EFFECT OF VARIOUS LOW FREQUENCIES FOR CRACK DETECTION IN NON-LINEAR VIBRO-ACOUSTIC METHOD

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This report is submitted
in fulfillment of the requirement for the degree of
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DECLARATION

I declare that this project report entitled “Effect Of Various Low Frequencies For Crack Detection In Non-Linear Vibro-Acoustic Method” is the result of my own work except as cited in the references

Signature : ....

Name : ....

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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 (Plant & Maintenance).

Signature :. ....

Name of Supervisor : ....

Date : ....

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DEDICATION

To my beloved mother and father

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ABSTRACT

Structural Health Monitoring is a very common and popular in maintenance engineering to maintain the performance and reliability of the structure. This technique is used to detect detection in the structure for further maintenance. Non-linear vibro-acoustic is a unique technique that suitable for fatigue crack detection. Vibro-acoustic technique is a method which introducing two type of frequency into a structure for defect detection. The two frequencies are high frequency acoustic wave and low frequency excitation. Wave distortion effects will be produced when the acoustic wave interact with the damaged in the structures. There are few parameters which will affect the non-linear vibro-acoustic test which included high frequency acoustic wave, low frequency vibration excitation, excitation locations and location of sensor. However, the study of non-linear effect of low frequency excitation to detect the crack is still not much done by previous researcher. Thus, experimental works performed with resonance and non-resonance frequency as low frequency excitation to determine the non-linear effect of low frequency in the vibro-acoustic test. Nonlinear acoustic tests performed on an aluminium plate with total of 10± 1mm fatigue crack and result proved that the low frequency excitation will affect the modulation intensity in vibro-acoustic test.

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ABSTRAK

Struktur Pemantauan Kesihatan adalah popular dan sangat biasa diguna dalam bidang kejuruteraan penyelenggaraan untuk mengekalkan prestasi dan kebolehharapan struktur. Teknik ini digunakan untuk mengesan bocoran dalam struktur untuk aktiviti penyelenggaraan. Nonlinear vibro-akustik adalah teknik yang unik yang sesuai untuk mengesan retak lesu. Teknik Vibro-akustik adalah satu kaedah yang memperkenalkan dua jenis frekuensi ke dalam struktur untuk mengesan kerosakan. Kedua-dua frekuensi frekuensi tinggi gelombang akustik dan pengujaan frekuensi rendah. Kesan distorsi akan dihasilkan apabila gelombang akustik berinteraksi dengan yang kerosakan dalam struktur. Terdapat beberapa parameter yang akan menjejaskan ujian nonlinear vibro-akustik termasuk frekuensi tinggi gelombang akustik, getaran frekuensi rendah, lokasi pengujaan dan lokasi sensor. Walaubagaimanapun, kajian kesan pengujaan frekuensi rendah untuk mengesan retak dalam nonlinear vibro-akustik masih tidak banyak dilakukan oleh penyelidik terdahulu. Oleh itu, kerja-kerja eksperimen dilakukan untuk menentukan kesan frekuensi rendah dalam ujian vibro-akustik dengan menggunakan frekuensi resonans dan bukan resonans sebagai pengujaan frekuensi rendah. Ujian vibro-akustik dilakukan pada plat aluminium dengan celah sepanjang 10 ± 1mm dan hasilnya membuktikan bahawa pengujaan rendah akan menjejaskan kekuatan modulasi dalam ujian vibro-akustik.

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LIST OF ABBEREVATIONS

SHM	Structural Health Monitoring
NDT	Nondestructive Test
PZT	Piezoelectric Transducer
FRF	Frequency Response Function

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CHAPTER 1

INTRODUCTION

1.1 Background

Nowadays, Structural Health Monitoring (SHM) technique is a very common technique which used in the maintenance engineering to maintain performance and reliability of the structures. SHM is the process of defect detection to plan for further maintenance activities. There is various damage detection methods used to detect different type of damages on the structure more effectively.

Damage in structure is the main cause which could affect the structure's performance. Jean Lemaitre (2005) [1] define damage as that creation and growth of microvoids or microcracks that propagated in the structure. Damages which commonly found in the metal structures are fatigue failures, ductile failures, and brittle failures [1].

Fatigue crack is the major causes of aircraft accident since in the 1948 [2]. Fatigue is localized damage which caused by repeatedly applied loads. The fatigue crack still occur in the structure although the strength of material is much higher compare to the normal maximum stress which applied to the structure. When the material is subjected to frequent loading and unloading, the stress will occur in the microscopic crack and cause the size of crack increase. Finally when the crack reaches certain size, the crack will propagate rapidly and fracture of structure will occur.

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In maintenance engineering, various Nondestructive Test (NDT) methods are used to detect the damage which occurs in the structure. NDT consist of two type of measurement system which are contact and non-contact. The main purpose of NDT is to evaluate the structure's condition without damaging it. As recalled by Staszewski et. al. (2004) [3] and Gdoutus [4], there are various NDT techniques commonly used to evaluate the crack on the structure such as dye penetration, ultrasonic, acoustic emission, eddy-current and magnetic particle. The main purpose for using NDT techniques is to detect the crack without damaging the structures.

Dye penetration is a method which uses dye or color to detect surface flaw. Color or dye will apply on the surface of surface claw and then post–penetrant material such as chalk will be applied on it. After that, the color line will be seen the flaw. This technique is very fast and efficient on detecting surface flaw.

Ultrasonic is a method which uses very high frequency sound waves to defect crack. The sound waves will propagate through the specimen and if there is any flaw surface or crack the wave will be reflected. Next by using transducer, the wave will be changed into electrical signal and displayed on the monitor screen. The location of the crack can be determined by some calculation on the travel time.

Acoustic emission is a method which used for testing for stationary equipment such as tanks, pipelines and pressure vessels [5]. Due to the high sensitivity of the acoustic emission, this method can detect the growth and formation of the micro-crack [6, 7].

Infrared thermography is also one of the methods which widely used to detect the crack. There are three classical techniques of thermographic which mostly use in the industry,

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known as lock-in thermography, vibrothermography and pulsed thermography are described by Chen (2007) [8]. Besides these three classical active thermographic techniques, there are various different thermographic techniques can be done based one the subsequent aspects such as type of heating, the size and shape of excitation source, and the arrangement between sample and heating source [9].

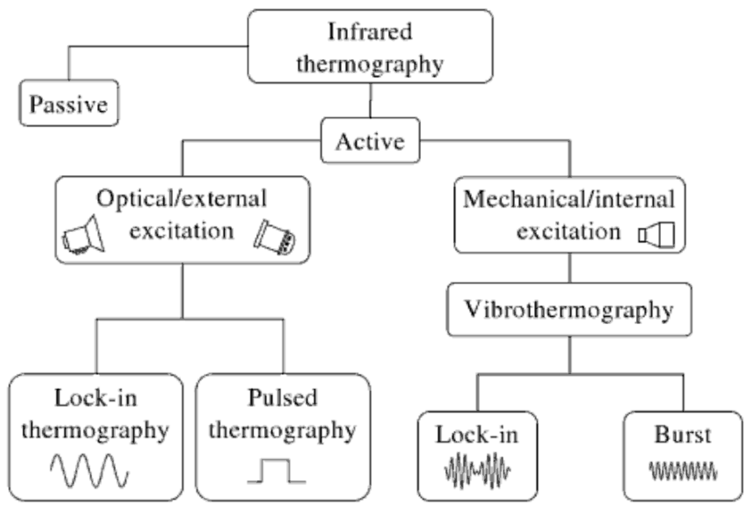

Figure 1-1: Infrared thermography approaches [8]

Vibro-acoustic method is another method for crack detection which can effectively detect the defection. There are two types of frequency which introduced in this method included high frequency acoustic wave and low frequency excitation. In his method, the interaction between the two waves is used to determine the cracking. Wave distortion effect will be occurs whenever the geometric properties is changing. In this method, low frequency excitation is a very critical element. This is because the level of excitation may maximize the effect of crack on natural frequencies and the effect of the crack on energy dissipation and modulations.

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1.2 Problem Statement

Vibro-acoustic technique is a method which introducing two type of frequency into a structure for defect detection. The two frequencies are high frequency acoustic wave and low frequency excitation. There are few parameters which will affect the non-linear vibro-acoustic test which included high frequency acoustic wave, low frequency vibration mode, excitation locations and location of sensor. However, the study of non-linear effect of low frequency excitation to detect the crack is still not much done by previous researcher. Therefore, study of non-linear effect of low frequency will be done through the non-linear vibro-acoustic test.

1.3 Objective

The objectives of this project are as follows:

1. To determine the relationship between low excitation frequencies and modulation intensity.
2. To investigate the effect of low frequency excitation on the amplitude modulation effect.

1.4 Scope of Project

The scopes of this project are:

1. Specimen preparation and crack preparation for the vibro-acoustic test.
2. Modal analysis to obtain modes of vibration and mode shapes of the specimen.
3. Vibro-acoustic test to identify the effect of low frequency for crack detection in this method.

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CHAPTER 2

LITERATURE REVIEW

2.1 Damage in Structures

Damage in structure can be defined as the change of geometries properties of the material in a structure which will degrade the stiffness of material and cause decreasing of load carrying capacity. Reifsnider in 1980 proposed a sequence of the formation of damage which can be summarized as below:

i) Crack nucleation in off-axis plies.

ii) Crack coupling as a result of the interface debonding once the crack tips reach the interfaces.

iii) Formation of a wider broken region by the previous method.

iv) Crack growing through the thickness by crack coupling.

v) Final fracture of fibres within the direction of the load.

Fracture of solid is mainly caused by the stress in two modes which are ductile and brittle. Most of the metals can withstand some large deformation without failing to allow the metals to be use in different structures. As the increase in deformation past the yield point, the micro cracks will be formed as shown in Figure 2-1.

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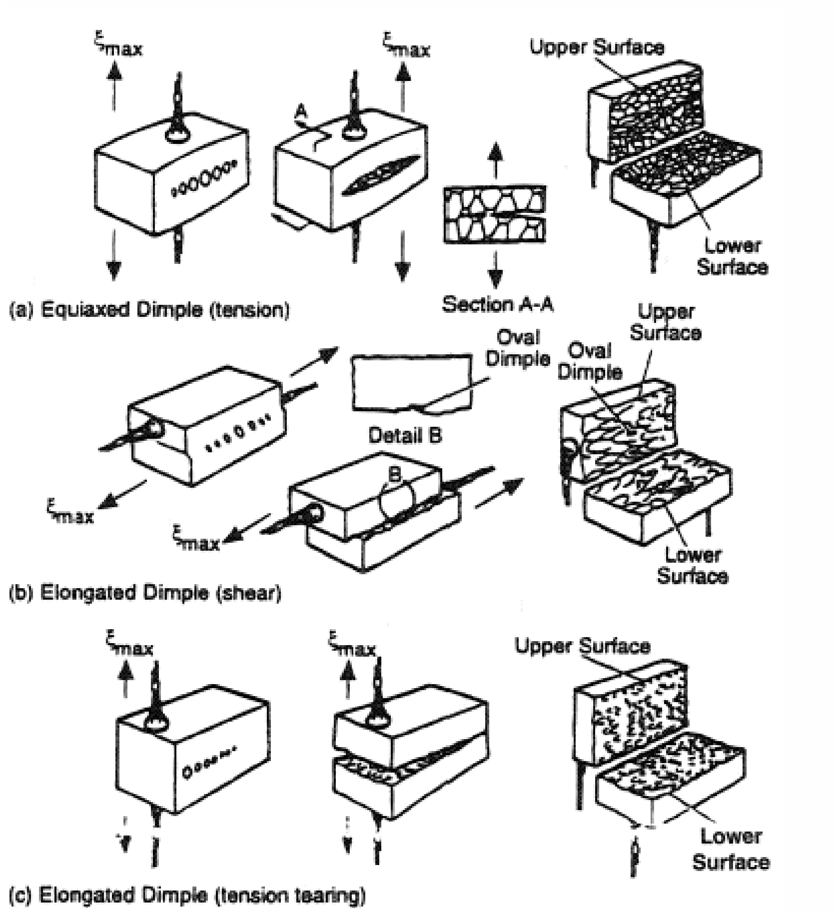

Figure 2-1: Example of fracture surfaces from microvoid coalescence. [10]

2.2 Fatigue Crack

Up to 90% of screw ups of in-carrier metal structures have been attributed to fatigue cracks [11]. This is because the fatigue crack will grow rapidly and caused the fracture of the structure once the crack is obvious and detectable by the techniques of conventional linear. Thus, the detection of fatigue crack in early stages is very important [12]. Several studies have shown that non-linear feature of the fatigue crack is hard to be achieved by conventional linear ultrasonic techniques [12-15].

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No matter how high is the strength of the structure, fatigue crack might still occur due to repeatedly applied loads. Thus, fatigue analysis is carried out by methods based on fatigue test and estimation of cumulative damage to characterize the fatigue properties. The formation and propagation of fatigue damage can be described in a few stages. In the first stage, the microstructural changes will cause the formation of nucleation. After that, microcracks will occurs and growth to form a dominant crack. This is the stage where the crack initiates to begin the crack propagation. Next stage is the propagation of dominant crack which will lead to a macro dominant crack. This will cause the instability of the structure and in the end the structure will fracture.

The fatigue crack will appeared with different mode when different stress is applied on the structure. The basic modes of fatigue modes are shown in Figure 2-2. The fatigue can extend as the three basic modes, which are defined as:

Mode I: This is the opening mode where the crack surfaces move directly apart in y-direction.

Mode II: This is the sliding mode where the crack surfaces slide over each other in direction which perpendicular to the leading edge of crack (x-direction).

Mode III: This is the tearing mode where the crack surfaces move relatively to one another and parallel to the leading edge of the crack (z-direction).

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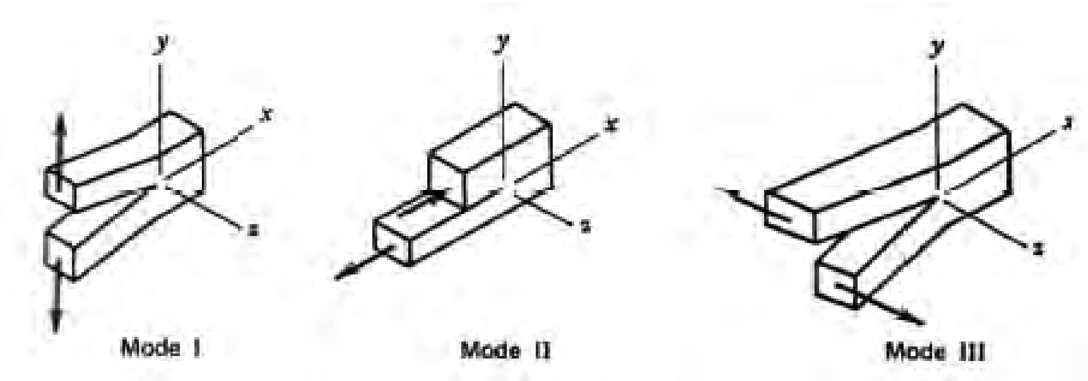

Figure 2-2: Three basic modes of fatigue crack [16].

2.3 Method of Detect Fatigue Crack

In recent years, applying of nonlinear effects of acoustic waves in discovering defect has been extensively studied. This is because of the advantage of this effect on detecting tiny crack or the early phase of defect [3] and it is easier to detect the crack compared to traditionally use linear measurement [20].

Since 1970s, nonlinear acoustics has been studied by Rudenko, Sutin, Zaitsev and others. There are several reports relating to the nonlinear effect in defect detection in soils, glass and metals. Study of nonlinear from acoustic waves has been done. In 1979, Morris *et al.* observed the formation of fatigue cracks in aluminium alloy using second harmonic generation [17]. In 1993, Shkolnik. used nonlinear ultrasonic parameters to evaluate the material properties of concrete [18]. In 1994, in order to detect the defects in metal, sound modulation excited with vibration method is used by Korotkov et al. [19]. Nonlinear ultrasonic has been used by Nagy (1998) [20] in order to detect the fatigue cracks in plastics,

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