DETECTING AND MONITORING DEFECTS AND DAMAGES ON A PIPELINE USING SELF-DEVELOP GUIDED LAMB WAVE SYSTEM

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A project report submitted in partial fulfilment of the

requirements for the award of the degree of

Master of Engineering (Mechanical)

Faculty of Mechanical Engineering

Universiti Teknologi Malaysia

SEPTEMBER 2014

Dedicated to my beloved family.

ACKNOWLEDGEMENT

In successfully finishing my master project in Universiti Teknologi Malaysia (UTM). First of all, I would like to thank my main supervisor, Dr Raja Ishak Bin Raja Hamzah and my co. supervisor Dr. Zair Asrar Ahmad for the support and guided in ideas, knowledge, experiences and equipments needed in finishing my project.

I would like to also thank the technicians of Noise and Vibration lab, Elfandy Bin Jamaludin and Mohd Nurfairuz Bin Azman for attending my needs through out my project in the lab.

Lastly, my appreciation to my family for their support and motivation in my endeavour to finishing up my master project. Thank you for all your supports.

Thank you.

ABSTRACT

This project was done as a first step to develop applied technology for Lamb wave Structural Health Monitoring (SHM) system. First part was to self-develop the system, where we concentrate on the actuator and sensor using Piezoelectric Buzzer (PB) that can be easily obtained in the market. In determining its feasibility; we investigate its natural frequency, electrical to mechanical conversion and vice versa, its performance against different frequency and its circuit configuration in relation to the systems. From there, we configure the system to create the simplest system to generate and detect the Lamb wave. From this system, we experimenting the symmetrical and asymmetrical wave on a mild steel plate with a thickness of 1mm for frequency between 0-2000Hz to find its velocity and used it to compare to the theoretical calculation. Second part was using the self-develop SHM system, we introduce defects or asymmetrical obstacle to the plate. The asymmetrical obstacle parameter was manipulated where we change the distance of the defect from the actuator, the mass of the defect and the area of contact. It was discovered that the Lamb wave velocity changes with the distance and with the surface area of contact of the obstacle but do not change with mass. The wave amplitude ratio changes with distance and surface area of contact but do not change with mass. Although it was still a crude design but some obstacle could be detected by this self-developed Lamb wave SHM system.

ABSTRAK

Projek ini telah dilakukan sebagai langkah pertama untuk membangunkan teknologi gunaan gelombang Lamb untuk Sistem Pemantauan Kesihatan Struktur. Bahagian pertama adalah membina sendiri sistem, di mana kita menumpukan kepada aktuator dan sensor menggunakan penggera piezoelektrik yang mudah diperoleh di pasaran. Dalam menentukan kebolehlaksanaan penggera piezoelektrik; kita menyiasat frekuensi semula jadi, penukaran elektrik kepada mekanikal, prestasi penukaran elektrik melawan frekuensi dan konfigurasi litar piezoelektrik dalam berhubung dengan sistem. Dari sana, kami mengkonfigurasi sistem untuk mewujudkan sistem yang paling mudah untuk menjana dan mengesan gelombang Lamb. Daripada sistem ini, kami bereksperimen menggunakan gelombang simetri dan tidak simetri pada plat keluli lembut dengan ketebalan 1mm untuk frekuensi antara 0-2000Hz untuk mencari halaju dan menggunakannya untuk membandingkannya dengan pengiraan teori. Bahagian kedua ialah menggunakan sistem tersebut dengan memperkenalkan kecacatan atau halangan tidak simetri kepada plat. Parameter halangan tidak simetri yang dimanipulasi adalah jarak kecacatan dari aktuator, jisim kecacatan dan keluasan kecacatan. Ia telah ditemui bahawa terdapat perubahan kepada halaju gelombang Lamb dengan jarak halangan dan sedikit perubahan dengan keluasan halangan tetapi tidak berubah dengan jisim. Nisbah amplitud gelombang berubah dengan jarak dan keluasan kecacatan tetapi tidak berubah dengan jisim. Walaupun masih rekaan yang kasar tetapi sistem binaan sendiri ini masih dapat mengesan sebahagian kecacatan yang ada.

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LIST OF ABBREVIATIONS

SHM	Structural Health And Monitoring
PB	Piezoelectric Buzzer
SC	Sound Card
S	Sensor
NDT	Non Destructive Test
LW	Longitudinal Wave
SVW	Shear Vertical Wave
SHW	Shear Horizontal Wave
FW	Flexural Wave
TW	Torsional Wave
DAQ	Data Acquisition
DAC	Digital to Analog Converter
SNR	Signal to Noise Ratio
PWAS	Piezoelectric Wafer Active Sensor
LDV	Laser Doppler Vibrometer
EMAT	Electromagnetic-Acoustic Transducer

LIST OF SYMBOLS

a	radius of PB
h	PB thickness
i	number of nodal diameters
j	number of nodal circles
E_{brass}	Young's Modulus of Brass
γ	mass per unit area
ν_{brass}	Poisson's ratio of brass
λ_{ij}	Dimensionless frequency parameter for clamped circular plate.
d	plate thickness,
k	wavenumber,
w	angular velocity,
C_p	longitudinal velocity,
C_s	shear velocity
λ	Lame's first parameter
μ	Lame's second parameter
p	plate mass density
$E_{mild\ steel}$	Young's Modulus for mild steel

$v_{mild\ steel}$	Poisson's ratio of mild steel
c	Lamb wave velocity
f	Lamb wave frequency
π	pi (ratio of circle circumference and diameter)
t	time
v	wave velocity
q	the distance of the actuator and sensor

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CHAPTER 1

INTRODUCTION

1.1 Background Of Research

In fuelling our civilization, we have built and create structures and services to meet our needs. These structure and services had been the vein of our life and are essential for our living. Hence many authorities have been aware on the importance of insuring these veins are in a tip top condition and this is when Structural Health and Monitoring (SHM) system play a major role in providing these services.

The petrochemical industry is one of the veins that contribute in ensuring the continuity of human way of life. The supply of oil and natural gas are regrettably essential in providing energy to people and hence the pipelines that supply it are crucial. These pipeline need to be maintain but however thorough the SHM system is, defects and damages will still occurred and sometimes it causes some major disaster. From records, it is discovered that corrosion, external initial crack and external built up had contributed to the most damages and accidents in the industries.

SHM is a field that is important in monitoring these pipelines. There are two types of system that are active and passive system. Active system is where the system actively detecting defect and its propagation. Passive system is a system that monitors all of the structures parameter and compares it to the baseline parameter where this baseline is assuming that the structure is in good health.

Currently they are many SHM systems available in market using visual inspection, optical method, Eddy current method, acoustic emission method, vibration base method, radiographic method and thermography method. In regarding of these systems, most of them are point scanning system where they are time consuming and some of them are very expensive.

For improving the SHM system we are trying to develop a system that can be used to monitors defect that is difficult to be detected by common SHM. Hence, here we are exploring the possibility of SHM system that is cheap and faster but still reliable. Here we are introducing SHM system using of wave propagation method using Lamb wave as a method to detect the defects and damages.

1.2 Objective

1. To understand Lamb wave and its' potential in the Non-Destructive Test (NDT) application.
2. To self develop SHM system for pipeline using guided Lamb wave that is faster, efficient and cheap.
3. This self develop SHM system can be used to detect and monitor defects and damages in a pipelines.

1.3 Scope

1. Self develop simple SHM system using piezoelectric buzzer as a sensor and actuator.
2. Using isotropic homogenous plate problem to represent continuous isotropic homogenous metal pipelines.
3. Detecting defects and damages due to corrosion and external built up on the plate where asymmetrical obstacles that represent these defects and damages are introduces.

1.4 Problem Statement

In years, we have heard many accidents regarding equipment such as ship platting and pipelines and it is discovered that all were due to defects and damages that is difficult to be detected by conventional SHM system. The two defects and damage proposed are corrosion, external initial crack and external built up where those damage that is critical in the petrochemical industry but is hard, time consuming and expensive to detect and monitor. Here we are proposing using Lamb wave propagation to solve the problems stated.

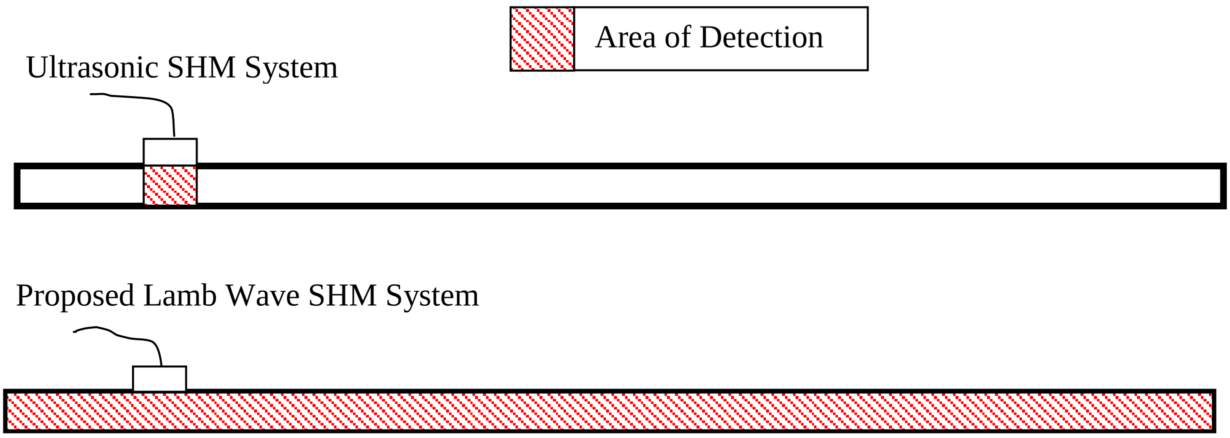

Figure 1.1: Detection comparison between ultrasonic and proposed self-develop Lamb wave SHM System

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