THE EFFECT OF LOW-FREQUENCY VIBRATION VARITATIONS IN VIBRO-ACOUSTIC TEST FOR CRACK DETECTION

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A report is submitted in fulfilment of the required requirements for Bachelor of Mechanical Engineering

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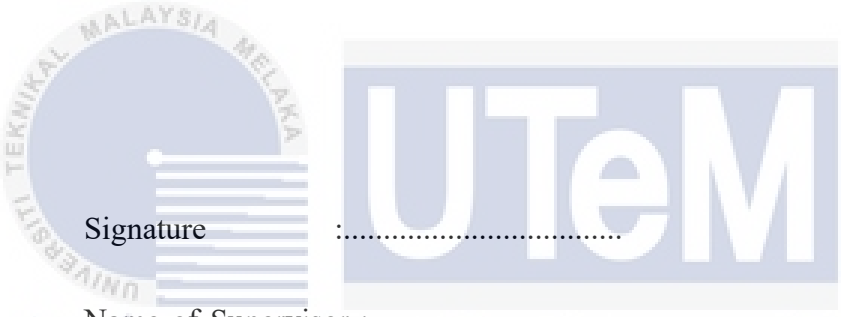
SUPERVISOR'S DECLARATION

I have checked this report and the report can now be submitted to JK-PSM to be deliveredback to supervisor and to the second examiner.



Signature :.....

Name of Supervisor :.....

Date :.....

APPROVAL

I hereby declare that I have read this project report and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering.

Signature : …….

Name of Supervisor : …….

Date : …….

DEDICATION

To my beloved parents (Mariati Binti Yunos and Khalid Bin Abd Rahman)

ABSTRACT

This report is the study of the effect of low frequency excitation on nonlinear vibro-acoustic test to detect crack on a structure. In general there are various type of damage and flaw that can impact on a microstructure and some test needed to be run in order to analyze condition of the structure. Past study shows that vibro-acoustic test is one of the effective way to detect crack on metallic structure. In this thesis, low frequency vibration was introduced to both damage and undamaged structure in order to gain the modulation intensity of the specimen. Using a non-linear vibro-acoustic test, this research investigates the influence of low and high frequency stimulation on structures with various types of cracks. To begin, learn how to use all of the equipment used in vibro-acoustic testing in the laboratory. Then, articles and journal from previous study regarding the topic needed to be collected and to make literature review. From the data collected from each study, the result of modulation intensity are taken down to analyze the factor that causes increment of the R-value. Lastly, the difference of modulation intensity of each journal is discussed and compared in this thesis.

ACKNOWLEDGMENT

First and foremost, I want to thank God, the Almighty for being able to complete this final year project report prepared within the date line given with success.

I would like to express my deepest gratitude and appreciation towards my supervisor, Dr Ruztamreen Bin Jenal, whose valuable guidance has been ones that helped me patch this report and make full proof success his suggestions and his instructions have served as a major contributor toward the completion of my study. He has also provided me with necessary insight and enlighten me much with engineering career which I have very little exposure about it before this. Without any reluctance, I probably will end up failing to complete the task given without his constant support and appropriate advices.

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LIST OF ABBREVIATIONS

NDT	Non Destructive Testing
VAM	Vibro Acoustic Modulation
SLDV	Scanning Laser Dopple Vibrometer
FFT	Fast Fourier Transform
FRF	Frequency Response Functio

CHAPTER 1

INTRODUCTION

1.1 Background Study

For the past decade, non-linear interactions is common research to tackle the structural integrity in engineering field. The interactions involved with low frequency and high frequency wave is the parameters that is necessary to be implied on ancient or aging structureto improve their structural integrity.

The common issues is the fatigue crack which can be identified using Non-Destructive testing (NDT) such as Liquid Penetrant testing, Ultrasonic testing,

Magnetic Particle Testing and other several techniques. These various technique of NDT is implemented based on different type of structural failure in many conditions. Reliable method required for achievingwell result as NDT is important for safety aspects to examined any possible failure on the infrastructure of any material.

A study on 2010 regarding aircraft integrity that can lead to fatigue crack shows that to build a lighter aircraft, the high stress required can actually lead to fatigue failure occurrenceat several parts of the structure. (Molent, Loris and Barter, Simon, 2010, 04, 363-377,The Lead Fatigue Crack Concept for Aircraft Integrity, 2, Procedia Engineering).

Vibro-acoustic method (VAM) is a technique to identify the propagation of high frequency acoustics waves in solid structures with low-frequency excitation. VAM is usuallya dimensioning load case for light-weight structures like antenna reflectors and solar arrays. For equipment mounted on the panels of a spacecraft, the dynamic response of the panels to the acoustic load leads to high and, often dimensioning, random vibration loads. In short,VAM is reliable technique to detect any fatigue failure and crack that can disrupt the structural integrity.

For some cases, non-linear fatigue failure is more easily disrupted compared to linear ones,so non-linear VAM is necessary to gain more accurate data regarding the flaw.

1.2 Problem Statements

In general, Vibro Acoustic method can inspect linear fatigue cracks according to the wave speed such as the propagating technique of ultrasonic method. The results of the test is well obtained to measure any possible open and micro-crack present in materials. However, for some cases, non-linear fatigue failure is more easily disrupted compared to the linear ones. Sonon-linear VAM approach is necessary to gain more accurate data regarding the flaw. Non- linear VAM is one of the way to overcome the problems regarding non-linear damage on certain material and giving more reliable data to analyse the crack on the infrastructure.

1.3 Objective

The aim for this report is to review the effect of low frequency excitation and location on center crack of aluminium pipe using the technique of non-linear vibro-acoustic method.The interaction between low frequency and high frequency on different locations of the damage will result on wave modulation or R-value look over at the end of the research.

1.4 Scope of Project

The main scopes that will be covered across this study is:

i. A sample specimen of aluminium plate to be prepared with parameter of 400 mm x150 mm x 2 mm.
ii. Run a modal analysis on the specimen to obtain natural frequencies and mode crackof the plate.
iii. A test of non-linear vibro acoustic test to be conducted to gain the experimental dataof the wave modulation effect or the R-value.

CHAPTER 2

LITERATURE REVIEW

2.1 Fatigue Crack

A crack structure usually happened due to extensive stressed applied upon a material, exceeding its own strength. The extra stress could harm the structural integrity which can cause crack, or most probably collapsing the entire infrastructure. (The Welding Engineer'sGuide to Fracture and Fatigue, 2015). Each materials have its own parameters which every part of them have the possibilities to crack or undergoes any sign of fatigue failure. Usually the discontinuities on the surface material have to be treated in order to analyse the crack growth as the fatigue test such as non-destructive test is required to produce a long life-spanproduct that is safe and reliable in industry. (L. Molent and S.A. Barter *et al.* 2010). Hence,the growth crack can be initiated by cyclic loading due to stress range, stress amplitude, frequency, waveform effects and many more parameters. When any cyclic deformation detected, further test or method should be utilize to consider whether the material undergoesfatigue failure or not. Based on figure 2.1, it shows the system

proposed by Hoeppner, 1971 regarding the initial parameters of cyclic loading to determine fatigue failure. (Hoeppner

D.W. *et al.* 2013).

The fracture of material can be divided into three different modes. The first ones is the opening crack mode due to any possible orthogonal tensile stress acting uponthe plane of the crack. Next is the sliding mode where the stress is parallel with the surface crack but it is also perpendicular to the crack front. Next is the sliding mode where the stress is parallel with the surface crack but it is also perpendicular to the crack front. The last mode is the tearing mode where the shear stress is acting on both surface plane crack and crack front.

Figure 2.2 shows the illustration of the mode crack. (Alan T. Zehnder *et al.* 2013).

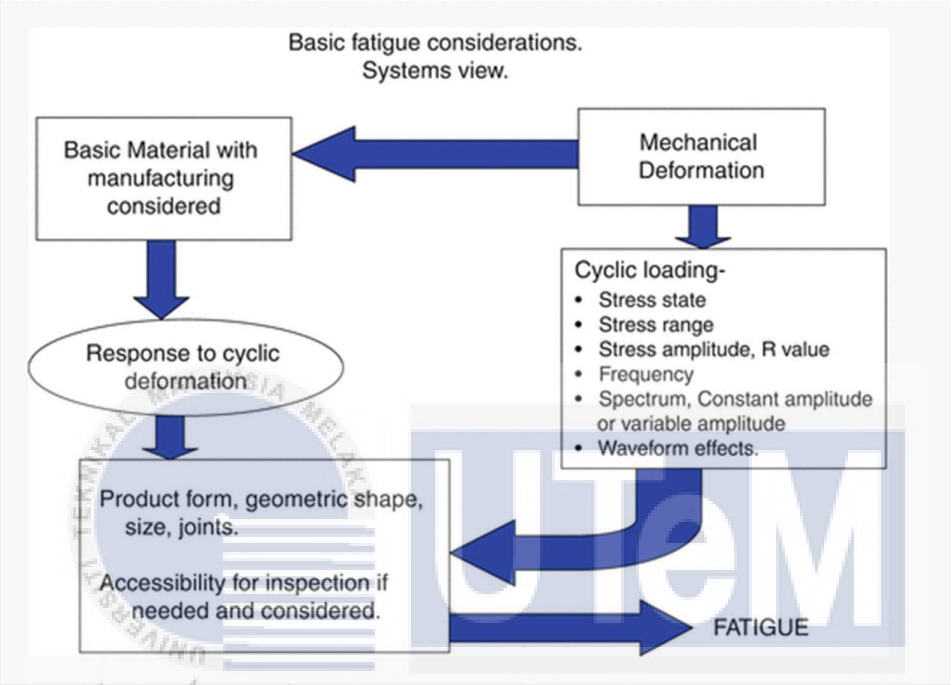

Figure 2.1: Parameters of cyclic loading to consider fatigue failure

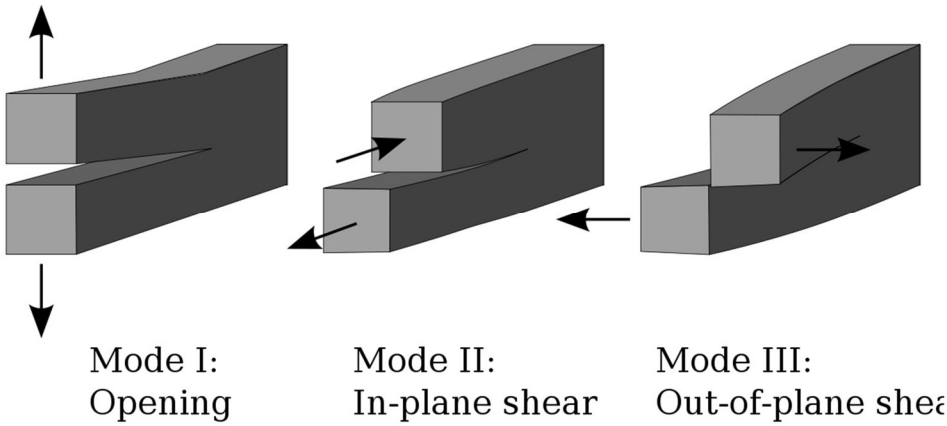

Figure 2.2 : Three types of crack modes

2.2 Modal Analysis

A modal testing is one of the way to study the vibrations behavior in a certain mechanicalproperties. In the year 1940, an early approach was done by engineers to determine the critical part of an aircraft that probably have the high risk of fatigue failure under dynamic loadings by measuring the same wave of frequency response function. (D.J. Ewins *et al.*

2001). A mathematical form of data can be obtained when any excitation and response signaldetected on the surface material, performing an analyzed data of measurement to study the behavior of the vibration. (*Power Ultrasonic, Modal Testing 2015*) Further study also stated that modal analysis role is to gain the natural frequency and mode shape that will give a brief explanation of any movement on any parts of mechanism which undergoes dynamic loading condition. (*Research Studies Press, 1985*).

According to *Basic of Modal Testing & Analysis* journal on 2016, the procedure of modalanalysis begins with the measurement of excitation and response of the materials. By applying force to excite the structure, Frequency Response Function (FRF) data can be obtain as the excitation resulting the response vibration that is commonly the acceleration being measured. The data obtained is adequate to provide the information of modal parameters such as the natural frequencies, damping computation and the mode shape of thestructure. Figure 2.3 (Klepka *et al.* 2017) shows the basic setup of modal test.

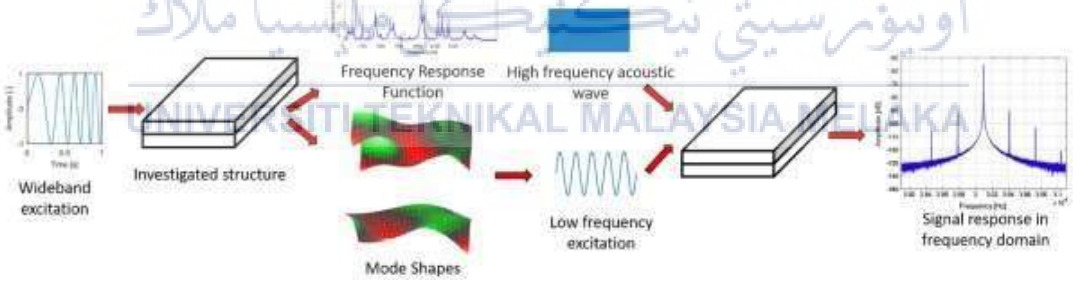

Figure 2.3 The schematic diagram of setup of modal testing

There are various way to excite the structure to gain vibrating response which is by usingimpact hammer and modal shaker method. For uncomplicated structure, impact hammer method is adequate to excite the structure while generating voltage signal to measure the excitation force. The hammer tip hardness is adjustable according to the required amount fofrequencies. To gain low frequency measurement, soft tip hammer can be used and harder ones for higher frequency detection.

For modal shaker method, the technique usually prepared for laboratory modal testing which is more complicated. When the experimental objective demands sufficient level of response, the modal shake size plays an important role. Instead of using hammer tips to excitevibration, this method applied a small thin rod as known as stinger. For measurement purpose, force censor and accelerometer mounted at the driving point of structure to measure excitation force and acceleration levels respectively.