</b>
<b>LIST OF EQUATIONS .....</b>	<b>XV</b>
<b>LIST OF SYMBOLS .....</b>	<b>XVI</b>
<b>LIST OF ABBREVIATIONS.....</b>	<b>XVII</b>
<b>LIST OF APPENDICES .....</b>	<b>XVIII</b>
<b>CHAPTER 1</b>	<b>1</b>
<b>INTRODUCTION</b>	<b>1</b>
1.1 Purpose of Study .....	4
1.2 Problem Statement .....	4
1.3 Objectives.....	5
1.4 Scope of work.....	5

<b>CHAPTER 2</b>	<b>6</b>
<b>LITERATURE REVIEW</b>	<b>6</b>
2.1 Background .....	6
2.2 Aluminum Material .....	8
2.3 Vibration Based Damage Detection .....	8
2.3.1 Natural Frequency .....	9
2.3.2 Damping Ratio.....	10
2.3.2.1 Under damped Vibration .....	12
2.3.2.2 Critical damped Vibration.....	12
2.3.2.3 Over damped Vibration .....	13
2.3.3 Mode Shape .....	13
2.3.3.1 Cubic Polynomial.....	14
<b>CHAPTER 3</b>	<b>19</b>
<b>METHODOLOGY</b>	<b>19</b>
3.2 Gather Information .....	21
3.3 Damage Mode Shape Curvature, $\phi^d$ .....	22
3.4 Undamaged Mode Shape Curvature, $\phi^u$ .....	24
3.5 Damage Index, Di .....	25
3.6 Damage Estimate Reliability, DER.....	26
3.7 Experimental Comparison.....	26

<b>CHAPTER 4</b>	<b>28</b>
<b>RESULT AND DISCUSSION</b>	<b>28</b>
4.1 Mode Shape Curvature and Damage Index.....	29
4.4 Discussion .....	46
<b>CHAPTER 5</b>	<b>49</b>
<b>CONCLUSION AND RECOMMENDATION</b>	<b>49</b>
5.1 Conclusion.....	49
5.2 Recommendation.....	50
<b>REFERENCES</b>	<b>52</b>
<b>APPENDIX</b>	<b>55</b>

## LIST OF TABLES

FIGURE	TITLE	PAGE
2.1	Example of curvature mode shape	18

# LIST OF FIGURES

<b>FIGURE</b>	<b>TITLE</b>	<b>PAGE</b>
1.1	Transportation	3
2.1	K-Chart	8
2.2	Modal response	11
2.3	Type of damping oscillator	12
3.1	Overall Project Flow Chart	20
3.2	Mode Shape Displacement of 10 points	21
3.3	Number of notches for centred finite divided difference method	22
3.4	Mode Shape Curvature between undamaged and damaged of aluminum material	25
4.1	Control zero damage with no depth	29
4.2	Single notch 150 mm depth 0.5 mm	30
4.3	Single notch 150 mm depth 1.0 mm	30
4.4	Double notch 150 mm depth 0.5 mm	31
4.5	Double notch 150 mm depth 1.0 mm	31
4.6	Double notch 150 mm depth 2.5 mm	32
4.7	Damage index for zero damage	36
4.8	Damage index for single notch 150 mm depth 0.5 mm	36
4.9	Damage index for single notch 150 mm depth 1.0 mm	37

4.10	Damage index for double notch 150 mm depth 0.5 mm	37
4.11	Damage index for double notch 150 mm depth 1.0 mm	38
4.12	Damage index for double notch 150 mm depth 2.5 mm	38
4.13	Damage estimate reliability for all sample of notch	40
4.14	Standard damage index for zero damage	42
4.15	Standard damage index for single notch depth 0.5 mm	42
4.16	Standard damage index for single notch depth 1.0 mm	43
4.17	Standard damage index for double notch depth 0.5 mm	43
4.18	Standard damage index for double notch depth 1.0 mm	44
4.19	Standard damage index for double notch depth 2.5 mm	44

# LIST OF EQUATIONS

1	Central Differences Method	23
2	Forward Differences Method	23
3	Backward Damage	23
4	GSM Cubic Polynomial	24
5	Damage Index	26
6	Damage Estimate Reliability	26

## LIST OF SYMBOLS

$\emptyset$	Displacement
$x$	Number of notches
$\emptyset_d$	Damage mode shape curvature
$\Delta X$	Total number of notches
$\emptyset_u$	Undamaged mode shape curvature



## LIST OF ABBREVIATIONS

SHM	Structural Health Monitoring
BVID	Barely Visible Impact Damage
NDT	Non-destructive Testing
VBDD	Vibration Based Damage Detection
MAC	Modal Assurance Criterion
COMAC	Coordinate Modal Assurance Criterion
IRLS	Iteratively Reweighted Least Square
FEA	Finite Element Analysis
GSM	Gapped Smoothing Method
SDI	Standard Damage Index
DER	Damage Estimated Reliability

## LIST OF APPENDICES

APPENDIX	TITLE	PAGE
A	VI Hierarchy	54
B	Zero Damage	55
C	Single Notch 150 mm depth 0.5 mm (51 points)	56
D	Single Notch 150 mm depth 1.0 mm (51 points)	57
E	Double Notch 150 mm depth 0.5 mm (51 points)	58
F	Double Notch 150 mm depth 1.0 mm (51 points)	59
G	Double Notch 150 mm depth 2.5 mm (51 points)	60
H	Zero Damage (26 points)	61
I	Single Notch 150 mm depth 0.5 mm (26 points)	61
J	Single notch 150 mm depth 0.5 mm (26 points)	62
K	Double notch 150 mm depth 0.5 mm	62
L	Double notch 150 mm depth 1.0 mm	63
M	Double notch 150 mm depth 2.5 mm	63
N	Damage Estimate Reliability of all sample of notch	64

## CHAPTER 1

### INTRODUCTION

#### 1.0 Background

Transportation is important for human being of their on daily life. Without transportation, its quite difficult for human being to move to one place to another. As highlighted by James H (2002), transportation is a science that cares about efficient movement of individuals and goods that is embraced with the goals of fulfilling tasks that require transferring from one place to another. In engineering, transportation was really worried about using scientific principles to the planning, design, operate and the management of transportation system. In another study, Quinet et al. (2011) examined the transportation also include services, goods and travelled people travelling from one location to another such as highways, cars, trucks, busses, aircraft, cargo ships, subways, railways, internet, television and water that are shown in Figure 1.1 below. Transportation that mostly goes through a lot of historical before humans started to use a car for travelling. According to Nolan (2015) the history of best transport closely parallels the history of civilization. The desire to create a reasonable transport framework for moving individuals and product is directly identified with humanity as a possible change from the traveling presence of seekers and gatherers to the stationary presence of an

agrarian culture. However, the revolution of significant urban communities and all constant human settlement may follow to similar advantage of position to best exchange. This locational benefit is deriving from the straight forwardness that is good, and individuals can be transported and exchanged as with other imperative areas.

In order to design structures, structural health monitoring is the way to execute damage detection and characterization strategy. There are four types involved in SHM such as health monitoring, operational evaluation, extraction of data features and development of statistical models. It makes difficult to re-examine the plan of the structure, fully management structure and the part of wider system that has been considered (Zinno *et al.*, 2019).

Transportation should basically undergo maintenance planning which is should be inspected on daily basis. Maintenance is any activity required to save and maintain an existing transportation facility within its option to proceed with the goal of using the facility securely and successfully for its intended purpose. There were four maintenance categories, including preventive maintenance, scheduled maintenance, unplanned maintenance, and normal maintenance. Preventive maintenance is minor repairs and usually scheduled inspection. Scheduled maintenance is the result of preventive maintenance reviews and planned. Unplanned maintenance is prompt action expected to correct unexpected occurrences that impact operational safety and productivity of operations. Normal maintenance is the facilities arranged and repeated everyday care. The importance for maintenance is to helps people to recognize the cause of damage or failure such as the failure due to design defects or failure to wear out. It also helps to decide which maintenance should be maintained if the damage occurs, whether to be replaced or repaired.

Besides detecting damage from external damage, detecting the detection inside crack is more important. When there is no maintenance for crack detection in transportation, it will be difficult to detect where the crack occurs. Cracking on transport material is usually difficult to detect if the crack occurs inside the composite structure. In transportation, there is harm to the user if there is a crack that cannot be seen by naked eyes, commonly referred to as barely visible impact damage (BVID) It is goods to go through the process of detecting damage so that it saves travel for transportation.



**Figure 1.1 Transportation (Quinet et al., 2011)**

## **1.1 Purpose of Study**

The purpose of the research is to investigate size of depth crack from 0.5 mm, 1.0 mm and 2.5 mm on aluminium 6061 by using cubic polynomial with numerical analysis method such as mode shape displacement, damage mode shape curvature, undamaged mode shape curvature, damage index and damage estimate reliability.

## **1.2 Problem Statement**

Transportation had many daily problems with people. The problem with non-destructive testing is that damage can only be detected on open surfaces, it takes time to complete one test, it cannot detect composite structure inside crack. Nondestructive testing methods requires high inspection costs and a bit messy. NDT methods are sometimes difficult when it comes to interpreting results. Other than that, NDT is sometimes to inspect NDT to apply painted objects. It is a problem if the damage can only be detected on outsider compare the damage inside the crack. There is good reason to choose vibration-based damage detection (VBDD) compared to NDT method because VBDD is very cheap in inspection and can detect small size of crack inside the composite structure. It is good if the crack can be detected with VBDD that cannot be seen with naked eyes because it can help the maintenance replace or repair the equipment. However, it is safe to first inspect the transportation before it is used to avoid accidents.

### **1.3 Objectives**

1. To identify undamaged and damage curve by using cubic polynomial regression method.
2. To detect the depth of crack from 0.5 mm, 1.0 mm and 2.5 mm.

### **1.4 Scope of work**

1. Use of aluminium 6061 as an experiment material.
2. Use Labview and Microsoft Excel software to calculate damaged and undamaged mode shape curvature.
3. Compare the numerical analysis result that obtain from both simulation and experimental for damaged and undamaged mode shape curvature.

## **CHAPTER 2**

### **LITERATURE REVIEW**

#### **2.0 Introduction**

To understand the vibration of damage identification and related method, the literature review is to detect the mode shape displacement, mode shape curvature for damage and undamaged curvature, damage index and damage estimate reliability. There are many inspections that can easily detect the vibration due to damage structure such as nondestructive testing (NDT) and vibration-based damage detection (VBDD).

#### **2.1 Background**

This basic concept vibration will undergo three characteristic such as aluminum material and vibration-based damage detection method. The method of detection of damage in vibration-based method consists of three types such as natural frequency, mode shape and damping. The K-Chart will briefly explain the exact flow for vibration according to the analysis and method is shown in Figure 2.1