ULTRASONIC TOMOGRAPHY FOR MULTIPHASE FLOW REGIME IDENTIFICATION

YASMIN BINTI ABDUL WAHAB

UNIVERSITI TEKNOLOGI MALAYSIA

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A project report submitted in partial fulfilment of the
requirements for the award of the degree of
Master of Engineering (Electrical- Mechatronic and Automatic Control)

Faculty of Electrical Engineering
Universiti Teknologi Malaysia

NOVEMBER 2009

Dengan nama Allah yang Maha Pemurah lagi Maha Pengasih.

To my beloved and supportive parents,

Ahmad Syamrim Bin Yusuf,

brothers and sisters.

ACKNOWLEDGEMENT

In preparing this thesis, I was in contact with many people, researchers, academicians, and practitioners. They have contributed towards my understanding and thoughts. In particular, I wish to express my sincere appreciation to my main thesis supervisor, Professor Dr. Ruzairi Bin Hj. Abdul Rahim, for encouragement, guidance, critics and friendship. Without their continued support and interest, this thesis would not have been the same as presented here.

A special thank to my PROTOM members which have been most kind give an idea and supporting during my project. To Mohd Hafiz Bin Fazalul Rahiman, thank you for your most helpful discussion and suggestion. My fellow friends should be also be recognized for their support.

Finally, I would like to give a special thanks to my beloved family and Ahmad Syamrim Bin Yusuf for their support and encouragement until the end of this thesis.

ABSTRACT

This project presents the application of ultrasonic tomography in the process and chemicals industries. This ultrasonic tomography system is to identify the multiphase flow regime which is liquid, gas and solid at once. This is due to the industry process where up till now no research had been investigate for the multiphase flow that display the tomogram of liquid, gas and solid at once. The transmission mode with fan shaped beam back projection had been implemented. The system also was designing non-invasively in other to provide information about the composition of the system without disturbing the nature of process being examined. In this system, 8 transmitters and 8 receivers which produce 8x8 projections were implemented. The linear back projection algorithm was implemented for the image reconstruction part. The system also was divided into two parts which are hardware system and software system. In the hardware system, the values of holding voltages were take note because it will use in the software system. Then, the linear back projection algorithm was implemented in the software system in other to get the concentration profile and display the tomogram. The experiments that had been conducted shows that the multiphase flow regime for liquid, gas and solid at once can be identifying by using ultrasonic tomography.

ABSTRAK

Projek ini mengenai aplikasi tomografi ultrasonik dalam industri proces dan kimia. Sistem ultrasonik tomografi ini bertujuan untuk mengenalpasti kepelbagaian aliran iaitu cecair, gas dan pepejal. Ini kerana di dalam industri proces, tiada lagi kajian yang dibuat berkaitan kepelbagaian aliran terutamanya untuk memaparkan gambar kepelbagaian aliran untuk cecair, gas dan pepejal pada satu-satu masa. Kaedah pancaran dengan bentuk sinaran kipas secara balikan telah dilaksanakan dalam projek ini. Sistem yang direka tidak melibatkan sentuhan pada aliran yang mana bertujuan untuk mendapatkan maklumat mengenai sistem ini tanpa perlu mengubah keadaan semulajadinya ketika penilaian proces dilakukan. 8 biji pemancar dan 8 biji penerima yang bertujuan untuk menghasilkan 8x8 pemancaran juga telah digunakan. Algoritma yang dikenali sebagai pemancaran balikan secara terus telah diaplikasikan dalam bahagian untuk memperolehi gambar. Sistem ini sebenarnya terbahagi kepada dua bahagian iaitu bahagian perkakasan dan bahagian perisian. Pada bahagian perkakasan, nilai penyekatan voltan yang diperolehi akan dicatatkan kerana ianya akan digunakan pada bahagian perisian. Selepas itu, pemancaran balikan secara terus telah digunakan dalam bahagian perisian untuk mendapatkan profil pekatan dan juga untuk memaparkan gambarnya. Daripada eksperimen-eksperimen yang telah dijalankan, keputusan menunujukkna bahawa tomografi ultrasonik boleh digunakan untuk mengenalpasti kepelbagaian aliran untuk cecair, gas dan juga solid pada satu-satu masa.

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LIST OF SYMBOLS

f	–	Frequency
$/M_{Tx,\ Rx(x,y)}$	–	Normalized sensitivity map for the view of Tx to Rx
c	–	Velocity
$M_{Tx,\ Rx(x,y)}$	–	Sensitivity map for the view of Tx to Rx
pe	–	Incident Wave Sound Pressure
pr	–	Reflected Wave Sound Pressure
pt	–	Transmitted Wave Sound Pressure
R	–	Reflection Coefficient
Rx	–	Receiver
$S_{Tx,\ Rx}$	–	Sensor Loss Voltage
T	–	Period
T	–	Transmission Coefficient
Tx	–	Transmitter
$V\ ref_{Tx,\ Rx}$	–	Reference voltage by ultrasonic receiver during full liquid flow
$V_{Tx,\ Rx}$	–	Ultrasonic receiver voltage (sensor value)
Z	–	Acoustic Impedance
λ	–	Wavelength
ρ	–	Density

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CHAPTER 1

INTRODUCTION

1.1 Overview of Process Tomography

Tomography technology involves the acquisition of measurement signals from sensors located on periphery of an object, such as a process vessel or pipeline. This reveals information on the nature and distribution of components within the sensing zone. Most tomography techniques are concerned with abstracting information to form a cross sectional image. The tomography technique is a combination of the sensor technique and the image reconstruction technique (algorithm) (Warsito et al., 1999).

The etymology of the word tomography comes from the Greek, *tomos*, a cut or slice, and *graphein*, to write (Northrop and Robert, 2002). Simultaneously, according to the Oxford English Dictionary the word tomography may be defined as:

Radiography in which an image of a predetermined plane in the body or other object is obtained by rotating the detector and the source of radiation in such a way points outside the plane give a blurred image. Also in extended use, any analogous technique using other forms of radiation (Williams and Beck, 1995).

Tomography system has been introduced and widely used in medical field, than it also applied in the industrial process. The first and foremost is X-ray computed tomography, or computed axial tomography (CAT) developed in the early

1970s in England by G.N Hounsfield and McCormack (Northrop, 2002). However this approach is not satisfied due to the high cost and safety constraints. These radiation-based methods also used long exposure times which meant that dynamic measurement of the real-time behavior of flow inside pipelines and process systems were not feasible. Beside, the industries application demands that the equipment of tomography must be in low cost and can be used for measurement rapidly.

In the middle of 1980s, the work started that present the process tomography system. A research on electrical capacitance tomography (ECT) for multi-components flow oil wells and pneumatic conveyors was carried out at the University of Manchester Institute of Science and Technology (UMIST) in England (William and Beck, 1995). At a same time, a group at the Morgantown Energy Technology Center in the USA was designing a Capacitance Tomography system for measuring the void distribution in gas fluidized beds. The capacitance transducers used for both these systems were only suitable for use in an electrically non-conducting situation.

Hoyle and Xu (1995) had carried out a research about the design and application of ultrasonic sensor in tomography. Nevertheless, process tomography is a technique still in its infancy, but it has the potential for enabling great improvements in efficiency and safety in process industries, while minimizing waste and pollution in a range of applications (Hafiz, 2005). It also can be applied to gain both quantitative and qualitative data needed in modeling a multiphase flow system. Since then, there were many researches about tomography for the industrial and medical applications carried out in the United Kingdom (UK) and United States of America (USA). Up till now, there are many researches still carrying out around the world and mainly in the universities. Beside, the international symposium, seminars and congress are held which involves researchers around the world.

1.2 Importance of Study

In recent years, applications of process tomography as a robust non-invasive tool for direct analysis of the characteristics of multiphase flows have increased in number (Warsito et. al., 2001). Process tomography involves utilization of tomography imaging methods to manipulate data from remote sensors to obtain precise quantitative information from inaccessible locations. The important of this project is to identify the multiphase flow regime using ultrasonic tomography.

The multiphase means that the phases are used either two or more than that and the phases usually identify are liquid, gas and solid. The multiphase of material flows through the pipe or vessel can be identified whether the condition are fully mixed, fully separated and anything in between depending on the nature and densities of the phases, the degree of turbulence induces in the mixture, the physical geometry of the pipe and the condition of the pipe or vessel itself whether in horizontal or vertical condition.

When the flow of condition is known, it is very useful where every phases of the flow can be identified. However, the identification or measurement of the flow condition it is quite difficult if any disturbance occurs in the pipe or vessel. Nevertheless, the nature of condition of the flow should be not disturbing while the process is examined. This is impossible from within the pipes as the very act of measurement disturbs the flow; hence it has to be from outside the pipe. Therefore the ultrasonic tomography is useful in this condition to identify the multiphase flow regime. As most sensors currently used in multiphase flow meters are affected by the distribution of components in the mixture, tomography imaging may possibly improve the accuracy and provides a wider measurement range (Hafiz, 2005).

1.3 Problem Statement

In the process and chemical industries, like the mixing industries, the oil and gas industries, and the paper pulp industries, multiphase flow plays an important role. A monitoring system that can be applied non-invasively is very important in multiphase flow system. The monitoring system should be able to provide information about the composition of the multiphase system. Tomography is the most beneficial technology that can be applied to solve the problem. An ultrasonic tomography is one of the techniques that have been successfully used in industries in other to monitor the actual process material such as in pipeline and vessel. Of course, the installation of ultrasonic tomography will not interrupt the process being examined. However, most of the researches that have been done only focusing on solid/liquid phase detection, liquid/liquid, gas/solid and liquid /gas flow detection. For instance, in 1999, Warsito and his friends had been published a paper according to the multiphase flow which indicate the liquid, gas and solid. However, the tomogram displayed not indicates the liquid, solid and gas at once but vice versa. Thus, up till now, no research has being developed in other to identify the three phases at once. Indeed, this project is to create a suitable ultrasonic tomography system to identify the three phase flow.

1.4 Objective of Project

To identify multiphase for liquid, gas, and solid flow regime by using ultrasonic tomography.

1.5 Scope of Project

The scopes of this project are:

- To design and develop a simple ultrasonic tomography system.
- To implement a suitable ultrasonic transducers non-invasively in multiphase flow regime identification.
- To design and implement an electronic measurement system for the ultrasonic tomography system such as the signal generator circuit and signal conditioning circuit.
- To implement microcontroller for controlling the ultrasound projection, and sample and hold
- To perform the image reconstruction using suitable image reconstruction algorithm and display the results using personal computer.

1.6 Organization of Thesis

This thesis consists of seven chapters. In chapter 1, the discussion was more on the introduction of the process tomography, important of the study, problem statement, objective of the project, and scopes of the project

Beside, chapter 2 presents the literature review about tomography itself. The basic concept of tomography, types of tomography and the paper that related to the ultrasonic tomography was presented.

Chapter 3 explains more on the theory of ultrasonic tomography including the principles of the ultrasound and the types of ultrasonic sensing mode.

Chapter 4 presents the image reconstruction algorithm. The concept of back projection was explained detail including the steps of tomographic imaging.

Simultaneously, the explanation of linear back projection algorithm that used in this project also presented.

Chapter 5 describe about the methodology of this project. The discussion on hardware system and software system that implemented in this project was presented and explained detail.

Chapter 6 presents the results obtained from the test profile and experiment. The discussions based on the results obtained were explained detail.

Last but not least, chapter 7 was discussing the conclusion and recommendation for future work that can be done for the future work.