LAMB WAVE PROPAGATION IN PLATE WITH DIFFERENT DEPTH OF CORROSION DEFECT

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DECLARATION

I declare that this report entitled *"Lamb Wave Propagation in Plate with Different Depth of Corrosion Defect"* is the result of my own research except summaries and quotations which have been acknowledged. The report has not been accepted for any other degree and is not concurrently submitted in candidature of any other degree.

Signature : .....
Name : NURUL FAHIMA BINTI MOHD KAMEL
Date : …….....

Dedicated to my parents,

Mohd Kamel b Ibrahim & Hosnah Ismail

My supporting siblings,

Muhammad Fahmi Akmal bin Mohd Kamel

Nurul Fazilah binti Mohd Kamel

and

My entire friends in UTeM

For their encouragement

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ABSTRACT

Lamb wave propagation is one of the guided wave techniques that had been rapidly develop in the industries especially for the inspection of thin plate structures. Therefore, a study related on the Lamb wave propagation had carried out with the purpose on investigating and analysing the wave propagation produced when the wave is in contact with the defect on the thin plate. The plate modelling is perform using the ABAQUS software and excitation of the wave propagation will be compare with the experimental waveform propagation. Behaviour of the wave interaction with the defect will be compared and discuss. The wave modes that are used in the case study are symmetrical and anti-symmetrical modes which known as S0-mode and A0-mode respectively. Both wave modes are excited in 6 mm aluminium plate using a 5 cycles of tone burst signal at canter frequencies of 80 kHz, 100 kHz, and 120 kHz. The Lamb wave propagation study covers the effect of the wave propagation when different depths of rounded defects are applied. The study covers the investigation on effect frequency and the defect orientation into the wave propagation in the plate structures.

ABSTRAK

Penyebaran gelombang Lamb merupakan salah satu teknik gelombang berpandu yang kian berkembang maju dalam industri terutamanya untuk memeriksa struktur ke atas plat aluminium yang nipis. Oleh itu, satu kajian ke atas gelombang Lamb telah dijalankan untuk melihat dan menganalisa kesan terhadap penyebaran gelombang Lamb apabila melalui kawasan yang rosak atau cacat kesan dari hakisan pada struktur plat. Proses permodelan plat aluminium dilakukan dengan menggunakan simulasi ABAQUS untuk mendapatkan kesan penyebaran gelombang Lamb. Kesan penyebaran Lamb secara simulasi akan dibandingkan dengan keputusan gelombang yang diperoleh secara ujikaji yang sebenar iaitu pada plat aluminium sepanjang 1 m. Kajian ini juga merangkumi kesan ke atas penyebaran gelombang apabila kedalaman hakisan pada struktur plat, perbezaan frekuensi yang digunakan untuk menghasilkan gelombang serta kedudukan hakisan pada plat aluminium. Selain itu, simulasi pada plat dilakukan untuk mengetahui jenis mod gelombang yang digunakan dalamkajian sam ada S0-mod mahupun A0-mod.

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V_l	=	group velocity of the incident longitudinal wave
V_p @ $V_\emptyset$	=	phase velocity of the incident longitudinal phase
φ	=	angle of the incident longitudinal wave
ω	=	Angular velocity, rad/s
C	=	Wave speed of material, m/s
k	=	Wave number

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CHAPTER I

INTRODUCTION

1.0 OVERVIEW

This chapter will cover the overall introduction about the project background, problem statement of the project, objectives, and the scope of the project.

1.1 BACKGROUND

The theory of Lamb waves was originally been developed by Horace Lamb in 1916 to describe the characteristics of waves propagating in plates. According to Rose (2002), Lamb wave type propagation can travel not only in a thin plate but also in multi-layer plates, rods, tubes, pipe and others where the components of vector can be in parallel and perpendicular to the particle vibration in the vertical plane through the structure. The Lamb wave opposed to the horizontal shear wave where the particle motion is normal to the wave vector in a horizontal plane as the waves are propagates through the plate structure. The Lamb waves referred to plate waves where it had been introduce in guided wave propagation especially in the thin plate. The ability of the

Lamb wave to travel in long distance to detect the defect within the plate (Shelke 2011) currently had been experimented and analysed especially for non-destructive testing (NDT). Therefore, when some high frequency wave is been shoot to the plate surface, the wave will be reflect back toward the transducer and the defect can be observe. The behaviour of the wave propagations is different due to the geometry and the thickness of the plate structure (Salim *et al.* 2013). To study the wave propagation of the guided wave, the piezoelectric transducer, wedges and also thin plate are needed to excite the asymmetric and the symmetrical mode of the Lamb wave. Therefore, the reflected wave will be observed and the flaw pattern are been studied.

1.1.1 Lamb Wave Propagation

Lamb waves can be generate in a plate with free boundaries with an infinite number of modes for both symmetric and anti-symmetric displacements within the layer. Lamb waves are similar to longitudinal waves, with compression and rarefaction, but they are bind by the sheet or plate surface causing a wave-guide effect.

The partial wave technique where wave propagation in plates is considers as a combination of bulk waves that are reflecting between the boundaries of the plate. This method provides insight into the physical nature of the Lamb waves. (Ghandhi 2010)

1.1.2 Technique to Generate the Lamb Wave Propagation Using Guided Wave

There are two common techniques to generate the guided waves such as using the angle beam transducer by pulsing a piezoelectric element on the wedge placed on a test plate which had produce a different variety of waves propagated in the structure. The piezoelectric will leads to the interference pattern of the wave vector. The second technique is by using the comb transducer where a number of elements are place on the structure with some spacing that pumps energy into the structure causing the guided wave to propagate in both directions along the structure.

However, for this case, the technique used for the Lamb propagation is using the angle beam transducer where the piezoelectric element and wedge are need.

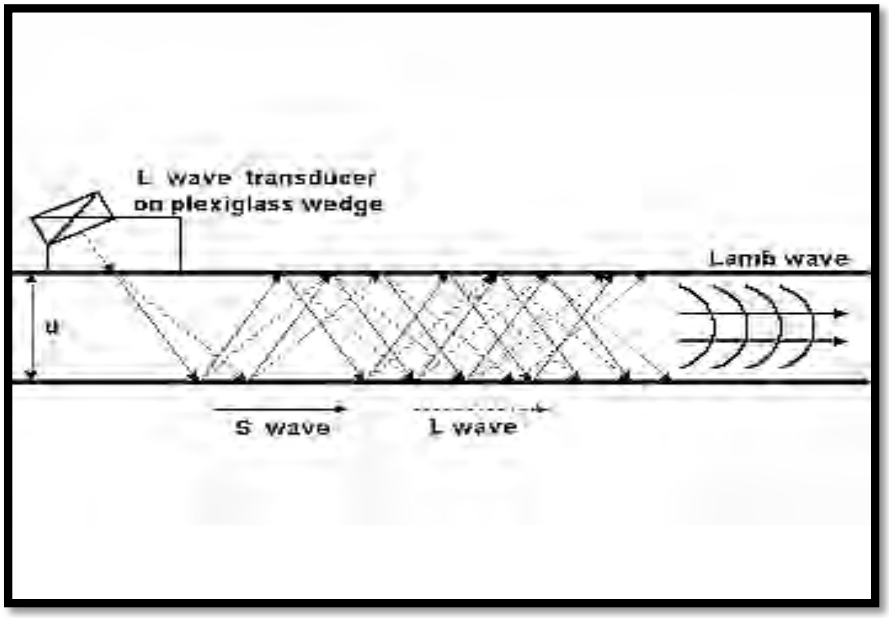

Figure 1-1: Guided wave set up. (Source: Salim 2013)

The guided wave are consists of transducer, made by piezoelectric (PZT), and also wedge so that the lamb wave can excite the symmetrical mode (S0-mode) and asymmetrical mode (A0-mode) in plate so that the wave propagation can be observed and analysed when propagates through the defects (Salim 2013). The basic guided

setup can be refers in Figure 1.1. The wave can travel in a long inspection distance where the frequencies for the S0-mode are between 80 kHz to 120 kHz using acrylic whereas; A0-mode is being excited using the aqualene wedge.

When the Lamb wave propagate through the plate, the defect can be detect based on the dispersion curve based on the frequency used, therefore the behaviour of the defect can be measured and analysed (Takahiro *et al.*2012). The Lamb waves often refer as the plate wave where the component of the extensional wave is perpendicular to the surface. The waves are generated when the longitudinal waves are intersects with a surface and it is very sensitive to a defects. Therefore, as the lamb wave can travel in a long distance, the defects can easily detected even the spaces are narrow and difficult to reach.

1.2 ADVANTAGES OF LAMB WAVE PROPAGATION

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The most important benefit of the guided wave using Lamb wave propagation is that the inspection area for the specimen in thin plate or pipe will be increase compared to the Ultrasonic testing technique. The wave propagation of the guided wave can travel in a long distance with low attenuation. Therefore, most of narrow part or extremely large area can be inspect easily in a short time. Hence, the defect can be easily be spotted using the guided Lamb wave propagation.

In addition, using the Lamb wave propagation, the inspected area of plate can be screened easily using several transducers for the wave excitation. Hence, this technique will significantly will reduce the time preparation and the work force to do the inspection testing for industrial purpose.

For the industrial cases or in a plant, the guided lamb wave techniques are important to detect the defect on the thin wall of the structure. Hence, any signal produce on the monitor will signifies the defect on the structure. After all, the inspection using the Lamb wave are useful as it will gives such a comprehensive condition information about the defect or crack in or on the structure immediately.

1.3 PROBLEM STATEMENT

Guided wave inspection had been one of the latest techniques in non-destructive test (NDT) and material evaluation. The propagation of the guided wave such as Lamb wave are used to detect the defect on the surface structures especially on the thin plate and reflects the echoes when the defect are detected. The surface defect can be known when the high frequency of wave is pointed on certain location of the plate or thin surface. The suitable selection of the guided mode and frequency range are important for the inspection to be succeeded. As the guided wave propagation of Lamb wave are still being develop, the potential of guided wave inspection using Lamb wave propagation to detect the defect are still not being used domestically in plant and industry. However, the misinterpretation from inexperience NDT staff might leads to the miss-defect during site inspection. Therefore, this study will investigate the behavior of wave interaction with different types of defect.

1.4 OBJECTIVES

The objectives in this study are;

1. To study the effect of defect geometries, depths, and orientations on guided wave propagation.
2. To verify depend of frequency on guided wave propagation.

CHAPTER II

LITERITURE REVIEW

2.0 OVERVIEW

This chapter will focus on the dispersion curve and the beam focusing on the guided waves of Lamb Wave propagation. The review are gathered based on the past research from the journals, technical papers, reference books, which related article on guided waves of Lamb Wave propagation.

2.1 DISPERSION CURVE OF PHASE VELOCITY AND GROUP VELOCITY

2.1.1 Dispersion Curve

Based on Rose (2013) in Materials Evaluation, the dispersion curve can be relate by the relation between the phase velocity and the frequency or the frequency and thickness of the plate structure. Dispersion curve shows all the constructive interference zones that could be create as the waves are reflected inside a structure,