UNIVERSITI TEKNIKAL MALAYSIA MELAKA

STRUCTURE ANALYSIS IN ALUMINIUM 6061 USING FINITE ELEMENT ANALYSIS FOR DAMAGE DETECTION

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 "Structure Analysis in Aluminium 6061 Using Finite Element Analysis for Damage Detection" 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

I hereby declare that I have read this dissertation/report and in my opinion this dissertation/report is sufficient in terms of scope and quality as a partial fulfillment of Bachelor of Mechanical and Manufacturing Engineering Technology (Maintenance) with Honours.

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ABSTRAK

Pemantauan Kesihatan Struktur (SHM) telah digunakan untuk mengekalkan keselamatan dan integriti struktur dalam pelbagai aplikasi seperti pesawat, mesin, dan struktur awam. Komposit biasanya digunakan dalam bidang pesawat kerana penyahmampatan dan kerosakan impak yang tidak dapat dilihat (BVID). Teknik pemeriksaan tanpa musnah (NDI) telah digunakan untuk mengesan pencemaran, seperti termografi, ujian ultrasonik, ujian semasa Eddy, ujian pancaran akustik, dan radiografi. Tetapi struktur perlu menyediakan operasi untuk memulakan operasi NDI jika struktur besar memerlukan masa yang lama. Objektif utama kajian ini adalah untuk mengesan kedalaman retakan 0.5 mm, 1.0 mm dan 2.5 mm dalam bahan isotropik. Kajian ini untuk mengenalpasti anjakan bentuk mod bagi setiap titik dalam bahan isotropik. Kajian ini menggunakan data simulasi Finite Element Analysis (FEA) yang dijalankan menggunakan perisian simulasi ABAQUS. Proses ini bermula dengan penciptaan geometri menggunakan perisian SolidWorks dan menghasilkan geometri untuk perisian ABAQUS, memberikan sifat material, memilih jenis elemen dan membuat mesh, menggunakan beban dan kekangan, dan mengkaji semula bentuk anjakan bentuk mod untuk 51 mata. Hasilnya adalah membandingkan hasil simulasi dan keputusan eksperimen dengan menggunakan ujian kesan tukul. Dari data simulasi, graf tersebut menunjukkan kelengkungan licin untuk kawalan atau spesimen yang tidak rosak dan spesimen yang rosak hampir serupa. Tetapi, bentuk yang sangat sedikit berbanding dengan grafik hasil eksperimen kerana terlalu banyak dan terdapat kerosakan atau kecacatan pada spesimen.

ABSTRACT

Structural Health Monitoring (SHM) has been applied to maintain the safety and integrity of the structure in different applications such as aircraft, machine, and civil structure. Composite is commonly used in the aircraft field due to delamination and Barely Visible Impact Damage (BVID). Non-Destructive Inspection (NDI) techniques have been used to detect delamination, such as thermography, ultrasonic testing, Eddy current testing, acoustic emission testing, and radiography. But the structure needs to prepare for the operation to start the NDI operation if a large structure takes a long time. The main objective of this study is to detect the depth of crack of 0.5 mm, 1.0 mm and 2.5 mm in isotropic material. This study to identify mode shape displacement for each point in isotropic material. This study using Finite Element Analysis (FEA) conducted simulation data using ABAQUS software. The process begins with the creation of geometry using SolidWorks software and generates geometry for ABAQUS software, assigning material properties, selecting the type of element and creating a mesh, applying loads and constraints, and reviewing mode shape displacement results for 51 points. The result is to compare simulation results and experimental results using the hammer impact test. From the simulation data, the graph shows smooth curvature for control or undamaged specimen and damaged specimen is almost similar shape. But, a very slightly different shape compare to the graph of experimental result because there are too much and there was damage or defect in the specimen.

DEDICATION

Special dedicated to my beloved father and mother,

Hambali Bin Ismail

Kamaduyah Binti Mohd Sari

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In performing this final year project, the most gracious and most merciful to the Allah S.W.T that I can completely manage for this final year project without any problems occurs.

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CHAPTER 1

INTRODUCTION

1.1 Background

Transportation uses a variety of vehicles to move people and goods across different infrastructure systems from one place to another. It does this not only by using technology such as vehicles, energy, and infrastructure, but also by using people's time and effort to produce not only the desired passenger and transport travel outputs, but also adverse effects such as air pollution, noise, congestion, crashes, injuries, and death. Figure 1.1 shows the transportation inputs, outputs and outcomes. Function of transportation is a transportation creates the place's usefulness. Cultural and geological factors in particular force industries to distance themselves from markets and places where product demand do not exist. Transport bridges the gap between centers of production and distribution.

A transport should normally undergo maintenance planning, which should be inspected on a daily basis. There are four maintenance types, such as preventive maintenance, scheduled maintenance, predictive maintenance, and corrective maintenance. Transportation maintains technology because it changes the types of information and infrastructure that need to be maintained. Advanced technology is increasingly being integrated in the transport infrastructure, resulting in the need for new maintenance procedures and a very different set of skills for both maintenance employees and maintenance staff. Technology affects the performance of maintenance. Information technology governmental and departmental barriers throughout the company particularly progress in integrated information systems.

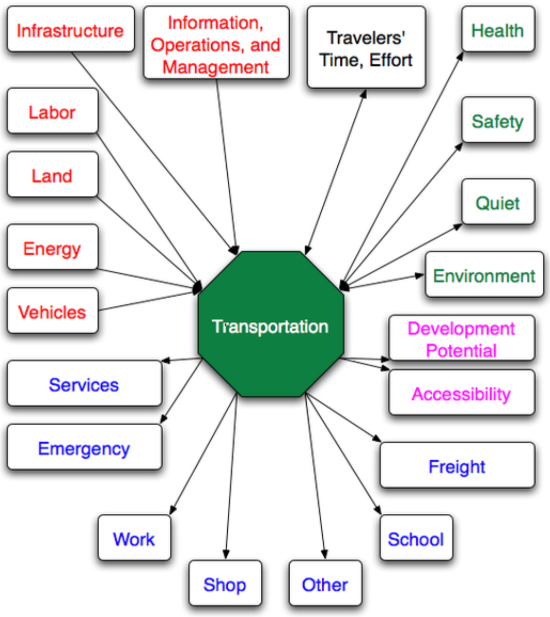


Figure 1.1: The inputs, outputs, and outcomes of transportation (www.FundamentalsofTransportation.com)

Structural Health Monitoring (SHM) is the process of applying a damage detection and character development strategy for engineering structures. According to Hua and Yi (2018), Structural Health Monitoring (SHM) is a process of the in service health assessment for a structure through a computerized monitoring system and will be a key element of cost effective strategies for condition-based maintenance. SHM is an important tool for ensuring the integrity of structures and the safety of different structures such as aircraft, machine, and civil structures. SHM includes health monitoring, operational evaluation, extraction of data features and development of statistical models. The goal of SHM to enhance the performance of an existing structure, monitor structures affected by external factors, and decline in construction and maintenance needs growth.

If transport maintenance is poor, it can cause transport damage. There are three types of damage in transportation such as minor damage, moderate damage, and severe damage, but all of this damage can be seen with eyes. Barely Visible Impact Damage (BVID) is the most dangerous damage in transport. According to P. Rozylo et al. (2017), there are two types of composite damage that are non-visible impact damage (NVID) or barely visible impact damage (BVID). Both result in reduced structural integrity of the material. The purpose of barely visible impact damage (BVID) to damage in a composite material such as carbon fiber-reinforced polymer (CFRP) caused during maintenance or operation by low velocity impact of objects. This damage cannot be seen with eyes. Example of BVID in transportation is crack inside the part body such as a wing aircraft. The outside surface is untouched, but inside there is crack.

1.2 Problem Statement

Non-Destructive Inspection (NDI) is a mechanism to detect defects in materials and structures during manufacturing or while in service. NDI methods are used in three ways in the process of repairing composite and bonded structures are location of damage, damage assessment such as type, size, shape and internal position, and quality assurance after repair. Example of NDI methods such as visual inspection, thermography, radiography, and ultrasonic, but it took a long time and expensive to implement NDI for large structure as the structure had to be discontinued in its operation. For example, when inspecting an aircraft on the wing. It takes a long time to cover the entire wing and detect the location of the damage area. In addition, lots of workers are needed, which will increase maintenance costs and the aircraft must be out of operation. The longer the aircraft remains in operation can have an effect on the company. The solution is Vibration-Based Damage Detection (VBDD) using finite element analysis to detect small size of crack in structure. This technique can reduce the time taken to inspect the large structure, reduce maintenance costs and optimize transport operating time.

1.3 Objectives

The objective of this project are as below:

1) To detect the depth of crack of 0.5 mm, 1.0 mm and 2.5 mm in isotropic material.
2) To identify mode shape displacement for each point in isotropic material using finite element analysis.

1.4 Scope

1) Detect damaged and undamaged on the specimen 0.5 mm, 1.0 mm, and 2.5 mm.
2) Use an aluminium 6061 as an isotropic material in simulation data.
3) Finite Element Analysis (FEA) conducted simulation data using ABAQUS Software.

CHAPTER 2

LITERATURE REVIEW

2.1 Background of Vibration

The study about vibration involves the oscillatory movements of the bodies and their forces. There are two types vibration that are free and forced. According to Florian et al. (2014), free vibration usually happens while the system oscillates under the motion of forces systemic as a whole but when there is no impressed external forces. The system under free vibration will vibrate as properties of the dynamic system at one or more natural frequencies by mass and stiffness. Damping is a general feature of free vibration. All systems are exposed to frictional forces and the energy of the vibrations decreases the amplitude. Forced vibration is the vibration which usually happens under the excitement of external forces. The system is forced to vibrate at the frequency of excitation when the excitation is oscillatory.

Vibration usually occurs in the mechanical compartment. Another studies by Stephen et al. (2014), the mechanical system vibrates when its parts undergo movement that oscillates in time. Vibration can be desirable or undesirable, such as motion of a turning fork, the reed in a woodwind instrument or harmonica, a mobile phone, or the cone of a loudspeaker. It is wasteful of energy and undesired sound in undesirable vibration, such as the vibrations in an aircraft's body part are typically unwanted. It happens because vibrations can cause unseen damage or crack that is not visible to the eyes. When an aircraft is in operation with the unseen damage, catastrophe can occur. Figure 2.1 shows of K-chart of vibration.

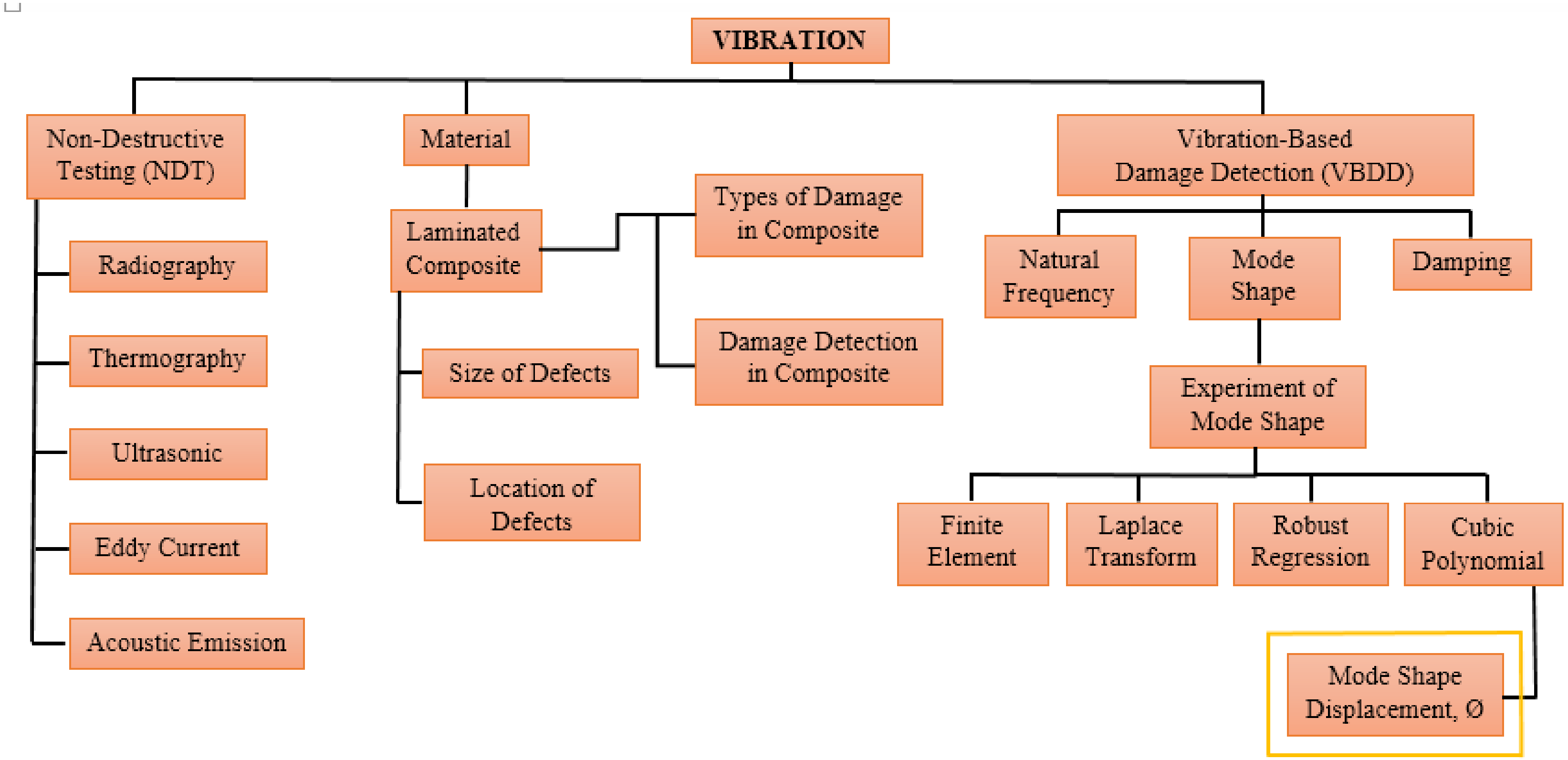


Figure 2.1: K-chart of Vibration

2.2 Non-Destructive Testing

Non-Destructive Testing (NDT) is the word used to represent a method by which physical principles are applied to determine the features of materials, components or structures and another objective is to detect identifying and damaging defects without affecting the effectiveness of materials, components or structures. As highlighted by Lockard (2015), NDT is now the most common in the quality control for the finished product but during different phases of production. NDT also used condition monitoring during operation to determine and evaluate the useful life of the component when maintaining its structural stability. NDT involves many technique like visual inspection, liquid penetrant testing, and magnetic particle testing, and others. There are many types of NDT for composite material defect detection such as radiography, ultrasonic testing, eddy current testing, acoustic emission testing, and thermography.

2.2.1 Radiography

Radiography is among the few techniques used for non-destructive testing. According to Lockard (2015), radiography is the most commonly used test technique. The main objective of radiography is to prove the involvement and nature of defects or other structural. Besides that, radiography is a matured method which has been used over a hundred years. But in non-destructive testing, radiography is the most expensive. In radiography, it is suitable to detect changes in material composition, thickness measurements and to locate unwanted or defective components that are hidden from view. Figure 2.2 shows the radiography principle.

Radiography can be used to inspect most types of solid materials, both ferrous and non-ferrous alloys, such as non-metallic materials and composites. It can be used to inspect the condition and proper placement of components for the measurement of liquid levels in sealed components. The method is used for casting, welding and forging when there is a critical need to ensure that the object is free of internal flaws. Radiography is suitable for inspecting semiconductor devices for the detection of cracks, broken wires, unsoldered connections, foreign material and misplaced components because other techniques are limited in the ability to inspect semiconductor devices.

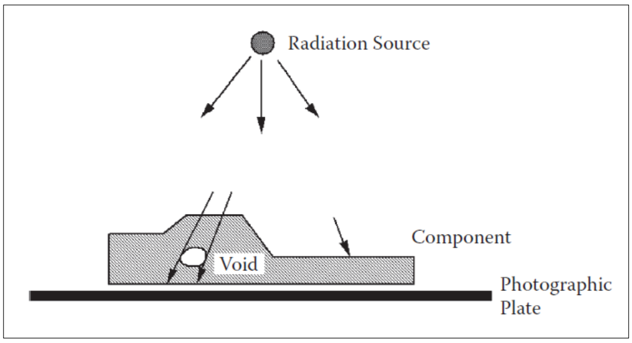


Figure 2.2: Radiography principle (Heslehurst, 2014)

2.2.2 Ultrasonic Testing

Ultrasonic testing is another method in NDT. Ultrasonic testing that will be useful for most materials, either metallic or non-metallic. According to Jolly et al. (2015), the range of frequency ultrasonic waves or sound waves from 500 kHz to 10 MHz. Ultrasonic waves are usually used for non-destructive testing application. Three types of sound waves are longitudinal waves, transverse or shear waves, and surface waves. Most commonly used in NDT application is longitudinal waves. A pulse-echo (A-scan) or transmission (C-scan) is two major ultrasonic methods. These two methods measure changes in sound attenuation as the sound goes through the area of interest. Ultrasonic C-scan methods are shown in Table 2.1, representative ultrasonic pulse-echo results are shown in Table 2.2, and graphite laminate ultrasonic C-scan results in Figure 2.3.

Table 2.1: Ultrasonic C-scan method (Heslehurst, 2014)

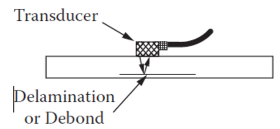
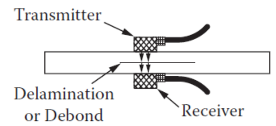
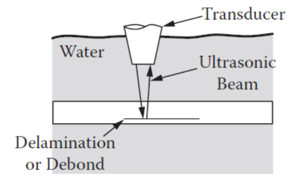
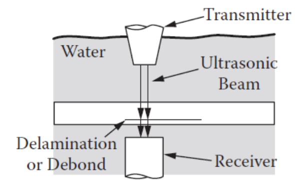
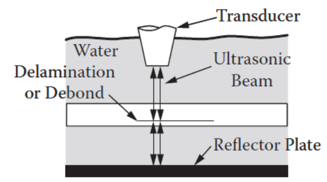
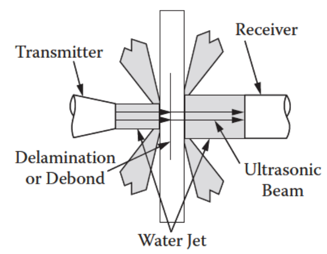
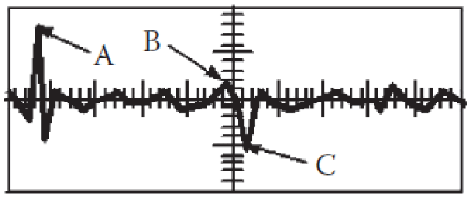
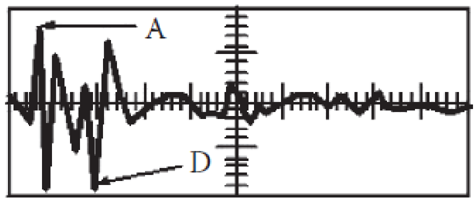
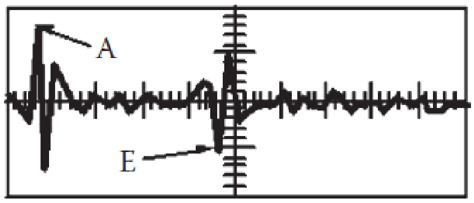
a) Ultrasonic methods inspection in contact pulse-echo.	
b) Ultrasonic methods inspection in contact through transmission.	
c) Ultrasonic methods inspection in immersion pulse-echo.	
d) Ultrasonic methods inspection in immersion through transmission.	
e) Ultrasonic methods inspection in immersion reflection.	
f) Ultrasonic methods inspection in water jet through transmission.	

Table 2.2: Representative ultrasonic pulse-echo results (Heslehurst, 2014)

A graphite composite skin and honeycomb core is a representative ultrasonic pulse-echo in a well-bonded sample.	
Representative ultrasonic pulse-echo results of a skin and honeycomb composite graphite in delamination of the skin.	
Representative ultrasonic pulse-echo results of composite skin and honeycomb graphite in skin to core debond	

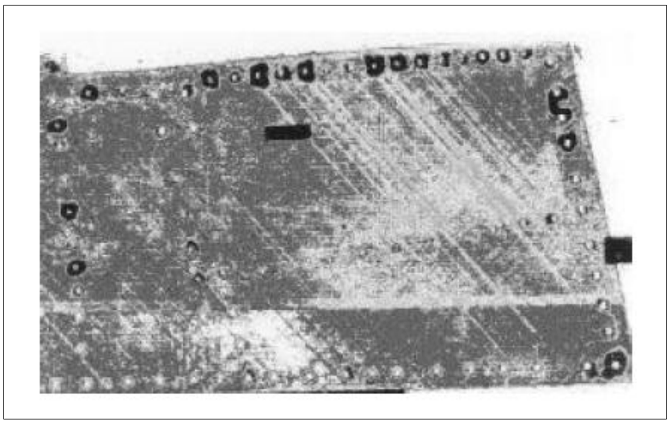


Figure 2.3: Graphite laminate ultrasonic C-scan results (Heslehurst, 2014)