CONCENTRATION AND VELOCITY MEASUREMENT OF FLOWING OBJECTS USING OPTICAL AND ULTRASONIC TOMOGRAPHY

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Dengan nama Allah yang Maha Pemurah lagi Maha Pengasih.
To my beloved and supportive wife Wan Sallha,
my sons Muhammad Danish Irfan and Muhammad Dini Irsyad

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ABSTRACT

This thesis investigates a simple measurement of concentration and velocity of objects flowing in a pipe of 100mm diameter. The project aims to analyze the accuracy and repeatability of measurements by comparing the results from the concentration and velocity measurement of various objects between optical and ultrasonic sensors. Both sensors are based on process tomography technique. The optical and ultrasonic tomography measurements circuit consists of sensors, signal conditioning circuits and data acquisition system. Sensors fixture are designed based on fan beam projection technique. The signal is transmitted from the transmitter to the receiver. Interfacing card is used to interface the analog signals to the computer. The sensors detect the attenuation of light for optical system and acoustic energy for ultrasonic system. This provides information on the concentration of the flowing objects. To measure velocity, two arrays of sensors are placed upstream and downstream on the pipe. The output from both sensors is cross-correlated. The peak of the cross-correlation graph represented the time for the object to move from upstream to downstream. The velocity is obtained by dividing the time and the distance between upstream and downstream. The velocity is obtained by simply dividing the time and the distance between upstream and downstream. Prototype circuits have been implemented for optical and ultrasonic measurement system. Visual Basic 6.0 is used for software algorithms on concentration and velocity measurement. The data is collected using data acquisition system and it was an offline process. The comparison of concentration profiles has shown that optical tomography produced a better result compared to ultrasonic tomography. Whereas for velocity measurement, ultrasonic transducer produced better accuracy but lower repeatability compared to optical transducer.

ABSTRAK

Tesis ini mengkaji pengukuran mudah terhadap penumpuan dan halaju objek bergerak di dalam paip berdiameter 100mm. Matlamat project in adalah untuk menganalisa ketepatan dan keboleh-ulangan pengukuran melalui hasil perbandingan daripada pengukuran penumpuan dan halaju ke atas pelbagai objek di antara pengesan optikal dan ultrasonik. Kedua-dua pengesan adalah berasaskan kepada teknik proses tomografi. Litar pengukur bagi tomografi optikal dan ultrasonik terdiri daripada pengesan, litar kondisi isyarat dan system pemungutan data. Alat pemasangan pengesan direka berdasarkan kepada teknik 'fan-beam projection'.Isyarat dihantar dari pemancar ke penerima. Kad penyambungan digunakan untuk menyambung isyarat analog ke komputer. Alat pengesan optikal mengesan pengecilan cahaya dan alat pengesan ultrasonik mengesan pengecilan kuasa akuastik. Dengan ini, maklumat tentang penumpuan dapat diperolehi. Untuk mengukur halaju, dua susunan pengesan dipasang di sebelah atas dan bawah paip. Isyarat yang keluar daripada kedua-dua jenis pengesan akan disilang-kait. Puncak tertinggi bagi graf silang-kait menunjukkan masa untuk objek bergerak dari atas ke bawah paip. Halaju ditentukan melalui pembahagian jarak atas-bawah dengan masa. Litar prototaip telah dilaksanakan ke atas pengukuran sistem optikal dan ultrasonik. 'Visual Basic 6.0' telah digunakan dalam perlaksanaan algoritma perisian untuk pengukuran penumpuan dan halaju. Pemungutan data dilakukan secara 'offline'. Perbandingan di antara profil penumpuan ke atas kedua-dua teknik tomografi menunjukkan bahawa keputusan tomografi optikal adalah lebih baik berbanding tomografi ultrasonik. Sebaliknya bagi pengukuran halaju, transduser ultrasonik menghasikan keputusan yang lebih baik berbanding transduser optikal.

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LIST OF SYMBOLS

Z	-	Acoustic impedance
ρ	-	Density
c	-	Velocity of sound
μ	-	The linear attenuation coefficient
I_0	-	Original intensity of source
I	-	Measured intensity
s	-	Thickness of object
R	-	Characteristic impedances
L	-	Distance
$f(x, y)$	-	Attenuation function
I_T	-	Energy intensity of transmitter
I_R	-	Energy intensity of receiver
f_R	-	Resonance frequency
f_H	-	Upper cutoff frequency
f_L	-	Lower cutoff frequency
R_{xy}	-	Cross correlation function
T	-	Transit time
$V_{\mathrm{LBP}(x,y)}$	-	Voltage distribution obtained using LBP algorithms
$S_{\mathrm{Rx,Tx}}$	-	Signal loss amplitude of receiver Rx-th for projection Tx-th in unit of volt
$\overline{M}_{Tx,Rx}(x, y)$	-	The normalized sensitivity matrices for the view of Tx–Rx Linear Back Projection algorithms

LIST OF ABBREVIATIONS

ECT	-	Electrical capacitance tomography
EIT	-	Electrical impedance tomography
DAS	-	Data acquisition system
IR-LED	-	Infra-red Light Emitting Diode
d.c	-	Direct current
GUI	-	Graphical User Interface

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CHAPTER 1

INTRODUCTION

1.1 Overview Of The Process Tomography

The imaging and measurement of flows provides an important inspection method in industrial processes (M.H. Fazalul Rahiman *et al.*, 2006). Various methods have been employed for measuring the volumetric concentration and the velocity of various objects through the pipeline. It has been of interest in many industrial applications to describe the characteristic of component flows using methods that are noninvasive, fast response, and suitable for optically opaque systems. Thus, ultrasonic technique holds good potential for matching these requirements (Ying Zheng *et al.*, 2004).

The ultrasonic sensor is sensitive to the density of sound changes and has the potential for imaging component flows such as oil, gas, and water mixtures. Ultrasonic tomography is one of the methods that enable the measurement of certain characteristics of objects that cannot be easily obtained by other methods. Ultrasounds can detect changes in acoustic impedance (Z) which is closely related to the density (ρ) of the media ($Z = \rho c$, where c is the velocity of sound) and thus complements other tomographic imaging technologies such as electrical capacitance tomography (ECT) and electrical impedance tomography (EIT) (M.H. Fazalul Rahiman *et al.*, 2006).

However, at present optical sensors techniques also plays an important role in measuring the volumetric concentration and the velocity of various objects. It will be applied widely in the fields of biomedical imaging, material structure analyzing and blurry martial target distinguishing and etc (Shi Zhiwei *et al.*, 2004). Currently, optical tomography is an attractive method since it is conceptually straightforward, relatively inexpensive and has a better dynamic response than other radiation-based tomographic techniques such as x-ray and positron emission tomography (S Ibrahim *et al.*, 1999). Naturally, optic fiber sensor with high sensitivity, small volume, and finely insulating is paid much attention in the development of optical tomography technology (Shi Zhiwei *et al.*, 2004).

Since both techniques have a potential demand in current industries and the measurement in the volumetric concentration and the velocity of various objects becomes more important to obtain a good quality of product industries, further study on the issues of the accuracy and repeatability of the measurement should be analyzed. Thus this project aims to highlight the above issues.

1.2 Objectives of the Project

The aims of this project are to analyze the accuracy and repeatability of measurements by comparing the results from the concentration and velocity measurement of various objects between optical and ultrasonic sensors. Specifically the objectives of this project are:

1. To investigate simple measurement of concentration and velocity of flowing objects in a pipe using optical and ultrasonic sensors.
2. To design and develop the electronic measurement system which consist of sensors, signal conditioning circuits and output.
3. To compare the results from the concentration and velocity measurement of various objects between optical and ultrasonic sensors. Analysis will be made in terms of accuracy and repeatability of measurement.

1.3 Scope of the Project

This project is divided into two stages, which are:

Stage 1: Hardware Development

Firstly, literature study on the concept of flow measurement techniques using optical and ultrasonic sensors are revised. Second, the selection of sensors and design sensor's fixtures are made. Than, the signal conditioning circuit are designed and tested. Finally, the concentration and velocity of flowing object in a pipe line in terms of dc voltage are measured.

Stage 2: Software development and Interfacing to the data acquisition system (DAS)

At this stage, the designing of graphical user interface will be made by using Visual Basic 6. Then, the signal conditioning circuit is interface to the DAS card. Data is captured using Keithley ExceLINX software. The offline monitoring of velocity and concentration object flowing into the pipe are made. Then, the results are analyzed and finally completed the thesis writing.

1.4 Project Planning

This project is implemented base on the project planning schedule. The project started from July 2006 to April 2007. The project planning schedule is presented in Appendix A.

1.5 Thesis Outline

Chapter 1 presents an overview to process tomography, the objectives of the project, project schedule and thesis outline.

Chapter 2 covers the literature review on the tomography technique for optical and ultrasonic tomography, the principle of optical and ultrasonic sensor system and the arrangement of transducers.

Chapter 3 describes in details the optical and ultrasonic system methodology, the hardware and software development, and the techniques used to display the concentration profiles as well as velocity of flowing objects.

Chapter 4 presents the results of both experiments concentration and velocity measurement. All the results have been discussed in details.

Chapter 5 discusses the overall conclusions, limitations of the project and suggestions for future work.