SUPERVISOR DECLARATION

“I hereby declare that I have read this thesis 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 and Maintenance)”

Signature : ....

Supervisor : DR. NOR SALIM BIN MUHAMMAD

Date : …………………………..

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DESIGN AND SIMULATION OF GUIDED WAVE TRANSMITTER FOR INSPECTION ON CONCRETE PLATE

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The thesis submitted in partial fulfilment of the requirements for the award of Bachelor of Mechanical Engineering (Plant and Maintenance)

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DECLARATION

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

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Author :SAAFUAN ALI BIN TUKIRAN

Date :………………………

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Specially dedicated to my father and mother,

Tukiran Bin Sarban & Rosita Binti Ismail

My beloved family and lovely friend.

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ABSTRACT

Non – Destructive Testing (NDT) is the best method to do inspection on critical and inaccessible surface or condition. Guided wave testing is the latest NDT method that offers great opportunity on inspection over large area in Structural Health Monitoring (SHM). It allows inspection of underground structures like pipes and piles as well as walls and beams on skyscrapers. The large coverage on the inspection offers effective method to perform an inspection and monitoring on concrete structures in shorter time inspection which greatly will reduce the total cost of the maintenance. Lamb wave is very well known in inspection of plate-like metal structures such as oil storage tank, pressure vessel, and air plane structures. However, there are very limited studies on the wave propagation in the concrete structures. This required to run a simulation of the guided wave propagation to understand the wave propagation from the computed result. There are two types of Lamb wave mode that important to understand which are symmetrical modes (S-mode) and antisymmetrical modes (A-mode). Lamb wave velocities related to thickness of the plate and demonstrate dispersive characteristic. Fundamental understanding of guided wave propagation and the wave modes are compulsory for a defect on concrete can be identified at specific location. Four types of concrete plates with singular defect have been modelled in ABAQUS software to understand the behaviour of wave propagation. In addition, two experiments have been conducted for in-plane and out-of-plane vibration analyse. In the conclusion, the experimental and simulation result shows that S0 mode and A0 mode is possible to be excited on the concrete plate.

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ABSTRAK

Ujian tanpa musnah adalah kaedah yang terbaik untuk melakukan pemeriksaan di permukaan atau keadaan kritikal dan tidak boleh diakses. Ujian gelombang berpandukan adalah kaedah ujian tanpa musnah yang terbaru yang menawarkan peluang hebat pada pemeriksaan di kawasan yang besar dalam *Structural Health Monitoring (SHM).* Ia membolehkan pemeriksaan struktur bawah tanah seperti paip dan lantai serta dinding dan *beam* pada bangunan pencakar langit. Liputan besar pada pemeriksaan menawarkan kaedah yang berkesan untuk melakukan pemeriksaan dan pemantauan ke atas struktur konkrit dalam pemeriksaan masa pendek yang akan mengurangkan jumlah kos penyelenggaraan. *Lamb wave* sangat terkenal dalam pemeriksaan struktur logam plat seperti tangki minyak penyimpanan, vesel tekanan, dan struktur pesawat udara. Walau bagaimanapun, kajian sedia ada sangat terhad pada perambatan gelombang dalam struktur konkrit. Ini diperlukan untuk menjalankan gelombang perambatan untuk memahami perambatan gelombang dari data yang diperolehi. Terdapat dua jenis mod gelombang *Lamb wave*yang penting untuk difahami iaitu mod simetri (S-mode) dan mod anti simetri (A-mode). Halaju *lamb wave* yang berkaitan dengan ketebalan plat dan menunjukkan ciri serakan. Pemahaman asas perambatan gelombang berpandu dan mod gelombang sangat diperlukan untuk mengenal pasti kecacatan di lokasi tertentu. Empat jenis plat konkrit dengan kecacatan tunggal telah dimodelkan dalam perisian ABAQUS untuk memahami tingkah laku perambatan gelombang. Di samping itu, dua eksperimen telah dijalankan iaitu *in-plane* dan *out-of-plane vibration* analisis. Kesimpulannya, hasil eksperimen dan simulasi menunjukkan bahawa mod S0 dan mod A0 berkebolehan untuk digunakan pada plat konkrit

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CHAPTER 1

INTRODUCTION

1.1 Background Of Study

Concrete structure is widely used in facilities development especially building. There has been a worst nightmare on every home owner's with foundation problems such as crazing, scaling, plastic shrinkage cracking, discoloration and honeycombing. To ensure the safety of worker and customer and public, structure and health monitoring are important to encounter most of the problems. Non – Destructive Method (NDT) was used in inspection on the concrete and there is many types of NDT that can perform this activities such as Ultrasonic Testing (UT), Radiography (RT) and Acoustic Emission (AE). Guided Wave Testing (GWT) is the latest method of NDT and play important role in structural health monitoring. But this method have specific applications and cannot be applied in every situation and required skilled personnel for execution and further interpretation of results. Guided Wave Testing have many different modes at a single frequency that are sensitive at different defect. Guided wave have some important of large-scale civil infrastructures such as capability of testing over long range with great sensitivity, ability to test multi-layered structure and cheap due to sensor cost. Structural health monitoring is so important in civil engineering and safety of concrete structure itself, with using guided wave testing it so effectiveness in detect the defect before it become worse with save time and cost.

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Guided wave use ultrasonic waves that propagate along the pipe in the axial direction. Guided Wave Testing allows the entire plate or pipe to be screened from a single transducer position within the diagnostic range of the test compare with ultrasonic testing (UT), its only inspect area underneath only or in the direct vicinity of the transducer.

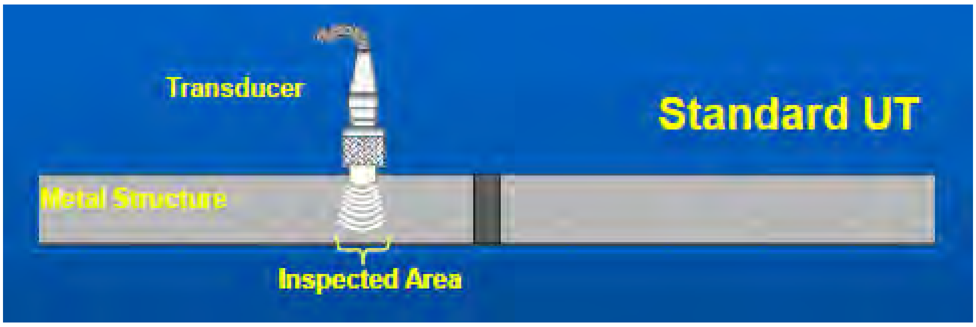

Figure 1.1: UT Inspection Area

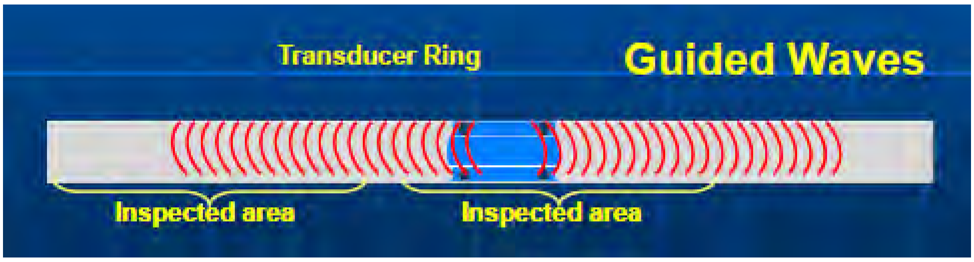

Figure 1.2: Guided Wave Inspection Area

Figure 1.1 and Figure 1.2 shows the different of ultrasonic testing and guided wave inspection. Defect size that can be seen with UT is smaller than guided wave that the wave can propagate along the plate. This is proven that guided wave is the most suitable NDT tools to inspect or screening long length concrete plate or pile for defect and the location of the defect precisely. There is some limitation of guided wave propagation is, small volume defect like pitting cannot be detect precisely and it also operate poor on corrode pipe and bitumen, its sizing is limited and need UT tools to follow up the result and require very experienced technicians.

This study investigates the behaviour of guided wave propagation in concrete plate with defect to develop technique for inspection of concrete plate. With design and run the simulation on concrete plate, the guided wave propagation and amplitude behaviour of concrete plate can be study before fabricate and take experimental data.

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1.2 Problem Statement

Guided wave is the latest method of Non-Destructive Testing (NDT) in structural health monitoring. Guided wave was mostly use on metal and composite research but not yet worldwide use in industry especially on concrete inspection because of the instrument cost, knowledge and skill. Most guided wave research focus on metal and composite but less research on concrete composite inspection. The limited literature reviews on guided wave propagation in concrete is one of the problem for the application of guided wave technique in concrete structures. The change of materials from metal into concrete provide difference properties of the waveguide medium for the acoustic wave propagations. Simulations are important to study the useable frequency range and behaviour of the wave propagation around volume defect in concrete plate and experiments are carried out to verify the possible guided wave mode from the simulation.

1.3 Objective

1. To design and analysis guided wave propagation in concrete with constant frequency and different size of defect using ABAQUS analysis.
2. To design transmitter excitation wave on concrete plate with different frequency and different position of sensor
3. To determine the lamb wave propagation in concrete plate using ABAQUS analysis
4. To determine the wave speed on concrete plate with different frequency using guided wave experiment analysis

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1.4 Scope

Following statement are the scopes of project.

1. Develop the concrete plate design by using ABAQUS software.
2. Study on guided wave propagation on different type of defect on concrete plate
3. Fabricate the concrete plate and perform guided wave experiment

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CHAPTER 2

LITERATURE RIVIEW

2.1 Guided Wave

The guided wave testing method (GW) is a new method of Non-Destructive Testing (NDT) that have been use worldwide because of time and cost efficient. It is important to detect the defect or damage on important area of concern in the design, operation, maintenance and repair in industrial and civil structures involving concrete plate structures. Guided wave travel along the surface and are guided by the geometry of the surface (Singh, 2014). The basic concept behind guided wave is that a structural component with invariant geometric and mechanical characteristic along one or more dimensions (waveguide), can be used as support to drive the wave propagation, thus providing a fundamental means for its inspection. Guided wave propagation are low frequency and long wavelength mechanical wave which allows a long range of coverage (Marques, 2008). Guided wave use ultrasonic waves that propagate along the plate or pile in the axial direction. While GW is the new method of NDT, few independent studies have been reported and this method have been compare with other detection capabilities of more established method like Ultrasonic Testing (UT). Guided waves in plate are commonly referred as lamb waves.

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2.2 Lamb Waves

If two boundaries in a solid such as a plate are sufficiently close together, the elastic wave motion on each surface will interact to produce lamb waves, whose propagation characteristics are partly a function of the separation between the two boundaries (Scruby, 1990). In a plate, longitudinal wave known as L are polarized in the direction perpendicular to the surface and shear wave known as SV plarized in vertical direction. These combination SV+L known as lamb wave (Singh, 2014). There are two basic types of lamb wave mode which is symmetrical (S0) and antisymmetrical (A0), it depends on the displacement on the two surface are in phase (flexural mode) or antiphase (breathing mode), i is order of mode. Lamb wave have dispersion nature, phase, group velocities that depend on material characterization, frequency, thickness and lamb wave mode. Lamb wave velocities is related to thickness of the plate or the structure and the wave are dispersive. In practice, lamb wave mode can be recognized with the velocities of the wave propagation which the lowest order symmetrical mode (S0) is the fastest of the mode and on experimental wavefrom it represent surface skimming compression wave while antisymmetrical mode (A0) slightly slower.

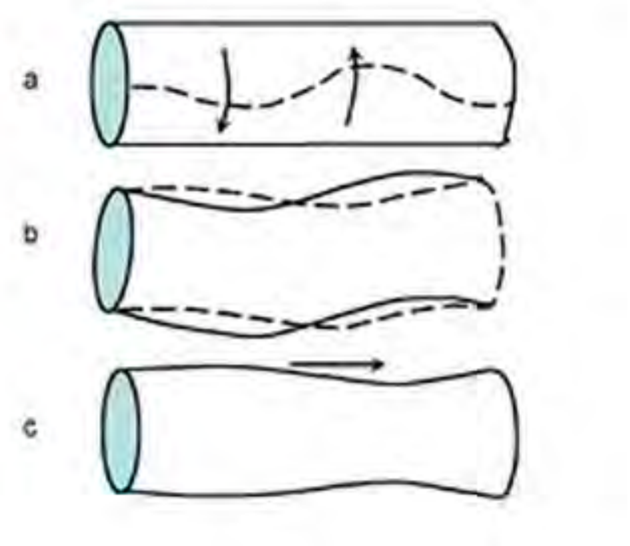

Figure 2.1: Lamb Wave Mode; (A) Torsional Wave, (B) Flexural Wave, (C) Longitudinal Wave.

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In this study only focus on flexural wave which is Ai and longitudinal wave which is Si.

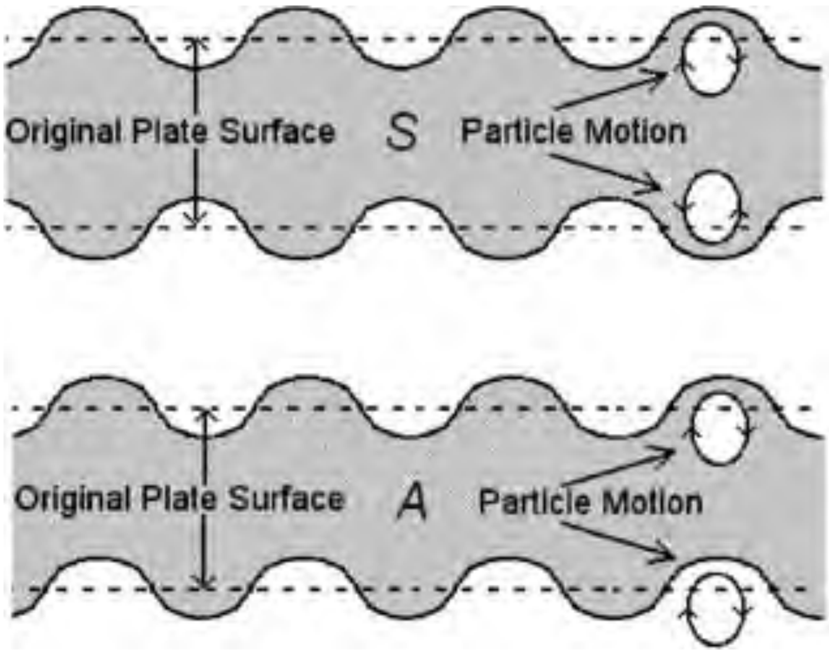

Figure 2.2: Schematic Of Particle Motion

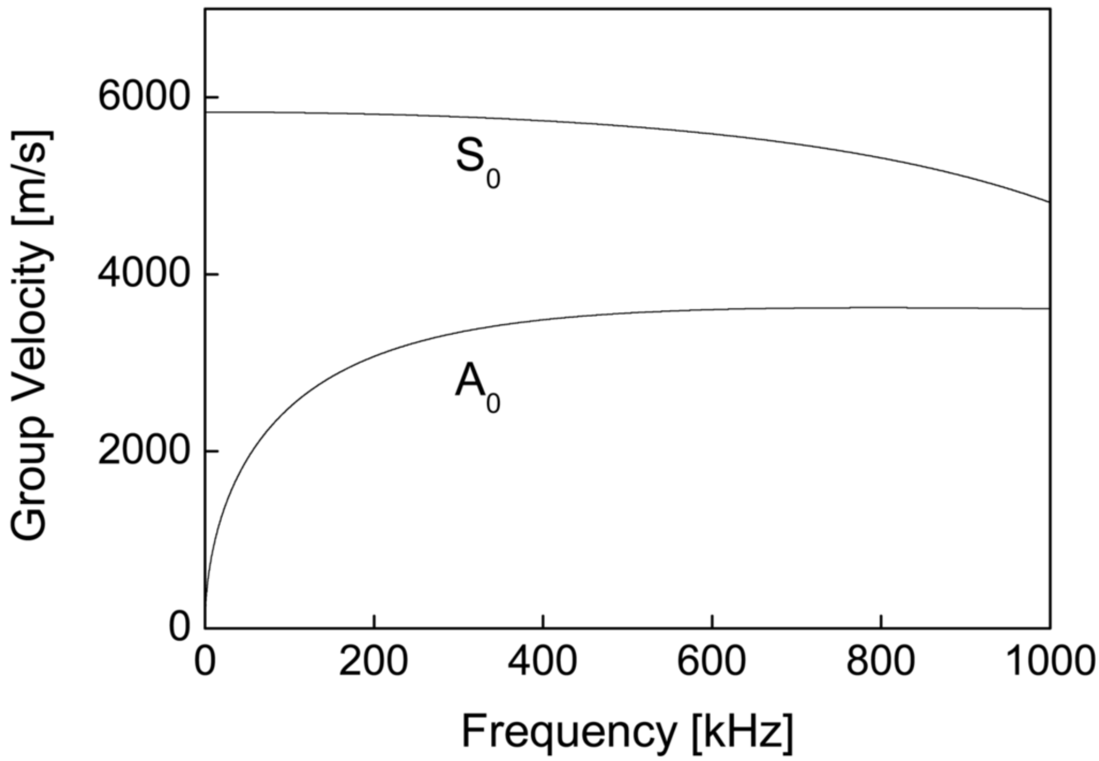

Figure 2.3: Graph Of Group Velocities

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A0 and S0 also can be recognized from particle motion and graph of group velocity as shown in the Figure 2.2 and Figure 2.3.

Lamb wave can be used to detect defect on the plate structure, hence knowledge of lamb mode is important to detect the defect at specific depth. Reflection and refraction of the lamb wave propagation at the interfaces will produce many new signal packets. Reflected and refracted energy within the plate will constructively interfere and form a plate wave but need to adjust the angle of incidence and frequency properly. Wave speed that dependence on the frequency is called dispersion and multiple values of the wave speed are obtained. Different wave speeds will represent different mode of the lamb wave propagation and the sensitivity of the defect depend on the plate thickness and the frequency used but the particle motion distribution through the thickness of the plate can be varied to increase the sensitivity to different defect. Guided wave have various mode selection by using various combination of different striking incident angle, frequency, sensitivity to detect different type of damage or defect, long distance wave propagation and the efficiency of guiding character. With those advantages, guide wave can allow researcher to inspect inaccessible location to identify the defect or screening also give make it easier to detect various type of structure damage like reinforcing bars in concrete, pipe and plate.

2.3 Application

In industries, corrosion defect on pipe and tube are common problem occur and it’s have been a main problem of certain industries especially in oil, gas, chemical, and petro – chemical industries. Even external corrosion is hard to detect on insulated lines without removing the insulation witch is costly and time consuming, the worse situation is pipeline underground. Excavation of the pipe for visual or conventional ultrasonic inspection (UT) can cost upward of 50,000 dollar (Cawley, 2006). With using low frequency ultrasonic guided wave propagation along the pipe wall is the best solution to industries for this problem, since they can propagate a long distance under insulation.

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