A NON-DESTRUCTIVE TEST CRACK DETECTION METHOD USING VIBRATION ACOUSTIC ON ALUMINIUM PLATE

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SUPERVISOR DECLARATION

"I admit to have read this report and it has followed the scope and quality in Partial Fulfillment of Requirement for the Degree of Bachelor of Mechanical Engineering (Automotive)"

Signature: .....

Supervisor: DR, RUZTAMREEN JENAL

Date: 24th JUNE 2013

DECLARATION

"I hereby declare that this report is my own work except for some summaries and information which have been duty acknowledged."

Signature: ……..

Name: NUR ILMI BT. MOHAMAD ROSLAN

Date: 24th JUNE 2013

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ABSTRAK

Kajian ini dilakukan adalah untuk mengkaji keretakan yang berlaku ke atas plat aluminium dengan menggunakan teknik getaran akustik secara tidak langsung. Getaran Akustik tidak langsung merupakan kaedah yang boleh digunakan untuk mengesan dan menganalisis sebarang kecacatan, walaupun keretakan yang sangat kecil. Kaedah ini merupakan suatu kaedah yang sangat cepat dan sangat sensitif untuk mengesan keretakan. Objektif utama adalah untuk mengesan keretakan terhadap plat aluminum dengan menggunakan kaedah getaran Akustik.Selain itu, untuk mengetahui hubungan di antara keretakan bahan dengan nilai indek yang juga dikenali sebagai (R-value). Dua ujian akan dijalankan iaitu ujian modal dan ujian getaran akustik tidak langsung. Modal ujian dijalankan untuk memilih nilai frekunsi rendah untuk merangsang plat. Manakala, ujian Vibro-akustik dilakukan untuk menyiasat kewujudan retak pada plat. Keretakan diukur dengan menggunakan keamatan gelombang pemodulatan dipanggil sebagai indeks "R-Value". Hasil menunjukkan bahawa, intensiti modulasi vibro-akustik bergantung kepada panjang retak; retak yang lebih besar menghasilkan jalursisi modulasi lebih dengan amplitud yang lebih besar. Berdasarkan kajian,untuk mode tertentu apabila panjang retak bertambah, nilai "R-Value" juga akan bertambah. Walau bagaimanapun, tidak semua frekunsi adalah sesuai digunakan untuk menentukan hubungan keretakan plat dengan "R-value".

ABSTRACT

This study is carried out to investigate the crack that occurs on the aluminum plate by using non-linear vibro acoustic method. Non-linear Vibro-Acoustic is a method that can be used to detect and analyze any defect, even very small cracks. This method is very fast and sensitive to detect cracks. The main objectives are to perform nonlinear vibro-acoustic test for detecting fatigue crack in aluminum plate. Beside, to determine the relation between fatigue crack sizes with nonlinear wave modulation effect, (R-value) .Two test will be carried out that is modal test and vibro-acoustic test. Modal test is performed to select the low frequency values to excite the plate. While, Vibro-acoustic test is performed to investigate the present of crack on the plate. The cracked identification is measured by using the intensity of wave modulation called as R-value index. The result shows that, the intensity of vibro-acoustic modulation depends on crack length; larger cracks produce more modulation sidebands with larger amplitudes. The finding shows that for certain mode when crack length increase, R-Value also increases. However, not all frequency is suitable to be used to determine the relationship of R-value and crack length.

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R	=	modulation index
A_0	=	ultrasonic amplitude
A_1	=	first sideband amplitude on the left
A_2	=	first sideband amplitude on the right

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Damage in structures can be defined as changes of material and/or geometric properties in a structure that could affect the structure's performance. [1, 25, 26].There are many ways than can be used to detect incipient damage in solid structure, a method to detect is linear analysis or non-linear analysis known as Nondestructive Test/Evaluation (NDT/NDE) methods. This measurement system evaluates a structure's properties without causing damage. Widely used NDT techniques are dye penetration, magnetic particle, eddy-current, radiography, ultrasonic and acoustic emission. [2, 3, 22].Dye penetration, magnetic particle, eddy-current, radiography, ultrasonic can be categorized as linear test while Vibro-acoustic test is non-linear test. Linear test can be defined as the method which get the direct result after test have been carried out, while non-linear test is the process where the result can only been obtained after few procedure have been taken.

However, from all of this method, these projects only use vibro acoustic method. Although, the evidence of test is still not satisfy due to the lack understanding of physical mechanism of the non-linear effect. But, it is really important to diagnose defects at an early stage for most types of materials with various geometries. Therefore,

this experiment is carried out to show evidence that non-linear vibro-acoustic method is possible to detect incipient crack in aluminums plate.

Vibro-acoustic is a method that will be used for fatigue crack detection based on propagation of high frequency acoustic waves in solid structures with low-frequency excitation [24]. The focus of the test is to determine the relation between fatigue crack sizes with nonlinear wave modulation effects [19, 30]. It is important to analyze the modal parameters of a cracked plate to understand the behavior of movement of crack edges in a plate and plate surface responses to the low-frequency excitation in vibro-acoustic testing [18, 19, 24]

Experimental modal analyses will be carried out on the uncracked and cracked aluminums plate to validate the simulation results. The experimental work was performed on a 150 mm × 400 mm × 2 mm aluminum plate.

1.1.1 APPLICATION OF NDT

NDT is widely use in industries because of its effectiveness to detect flaw or defect of material [21, 29]. However not all the method will work for all flaw detection or measurement applications due to the limited usage. Each of the method has their advantage and disadvantage. Some of application that is widely uses is;

- **Power plant inspection**

In power plants, for inspection test the plants will be shutdown periodically. In order to check for corrosion damage, inspectors will feed eddy current probes into heat exchanger tubes as shown in figure 1 below. During the process, if the structure has the damage, signal will be produces by the probes as shown in figure 1.1 below [17].

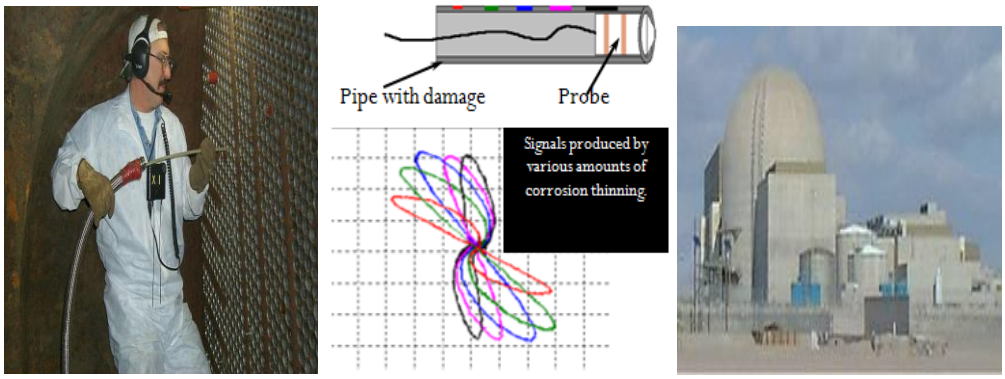

Figure 1.1: Application of NDT in power plant

(Source: Brian Larson 2009)

➢ **Air craft Inspection**

In aircraft, NDT is widely used for manufacturing purpose. Besides, during operation of the aircraft, this test is used to detect crack and corrosion damage. Figure 1.2 below show the result of the NDT test, from the figure we can see a crack that were exist [17, 34, 40, 43].

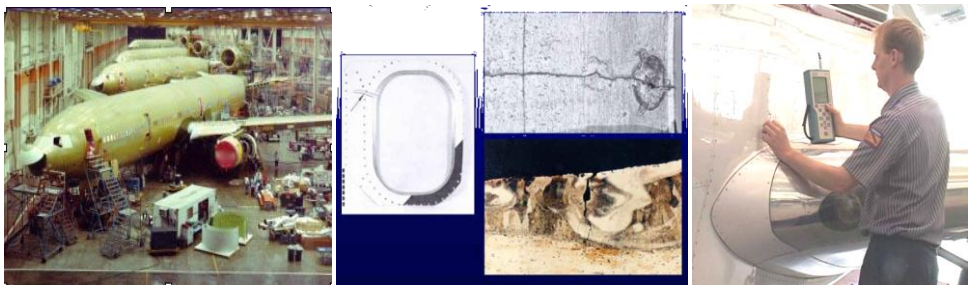

Figure1.2 : Application of NDT in air craft

(Source: Brian Larson 2009)

➢ **Bridge Inspection**

Every 2 year, a bridge will undergo a visual inspection for damage. Damage in the bridge such as cracking or corrosion could affect their performance, thus there are some bridges that were equipped with acoustic emission sensor to detect the crack growing. Figure 1.3 below show the silver Bridge that was collapse in 1967 which had caused in loss of 47 lives. Therefore, it is important to detect the crack or damage at early stage to avoid the accident [17, 22].

Figure1.3 : Application of NDT in bridge

(Source: Brian Larson 2009)

1.2 PROBLEM STATEMENT

Nonlinear analysis is an effective method used to detect incipient damage in solid structure. However, the evidence of test is still not satisfy due to the lack understanding of physical mechanism of the non-linear effect. But, it is really important to diagnose defects at an early stage for most types of materials with various geometries. Therefore, this experiment is carried out to show evidence that non-linear vibro-acoustic method is possible to detect incipient crack in aluminums plate.

1.3 OBJECTIVE

In order to complete this project, there are some objectives that need to be achieved, the objective are to:

- Perform nonlinear vibro-acoustic test for detecting fatigue crack in aluminum plate.
- Determine the relation between fatigue crack sizes with nonlinear wave modulation effects.

1.4 SCOPE

In this project, the scopes that need to be cover include:

- Setup experimental apparatus which include equipment setup, specimen preparation and measurement system.
- Perform non-linear vibro-acoustic test on uncracked and cracked plate by using modal test
- Analysis the experimental data to obtain the non-linear wave modulation effect
- Determine the relation between the crack sizes with the modulation effect.

1.5 STRUCTURE OF PROJECT

This section will brief about each of the chapter in this project. The project is carried out about 2 semesters which each student will be charged to a supervisor that will monitor and give a guide in order to finish the project. The project is totally being carried out in the lab, and data will be obtained by doing an experiment.

Chapter 2 reviews about literature review of non-linear analysis, which is Non-Destructive Vibro Acoustic method. The topics will cover about the non-linear effect on cracked and uncracked of aluminium plate.

Whereas, chapter 3 is discuss about methodology of the project. The method that will be use in this project is by doing an experiment. It will cover about material preparation, equipment set up, and the fatigue crack creation on the aluminums plate, modal analysis and data measurement.

Chapter 4 present experimental results and discussion. It consist of data analysis which can be use to determine the relation between fatigue crack size with nonlinear wave modulation effects of aluminums plate. Beside the result that obtained will also be discussed in detail in this chapter.

Lastly, Chapter 5 is about conclusion and recommendation of the project. All the result that obtained will be conclude and the recommendation for the better result will also be listed for the next project or research.

CHAPTER 2

LITERATURE REVIEW

2.1 NON-LINEAR ANALYSIS

In recent years, the application non-linear method in order to investigate structural damage based on acoustic wave has started receiving attention from the others. This is due to its ability to detect very small damage. In addition, it is also said to be able to detect cracks in a structure more easily when compared with linear measurements [27, 33, 35]

Nonlinear analysis is a technique of analyzing wave signal outputs that are unrelated to the signal inputs (i.e. wave amplitude and speed, scattering coefficient). Here are the main effects based on nonlinear acoustics [4]:

i. Transfer Reverb "Resonant Shifting"

ii. Wave motion: Generation "side bands"

iii. Amplitude modulation

iv. The principle of harmonic motion

Besides, it is a method by which it is able to be used to investigate different types of materials as well as various types of damage [39, 50]. Apart from that, it also can be used to investigate various types of materials and component design [36]. For both

applications, the technique is found to be able to conduct investigations more quickly [41, 44}. This is evident when Johnson, in "Los Alamos Seismic Research Laboratory", said in his report about the technique or method of investigation using nonlinear acoustics, where according to him this is a fast technique to evaluate qualitatively about whether a component in good condition or otherwise.[5]

However, since 1970, yet, there are many who have carried out research on the nonlinear acoustic effects, among them Rudenko, Sutin, and Zaitsev [20, 29]. This was proven when there are numerous reports about it. In addition, the Morris et al. [6] has been using second harmonic generation for monitoring fatigue crack growth in aluminum alloy, and then followed by Shkolnik, [6], which he has been using a nonlinear ultrasonic parameter to study the characteristics of the concrete material. After that followed by Korotkov, [7], when he was using the modulation sound through vibration to detect damage to the steel and Sutin (1994) also once again along with Nazarov has been using non-linear acoustics to detect cracks in the metal. Zaitsev et al. [8] have demonstrated the basic principles of nonlinear acoustics in solid materials using the interaction between high-frequency and a strong pump wave. While Nagy, [9] exploited the features of non-linear ultrasonic to detect fatigue cracking in plastics, metals, composites and adhesives. After that followed by Van Den Abeele et al. [10] in which he shows a harmonic generation and the "side bands" based on the characteristics of damage to sandstone and "plexiglass".

Generations of nonlinear acoustic waves are caused by the interaction between acoustic waves and low-frequency vibration [24]. This has been proven through studies that have been conducted to detect damage in a material. As evidence, Xiao and Nagy, [10] have used ultrasonic techniques to detect cracks ekograph very small [23, 31]. This technique is the use of thermo-optical modulation via pulses of infrared rays to produce heat stress on the specimen surface and using high frequency ultrasonic waves to detect very small damage. In addition, Van Den Abeele et al. [9] have introduced the "Nonlinear Elastic Wave spectroscopy (NEWS) technique" where this technique is the technique of applying two frequency bands on the specimen and detecting damage based on the harmonic and "side band". Zaitsev, [11], has also introduced a non-linear method

for detecting cracks. Apart from these results, there are many other study results on nonlinear acoustic applications.

However, from all effect state above this study only focused on the wave motion (Generation side bands) and amplitude modulation. This project is carried out to detect crack in aluminums plate as an experimental specimen of non-destruction test (NDT). There are includes identified the relation between fatigue crack size with nonlinear wave modulation effects to the structure material from the experimental data that we will be have in the non-destruction test (NDT) of vibro-acoustic method.

2.2 NDT INSPECTION METHOD

Nondestructive Testing (NDT) is widely use in detection of defect of solid structure. The application can be seen in tests that detect and characterize material condition and flaw that cause reactors to fail, trains to affect, pipelines to burst and planes to crash [4].

These tests are performed in a manner that does not affect or harm the structural of the material, which means NDT allows parts and material to be inspected and measured without affect them[47, 48]. Nowadays, NDT is widely applies to industrial inspections, such as power plant inspection, bridge inspection, aircraft inspection and etc [12].

There is various method of inspection in NDT. The most and popular that is always being use in industries are dye penetration, magnetic particle, eddy-current, radiography, ultrasonic and acoustic emission. Each of the method has their advantage and disadvantages [4, 13].