ANALYSIS OF HEAT EFFECT AGAINST NONLINEAR ACOUSTICS WAVE MODULATION INTENSITY – EXPERIMENTAL APPROACH

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SUPERVISOR DECLARATION

"I declared that I had read this thesis and at my opinion this thesis was brilliant from the aspect of scope and quality for the purpose to be awarded Bachelor of Mechanical Engineering (Structure and Material)"

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Date :

DECLARATION

"I hereby declare that the work in this report is my on except for the summaries and quotations which have been duly acknowledged"

Signature :

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Date : 22/05/2011

DEDICATION

My beloved parents, Harun Bin Embong and Hasnah Binti Shafie, friends, family members and lecturers

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Alhamdulillah, all praise to ALLAH, finally I managed to carry out and finish this study on time.

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ABSTRACT

The purpose of this research is to define the relationship of heat dissipation with the intensity of nonlinear acoustic modulation. Therefore, nonlinear vibro-acoustic technique will be used to analyze this relationship. Nonlinear vibro-acoustic is a highly reliable and sensitive method that generally used to detect the defects on the structures. Many researchers have used this method to detect the various types of defects on various types of materials. This method is based on the propagation of high frequency acoustic wave in solid structure with low-frequency excitation. Interaction of the acoustic wave with material or geometry properties changes will cause wave distortion effects. From previous researches, it is accepted that nonlinear acoustic modulation is caused by the crack opening/closing actions. But, there might be other physical mechanisms that involved behind the modulation such as heat dissipation. So, an experiment setup will be designed in order to identify the relation of heat dissipation on solid structure with the intensity of nonlinear acoustic modulation. Finally, the contribution of the heat dissipation against the nonlinear acoustic effect for crack detection will become more explanable. The results from this experiment show that the heat dissapation does not affect the intensity of nonlinear acoustic modulation. It is because the is no distortion of wave when propagate through the heated plate such as generation of sidebands.

ABSTRAK

Tujuan penyelidikan ini ialah untuk mentakrifkan hubungan pelesapan haba dengan keamatan modulasi akustik tidak linear. Oleh itu, teknik akustik vibro tak linear akan digunakan untuk menganalisis hubungan ini. Akustik vibro tak linear ialah satu kaedah sensitif dan amat boleh dipercayai yang umumnya digunakan bagi mengesan kecacatan pada struktur-struktur. Ramai penyelidik telah menggunakan kaedah ini untuk mengesan pelbagai jenis kecacatan pada pelbagai jenis bahan terutamanya bahan pepejal. Kaedah ini adalah berasaskan perambatan gelombang akustik frequency tinggi dalam struktur yang kukuh dengan pengujaan frekuenci rendah. Interaksi antara gelombang akustik dengan ciri-ciri bahan atau perubahan geometri akan menyebabkan kesan herotan gelombang. Dari penyelidikan sebelumnya, modulasi akustik tak linear itu disebabkan oleh pembukaan dan penutupan sesuatu celah. Namun, mungkin ada mekanisme fizikal lain yang terlibat pada modulasi ini seperti pelesapan haba. Jadi, satu langkah exsperimen akan dibuat untuk mengenal pasti hubungan antara pelesapan haba pada struktur dengan keamatan modulasi akustik tak linear. Akhirnya, sumbangan pelesapan haba menentang kesan akustik tak linear untuk pengesanan keretakan akan menjadi lebih jelas. Hasil dari ujikaji menunjukkan pelesapan haba tidak menjejaskan keamatan mudulasi akustik tidak linear. Ini kerana tiada herotan gelombang apabila disebarluaskan melalui plat hangat seperti kemunculan sideband.

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B	-	Ultrasonic amplitude
$A_{1,2}$	-	First sideband amplitude
R	-	Intensity of nonlinear acoustic modulation
ΔT	-	Temperature change

CHAPTER 1

INTRODUCTION

1.1 Background

In order to reduce the costs related to corrosion damage in metallic structures, it is vital to develop new robust, accurate and reliable damage detection methods. Nowadays, the application of nonlinear effects from acoustic waves for damage detection has been extensively studied. This is due to the advantage of detecting micro damage or early signs of damage and the fact that nonlinear manifestation due to cracks is more easily detected than traditionally used linear measurement [1]. In contrast with linear analysis, 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). The most common nonlinear effects that highly depend on the wave propagating medium are generation of side bands, amplitude dissipation, generation of harmonics and resonant waves shifting. Nonlinear effects such as amplitude modulation are better known as interaction of the wave with a micro-inhomogeneous medium. It is a common finding by most studies that nonlinear effects are highly correlated with defects like discontinuities present in the medium. An important advantage of the nonlinear acoustic methods is to discriminate between integrity reducing flaws and other inhomogeneities. Contact-type defects such as cracks, disbondings, delaminations, etc. lead to an anomalously high level of nonlinearity. Well-known acoustical manifestation of the nonlinear behavior is the nonlinear distortion of a sinusoidal wave or generation of its harmonics.

1.2 Problem Statement

This research will analyze the relationship between the heat dissipation and the nonlinear acoustic effect experimentally. We need to investigate either thermal condition will affect the propagation of sound or not. In this investigation, the type of the wave distortion, amplitude dissipation and wave delay will be observed.

This study will be focused on the mechanism of temperature change due to the behavior of fatigue crack surfaces interaction that causes the nonlinear acoustic effect. Based on study by R B Jenal [1], he suggested that there a few mechanisms involved in the phenomena such like heat dissipation from the crack surfaces due to surfaces friction and heat dissipation from the elasto-plasticity actions at crack tips.

1.3 Objectives

This study is to investigate the relation of heat dissipation from a small area at small heat capacity in a rectangular plate with the nonlinear acoustic effect, i.e. amplitude modulation effect.

From the above relationship, the minimum value of heat capacity that produces a significant nonlinear acoustic effect will be determined. Finally, the contribution of the heat dissipation against the nonlinear acoustic effect for crack detection will become more explanable.

1.4 Scope

There are three scopes for this project. The first scope is to study about the heat effect against the propagation of elastic wave. In this scope, the experiment evidences showing the distortion of elastic wave with variation of thermal condition will be investigated. Besides, the knowledge about the minimum of heat changes that can distort the wave propagation can be gained. The second scope is to design experimental approach, equipments and parameters for this project. For experiment design, the method of introducing heat, introducing low frequency and high frequency, and measuring the output signal will be studied. The level of the low frequency, high frequency and heat capacity from the heat sources also will be studied. The last scope is to analyze the wave propagation through the heated structure. From the result, the type of wave distortion, e.g. amplitude dissipation and wave delay caused by the heat change can be observed. Therefore, the relationship between modulation intensity and temperature can be verified.

CHAPTER 2

NONLINEAR VIBRO-ACOUSTIC

In this chapter, we will discuss about the nonlinear vibro-acoustic and its application. To avoid failure caused by cracks, many researchers have performed extensive investigations to develop structural integrity monitoring techniques. The purpose of this project is to define the relationship of heat dissipation with the nonlinear acoustic effect.

2.1 Introduction of nonlinear vibro-acoustic

Vibro-acoustic technique is an advanced and reliable method for detecting incipient damage such like fatigue crack [2]. This method is based on propagation of high frequency acoustic waves in solid structures with low-frequency excitation. Interaction of the acoustic wave with changes in material or geometric properties causes wave distortion effects. The causes, called nonlinear acoustic effects, are amplified with low frequency excitation [1]. The detection of micro-cracks at the early stage of fracture is important in refinery plants, nuclear power plants, or aircraft parts in order to ensure their structural safety. Ultrasound has been widely utilized in the field of nondestructive testing of materials, however most of these conventional methods using ultrasonic characteristics in the linear elastic region are mostly sensitive to gross defects and opened cracks but much less sensitive to such micro-cracks [4]. In contrast with linear analysis, 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) [1]. The most common nonlinear effects that highly depend on the wave propagating medium are generation of side bands, amplitude dissipation, generation of harmonics and resonant waves shifting. Nonlinear effects such as amplitude modulation are better known as interaction of the wave with a micro-inhomogeneous medium [1,3]. It is a common finding by most studies that nonlinear effects are highly correlated with defects like discontinuities present in the medium.

The application of vibro-acoustic methods for damage detection has been investigated for many years. The method uses measurement of weak high frequency wave modulation responses against the perturbation of stronger low frequency vibration. From the 1990s, many researchers have started to study nonlinear acoustic effects for damage detection. It is remarkably the most effective way for detecting the presence of micro or incipient cracks. A simple striking bell example can be used to explain this approach. When a bell is struck, it produces a sound that contains several acoustic harmonics. The frequency of these harmonics is a unique characteristic of the bell. It is independent on the striking force as long as no changes of the bell geometry and material properties occur. The presence of structural damage (e.g. fatigue crack) results in frequency shifts. New frequency harmonics and frequency/phase modulations can also appear in sound characteristics. These additional nonlinear effects are often used for fatigue crack detection, as illustrated in Figure 2.1.

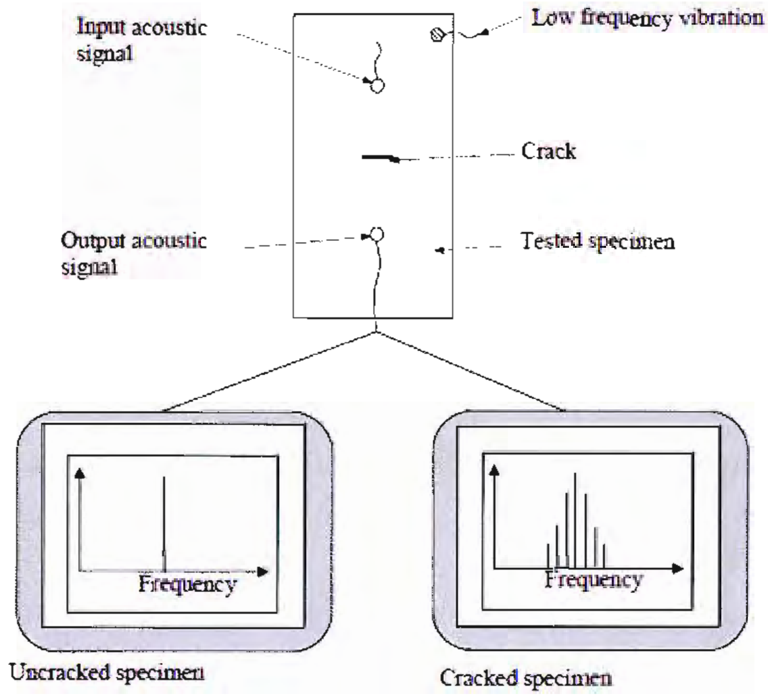

Figure 2.1: Schematic layout demonstrating the principle of nonlinear acoustics used for damage detection. [1]

2.2 Nonlinear vibro-acoustic effects

There are a few nonlinear acoustic effects that have been studied by many researchers. The present damage in structure can be estimate by observing and analyzing these effects. These effects can be observed on resonant frequency shifting, harmonic generation, sideband generations and amplitude modulation.

2.2.1 Resonant frequency shifting

It is well known that each solid body or structure has unique natural resonant frequencies. The structure will respond extensively to an external cyclic force excited at one of its resonant frequencies. Resonant frequency is a dynamic property for the structure which is very useful in engineering fields. It is an essential element in the design field and is widely used for investigating the behaviour of a material [2].

There are many reports regarding the application of amplitude-dependent frequency response for damage detection, termed as nonlinear elastic wave spectroscopy (NEWS) technique. The technique uses nonlinear response of a single or multiple resonant frequencies of a material to discern damage or microcracks in the material. NEWS technique is divided into two methods which are nonlinear resonant ultrasound spectroscopy (NRUS) and nonlinear wave modulation spectroscopy (NWMS). The method that can be used to evaluate the resonant frequency shifting is NRUS [15].

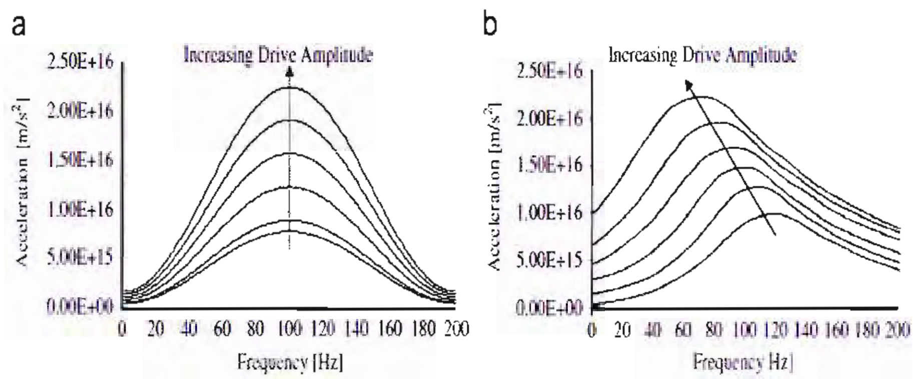

Figure 2.2: Resonance frequency versus drive amplitude. (a) Intact sample. (b) Damaged sample. [15]

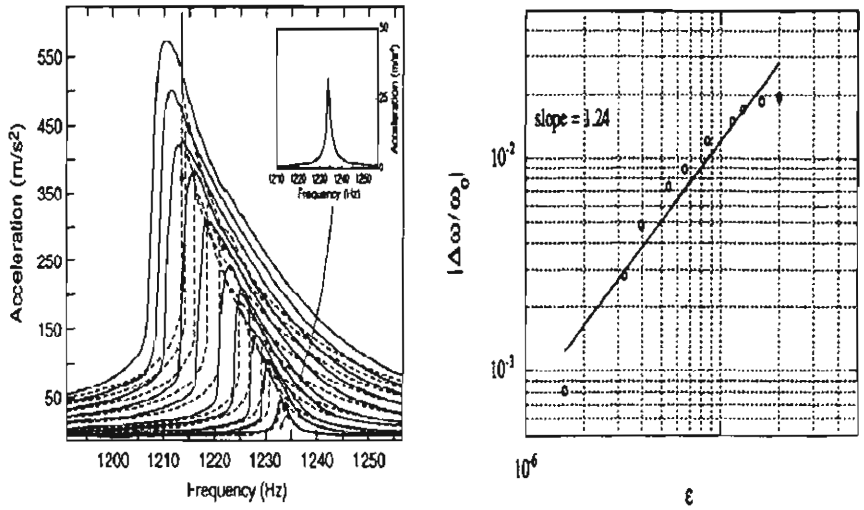

Figure 2.3: An example of (a) resonance peaks shifting and (b) ratio of the resonance shifting against strain level for sandstone material. [19]

Figure 2.3 shows an example of resonance peaks shifting and ratio of the resonance shifting against strain level for a sandstone material cited from [19]. The figure clearly showed that the resonant frequency shifting is highly proportional to the strain level.

2.2.2 Harmonics generation

Harmonics generation can be observed by introducing a single or multiple waves into inhomogeneous materials or materials containing voids or micro-crack. Nonlinear wave modulation spectroscopy (NWMS) can be used to observe this effect [1, 15]. Due to the material's nonlinearity, the propagation of waves can be distorted. The wave distortion will create accompanying harmonics which are known as multiplication of the fundamental wave frequency. The harmonic amplitude level can be used to estimate qualitatively the damage severity and mechanisms of the nonlinearity [1].

Kawashima *et al.* [18] related the mechanism of crack opening and closing as the cause of wave distortion. They predicted that in a closed condition