UTILIZING OF TRANSCEIVER METHOD TO IDENTIFY WATER AND OIL FLOW REGIME USING ULTRASONIC TOMOGRAPHY

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ABSTRACT

Tomography refers to imaging by sections or sectioning, through the use of any kind of penetrating wave. From point of view, process tomography refers to a method of acquiring the internal characteristics of pipelines flows or process vessel reaction from the measurement on the domain of interest. On recent years, the applications of tomography techniques were used by various fields such as in medical and also industrial process as it advantages to the system. For this project, both hardware and software used to demonstrate the system; hence the component in pipeline vessels can be analyzed. For the hardware part, it consists of ultrasonic sensor setup and electronic measurement setup which generate the pulse from the sensors through the pipeline. The output from the experiment was discussed and analyzed using oscilloscope. The purpose of this project is to develop a suitable ultrasonic tomography system for the pipeline. This project will produce 8x8 projections (8-transceiver) with utilizing of transceiver method for two phase flow regime identification. As a result, the identifying of water and oil flow regime can be analysis.

ABSTRAK

Tomografi merujuk kepada pengimejan oleh seksyen, melalui penggunaan apa-apa jenis gelombang penembusan. Dari sudut pandangan, proses tomografi merujuk kepada kaedah pemerolehan ciri-ciri dalaman saluran paip atau tindakbalas proses aliran daripada pengukuran pada bahagian tumpuan. Pada tahun-tahun kebelakangan ini, penggunaan teknik tomografi telah digunakan oleh pelbagai bidang seperti dalam proses perubatan dan juga industri kerana ia membawa banyak kelebihan kepada sistem. Untuk projek ini, kedua-dua perkakasan dan perisisan digunakan untuk mempamerkan sistem tersebut justeru komponen di dalam saluran paip boleh dianalisis. Untuk bahagian perkakasan, ia terdiri daripada persediaan sensor ultrasonik dan persediaan pengukuran elektronik yang menjana isyarat daripada sensor melalui saluran paip. Keluaran dari eksperimen tersebut telah dibincangkan dan dianalisis menggunakan osiloskop. Tujuan projek ini adalah untuk membangunkan sistem tomografi ultrasonik yang sesuai untuk saluran paip. Projek ini akan menghasilkan unjuran 8x8 (8-penghantar terima) dengan menggunakan kaedah penghantar terima untuk pengenalpastian dua fasa rejim pengaliran. Hasilnya, pengenalpastian rejim pengaliran air dan minyak boleh dianalisis.

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c	–	Velocity
f	–	Frequency
λ	–	Wavelength
ρ	–	Density
R	–	Reflection Coefficient
T	–	Transmission Coefficient
Z	–	Acoustic Impedance
V_{ref}	–	Reference Voltage
Tx	–	Transmitter
Rx	–	Receiver

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CHAPTER 1

INTRODUCTION

1.1 Overview of Ultrasonic Tomography

Oil and water are an important basic establishment in oil fields since a monitoring system for water and oil flow using ultrasonic tomography is implemented. Process tomography has become research tool in many laboratories and had been used in some industries application over two decades of research worldwide. Current industries such as oil and gas industry are increasingly interested of managing the use of tomography tools as it is bring much applications and also advantages. Tomography is one of the popular and beneficial technology that can be use in order to solve many problems.

The ultrasonic tomography is one of the non-invasive techniques that can be used in the industry for monitoring the flow composition of two liquids flow such as water and oil. The non-invasive method provides the ultrasonic tomography with easy installation and portable convenience. The ultrasonic sensors are very easy to be mounted around the pipeline compared with other sensors. The installation of the ultrasonic tomography system also does not require the shut down of the industry's process (B. S. Hoyle, 1996). Moreover, this monitoring system does not disturb the internal flow of the pipe.

Ultrasonic sensors have been successfully applied in flow measurement, nondestructive testing, and it is widely used in medical imaging. Ultrasonic sensor propagates acoustic waves within range of 18 kHz to 20 MHz. The method involves in using ultrasonic is through transmitting and receiving sensors that are axially spaced along the flow stream. The sensors do not obstruct the flow. As the suspended solids' concentration fluctuates, the ultrasonic beam is scattered and the received signal fluctuates in a random manner about a mean value. This type of sensor can be used for measuring the flow velocity. Two pairs of sensors are required in order to obtain the velocity using cross-correlation method (Hafiz et. al, 2010).

All this benefits support the ultrasonic tomography to be chosen over the other invasive system. Suitable with the purpose of this research, ultrasonic tomography can be used in order to identify water and oil in pipeline system. Due to economical and ecological advantages, it has excellent perspective for future demand.

1.2 Problem Statement

The usage of transceiver to identify water and oil flow regime using ultrasonic tomography can help to improve the performance of the process in certain industries and also not to interrupt the process. The problem that was contributed to this project is because of no specific information of component inside the vessels. Simultaneously, it is hard to determine whether the compound is water or oil flow since it is not visible inside the pipeline thus, to avoid this problem, the ultrasonic sensors that used in this project are put around the pipeline compare to the other sensor that hard to locate.

1.3 Objective of Project

The objective of this project is:

- To identify water and oil flow regime in pipeline system.

1.4 Scope of Project

The scopes of this project are:

i. To develop a simple ultrasonic tomography system.
ii. To implement the ultrasonic sensor around the pipeline for identify water and oil.
iii. To implement microcontroller for controlling electronic projection setup.
iv. To implement ocsilloscope to illustrate the pulse signal.

1.5 Organization of Thesis

Chapter 1 presents an overview of the project, problem statement, objective of the project, scope of project, and organization of thesis.

Chapter 2 covers the literature review on basic concept of tomography, ultasonic tomography, introduction to ultrasound and recent work related to ultasonic tomography.

Chapter 3 describes the ultrasonic methodology about an overview of the flow process, the hardware development and software development.

Chapter 4 discuss the result of the project. In this chapter, the result obtain from experiments illustrated by oscilloscope.

Last but not least, chapter 5 presents about the conclusion and recommendation of this project.

CHAPTER 2

LITERATURE REVIEW

2.1 Basic Concept of Tomography

El-sherbiny et. al (2003) in their paper was introduced about the concept of tomography in medical field which is an imaging technique, which aims to obtain high quality images for the inner structure of the human body. When an object rotates around an axis with a certain velocity, each point target of this object generates a *Doppler* shifted scatted signal relative to the incident signal frequency. The amplitude of this scatted signal is a function of frequency, which gives the line integral for the scatters at a certain cross-range. The line integral information changes from position to another. Finally, the constructed image depends on the received signals from these projection (projections), where the brightness of any visible dot on the image depends on the strength of these returned echoes. In that paper, they also proposed a new technique for continuous-wave ultrasonic tomography, avoiding tha false position and size problems of the reconstructed image.

2.2 Ultrasonic Tomography

The ultrasonic tomography is one of the non-invasive techniques that can be used in the industry for monitoring the flow composition of two liquids flow such as water and oil. The non-invasive method provides the ultrasonic tomography with easy installation and portable convenience. The ultrasonic sensors are very easy to be mounted around the pipeline compared with other sensors **(**Zulkarnay Zakaria ,2010)**.**

Ruzairi Abdul Rahim, Ng Wei Nyap, Mohd. Hafiz Fazalul Rahiman (2006) in their research, describe about the installation of the ultrasonic tomography system also does not require the shut down of the industry's process. Moreover, this monitoring system does not disturb the internal flow of the pipe. All this benefits support the ultrasonic tomography to be chosen over the other invasive system. It is obvious that the ultrasonic tomography of this research has the potential to contribute to the cooking oil, palm oil and petroleum industries. In this case, the ultrasonic tomography can be applied to determine the composition of the water and oil for the palm oil and the petroleum.

There are several types of process tomography such as X-Rays, Electrical Capacitance Tomography (ECT), Electrical Impedance Tomography (EIT) and Ultrasonic Tomography. Every process of tomography has its advantages and disadvantages is each application. Hence, the practical usage and the operating cost must be considered (Yasmin Abdul Wahab, 2009). In this project, ultrasonic tomography is used since it has been widely used in medical and succesfully applied in pipeline and vessel.

The ultrasonic tomography is related with ultrasound wave which produce frequency above 20 kHz and also the object imaged. Due to that, ultrasonic tomography is capable of on-line monitoring, has the opportunity to develop closed loop control systems and finally, it can be non-invasive and possibly non-instrusive system (Hoyle and Xu, 1995).

2.3 Introduction to Ultrasound

Ultrasound waves for imaging are generated by transducers, which convert electrical energy into sound energy. Basically, ultrasound is sound with frequency greater than 20,000 cycles per second or 20 kHz. Audible sound sensed by the human ear are in the range of 20 Hz to 20 kHz. However, sound waves cannot propagate in a vacuum at all. Beside, the behavior of ultrasonic that similar manner with audible sound, but has much shorter wavelenght make this sound can be reflected in a small surface such defect inside material (Yasmin, 2009).

2.3.1 Related Principle of Ultrasound

In this project, the basic principle of ultrasonic that are used are ultrasonic propagation, wavelength and frequency of ultrasonic, acoustic impedance and also attenuation of ultrasound.

2.3.2 Ultrasonic Propagation

From the previous researh, majority of them state that there were several types of waves propagation that occur based on the way the particles oscillate. Abdul Rahim et al. (2004) stated that ultrasonic waves can propagate as longitudinal waves, shear waves, surface waves, and in thin materials as plate waves in solids. Among them, only the longitudinal and shear waves propagation which are most widely used in ultrasonic testing (Fazalul Rahiman, 2003). Table 2.1 below shows the type of waves modes possible in liquid while Figure 2.1 shows the propagation of longitudinal and shear waves propagation.

Table 2.1: Types of waves

Waves Type in Liquids	Particle Vibrations
Longitudinal	Parallel to wave direction
Transverse (Shear)	Perpendicular to wave direction

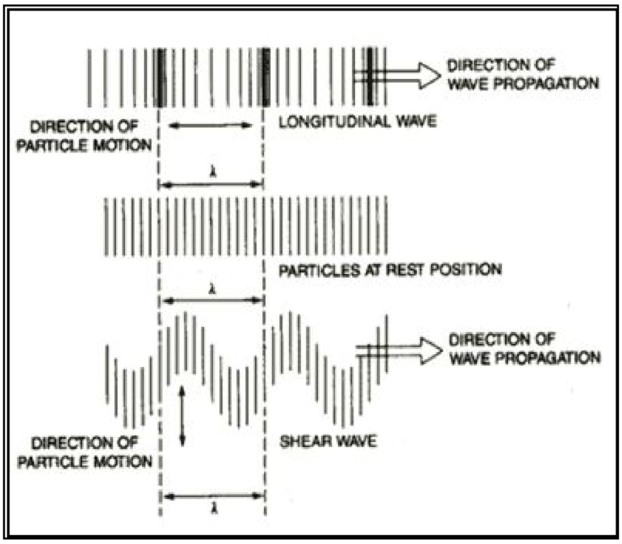

Figure 2.1: Propagation of longitudinal waves and shear waves

In longitudinal waves, the oscillations occur in the longitudinal direction or the direction of wave propagation. Since compressional and dilational forces are active in these waves, they are also called pressure or compressional waves. They are also sometimes called density waves because their particle density fluctuates as they move. Compression waves can be generated in liquids, as well as solids because the energy travels through the atomic structure by a series of compressions and expansion (rarefaction) movements.

In the transverse or shear wave, the particles oscillate at a right angle or transverse to the direction of propagation. Shear waves require an acoustically solid material for effective propagation, and therefore, are not effectively propagated in materials such as liquids or gasses. Shear waves are relatively weak when compared to longitudinal waves. In fact, shear waves are usually generated in materials using some of the energy from longitudinal waves.

2.3.3 Wavelength and frequency

Ultrasounds are elastic waves that propagate at frequencies higher than 20 kHz (Ruzairi, 2007). These waves shown in Figure 2.2 which are defined by the physical parameters according to the relation:

$$c = f\lambda \qquad \text{.....(2.1)}$$

Where:

f = the frequency

c = velocity of propagation

λ = wavelength

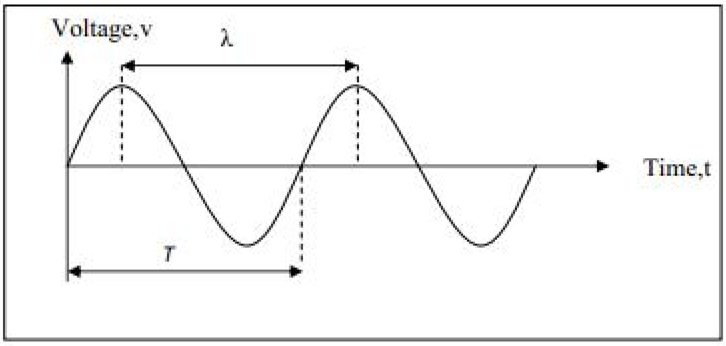

Figure 2.2: Parameter of Waves

2.3.4 Acoustic impedance

Acoustic impedance, z is the sound that travels through material under influence of sound pressure. Ultrasonic tomography technique is the use of ultrasound to detect the changes of acoustic impedance (z) which is closely related to density (ρ) of the media. The relation is given by the formula:

$$z = \rho c \qquad \textbf{.....(2.2)}$$

where c is speed of sound.

Every medium phase have their own acoustic impedance. Table 2.2 show the acoustic impedance of water and oil.

Table 2.2: Acoustic impedance of liquid

Medium	**Material**	**Acoustic impedance (kg/m^2s)**
Experimental column	PVC	3.27×10^6
Liquid	Water	1.50×10^6
Liquid	Palm Oil	1.35×10^6

The equation of reflection and transmission coefficient is stated as below (Yasmin, 2009):

$$Reflection\ coefficient, R = \frac{P_r}{P_e} = \frac{z_2 - z_1}{z_2 + z_1} \qquad \textbf{.....(2.3)}$$

$$Transmission\ coefficient, T = \frac{P_t}{P_e} = \frac{2z_2}{z_2 + z_1} \qquad \textbf{.....(2.4)}$$

From the equation 2.3 and 2.4, propagation of waves can be calculated based on the acoustic impedance according to the experimental medium used. The calculation of Reflection, *R* and Transmission, *T* can be shown as below:

i. Ultrasonic wave propagation between pvc pipe and water as shown in Figure 2.3.

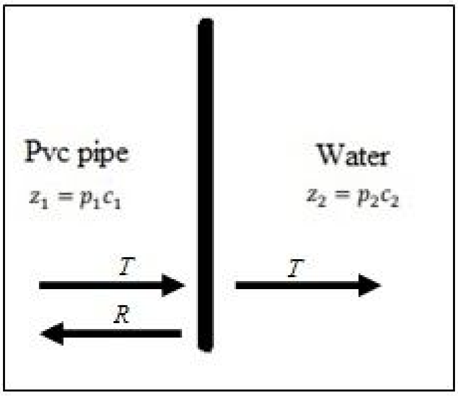

Figure 2.2: Propagation wave from pvc pipe into water

$$R_{(\,pvc/water\,)} = \frac{[1.50\times10^6]-[3.27\times10^6]}{[1.50\times10^6]+[3.27\times10^6]} = -0.377 \times 100 = -37.11\% \qquad \textbf{.....(2.5)}$$

$$T_{(\,pvc/water\,)} = \frac{2[1.50\times10^6]}{[1.50\times10^6]+[3.27\times10^6]} = 0.6289 \times 100 = 62.89\% \qquad \textbf{.....(2.6)}$$

From the calculation, transmission signal of medium is 62.89% while reflected signal is 37.11%. The negative sign indicate the reversal of the phase relative to the indicate wave (Yasmin, 2009).

ii. Ultrasonic wave propagation between pvc pipe and palm oil as shown in Figure 2.4.

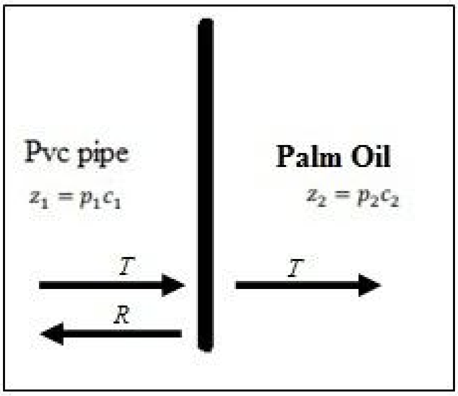

Figure 2.3: Propagation wave from pvc pipe into palm oil

$$R_{(pvc/palm\ oil\ )} = \frac{[1.35\times10^6]-[3.27\times10^6]}{[1.35\times10^6]+[3.27\times10^6]} = -0.42 = -42\% \quad \textbf{.....(2.7)}$$

$$T_{(\ pvc/palm\ oil\ )} = \frac{2[1.35\times10^6]}{[1.35\times10^6]+[3.27\times10^6]} = 0.58 = 58\% \quad \textbf{.....(2.8)}$$

Propagation wave of the medium show that the transmission signal is 58% while the reflected signal is 42%.

iii. Ultrasonic wave propagation between water and palm oil as shown in Figure 2.5.

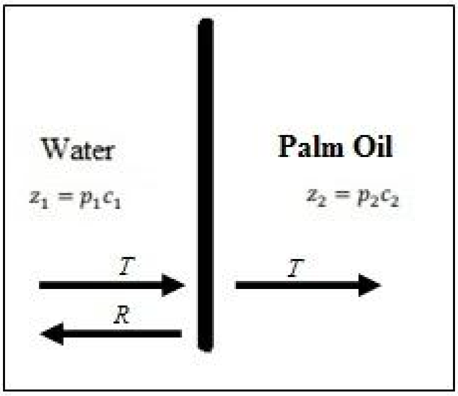

Figure 2.4: Propagation wave from water into palm oil

$$R_{(water/palm\ oil\ )} = \frac{[1.35\times10^6]-[1.50\times10^6]}{[1.35\times10^6]+[1.50\times10^6]} = -0.053 = -5.3\% \qquad \textbf{.....(2.9)}$$

$$T_{(\ water/palm\ oil\ )} = \frac{2[1.35\times10^6]}{[1.35\times10^6]+[1.50\times10^6]} = 0.947 = 94.7\% \qquad \textbf{.....(3.0)}$$

For propagation wave of water and oil, the transmission signal is 94.7% while the reflected signal is only 5.3%.