REAL TIME INFRA-RED TOMOGRAPHY FOR PIPELINE FLOW MEASUREMENT

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"This project report dedicated to the memory of my late beloved father,

(May Allah grant him Jannah, Aameen)

and to my affectionate mother

who always encouraged, motivated

and inspired me

throughout my journey of life."

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ABSTRACT

Information on flow regimes is vital in the analysis and measurement of industrial process flow. Almost all currently available method of measuring the flow of two-component mixtures in industrial pipelines endeavors to average a property of the flow over the pipe cross-section. They do not give information on the nature of the flow regime and they are unsuitable for accurate measurement where the component distribution is spatially or time varying. The overall aim of this project is to investigate the use of an optical tomography method based on infra-red sensors for real-time monitoring of solid particles conveyed by a rotary valve in a pneumatic pipeline. The infra-red tomography system can be divided into two distinct portions of hardware and software development process. The hardware development process covers the infra-red sensor selection, fixtures and signals conditioning circuits, and control circuits. The software development involves data acquisition system, sensor modeling, image algorithms, and programming for a tomographic display to provide solids flow information in pipeline such as concentration. The information is obtained from the of orthogonal system. Those information on the flow captured using upstream and downstream infra-red sensors are digitized by the DAS system before it was passed into a computer for analysis such as image reconstructions and cross-correlation process that provide two-dimensional image profiles represented by 8×8 pixels mapped onto the pipe cross-section.

ABSTRAK

Maklumat tentang regim aliran adalah sangat penting di dalam analisis dan pengukuran aliran proses pengindustrian. Hampir kesemua kaedah pengukuran aliran gabungan dua komponen di dalam paip pengindustrian berfungsi untuk mendapatkan purata aliran merangkumi keratan rentas paip. Mereka tidak memberi maklumat asal kawasan aliran dan tidak sesuai untuk pengukuran tepat di mana taburan komponen berubah secara ruang atau masa. Matlamat utama projek ini adalah untuk mengkaji penggunaan kaedah tomografi optik berasaskan kepada penderia infra-merah untuk pengawasan masa-nyata partikel pepejal yang dialirkan oleh injap berputar di dalam satu paip pneumatik. Sistem tomografi infra-merah boleh dibahagikan kepada dua bahagian proses pembangunan iaitu perkakasan dan perisian. Proses pembangunan perkakasan meliputi pemilihan penderia infra-merah, peralatan dan litar penyesuaian isyarat, dan litar kawalan. Proses pembangunan perisian melibatkan sistem perolehan data, pemodelan penderia, algoritma imej, dan pengaturcaraan untuk paparan tomografi di dalam menghasilkan maklumat aliran pepejal di dalam laluan paip seperti profil tumpuan. Maklumat diperoleh daripada ‘orthogonal’ sistem projeksi. Maklumat aliran yang diambil menggunakan penderia inframerah ‘upstream’ dan ‘downstream’ di digitalkan oleh sistem DAS sebelum memasuki sebuah komputer untuk analisis seperti pembinaan semula imej dan proses sekaitan-silang yang menghasilkan profil gambar dua-dimensional gambar yang dipetakan pada 8 × 8 piksel keratan rentas paip.

CONTENTS

CHAPTER	TITLE	PAGES
	PROJECT TITLE	i
	DECLARATION FORM	ii
	DECLARATION	iii
	SUPERVISOR DECLARATION	iv
	DEDICATION	v
	ACKNOWLEDGEMENT	vi
	ABSTRACT	vii
	ABSTRAK	viii
	CONTENT	ix – xii
	TABLE LIST	xiii
	FIGURE LIST	xiv – xv
	ABBREVIATIONS LIST	xvi

I	**INTRODUCTION**	1 – 7
	1.1 Background of problems	3 – 4
	1.2 Problems statement	4 – 5
	1.3 Objective of the project	6
	1.4 Scope Of study	6
	1.5 Methodology	7
II	**LITERATURE REVIEW**	8 – 30
	2.1.0 What is Process Tomography	8 – 10
	2.1.1 Tomography Sensors	10 – 11
	2.1.2 Electrical Capacitance Tomography	11 – 12
	2.1.3 Electrical Resistance Tomography	13
	2.1.4 Electrical Impedance Tomography	14 – 15
	2.1.5 Ultrasonic Tomography	15 – 16
	2.1.6 X-ray Tomography	16
	2.1.7 Optical Tomography	17
	2.1.8 Electrical Charge Tomography	18 – 19
	2.1.9 Microwave Tomography	19
	2.1.10 Mutual Inductance Tomography	20 – 21
	2.2 Applications of Process Tomography	21 – 24
	2.3 Infra-red Characteristics	24 – 25
	2.4 Optical Projection	26 – 28
	2.5 LabVIEW Software	28 – 30

III	**RESEARCH METHODOLOGY**		31 - 45
	3.1	Signal Conditioning Unit	31 – 32
	3.2	PCB Layout	33
	3.3	PCB Development	34 – 35
	3.4	Linear Back Projection	35
	3.5	The Optical Attenuation Model	36
	3.6	Hardware Development	37 – 38
	3.7	Software Development	38 – 45
	3.7.1	Initialize Software with Data Acquisition	40 – 41
	3.7.2	Acquiring Data	41
	3.7.3	Processing Data	42 – 43
	3.7.4	Image Construction	43
	3.7.5	The Complete Program	44 – 45
IV	**RESULT AND DISCUSSION**		46 – 57
	4.1	Introduction	46
	4.2	Circuit Simulation	47 – 48
	4.3	Receiver Circuit Test	48 – 49
	4.4	Receiver Circuit PCB Test	49
	4.5	The Measurement System Test	50 – 54
	4.5.1	Result for no object	51
	4.5.2	Result for test object one	52
	4.5.3	Result for test object two	53
	4.5.4	Result for test object three	54
	4.6	Real-time Performance	55
	4.7	Discussion	56 – 57

V	**CONCLUSION AND RECOMMENDATION**	58 – 59
	5.1 Conclusion	58 –59
	5.2 Recommendation	59
	REFERENCES	60 – 61
	APPENDIX	62 – 65

TABLE LIST

TABLE	TITLE	PAGES
4.1	Simulation result	48
4.2	Result for circuit construction	49
4.3	Output for receiver circuit	49
4.4	Voltage reading for test no object	51
4.5	Voltage reading for test objects one (1.5×1.5×1.5cm)	52
4.6	Voltage reading for test object two (3.0×3.0×3.0cm)	53
4.7	Voltage reading for test object three (3.0×5.0×3.0cm)	54

FIGURE LIST

FIGURE	TITLE	PAGES
1.1	Flow Chart of Research Methodology	7
2.1	An electrical capacitance tomography system	12
2.2	Diagram showing the electrical model of EIT	15
2.3	Block diagram of a typical EMT system	20
2.4	The electromagnetic spectrum	24
2.5	Types of projections for optical tomography.	27 - 28
3.1	Schematic of receiver circuit	32
3.2	Circuit of receiver and transmitter design using Proteus	32
3.3	PCB design for receiver and transmitter circuit	33
3.4	PCB fabrication step	34
3.5	PCB for receiver and transmitter circuit.	35
3.6	Block diagram	37
3.7	The Data Translation VI role	39
3.8	Flow of Programming	40
3.9	DT Get Board Selection VI	40
3.10	DT Shutdown VI	41
3.11	DT AI Sample Channels VI	41
3.12	Processing Block	42
3.13	Summing Loop Block	43
3.14	Image Construction Block	44

3.15	The Complete Program	45
4.1	The simulation circuit for receiver	47
4.2	The simulation circuit for sender	47
4.3	Circuit when infra red is trigger	48
4.4	Circuit when infra red is not trigger	48
4.5	The measurement system	50
4.6	Reconstructed image for no object	51
4.7	Reconstructed image for test object one	52
4.8	Reconstructed image for test object two	53
4.9	Reconstructed image for test object three	54
4.10	Voltage output Vs Infra red intensity	56
A-1	LM358 Datasheet (a)	62
A-2	LM358 Datasheet (b)	63
A-3	LM358 Datasheet (c)	64
A-4	LM358 Datasheet (d)	65

LIST OF ABBREVIATIONS

Tx	-	Receiver
Rx	-	Transmitter
CT	-	Computed tomography
PIC	-	Peripheral Interface Controller
ECT	-	Electrical Capacitance Tomography
SNR	-	Signal to Noise Radio
ERT	-	Electrical Resistance Tomography
EIT	-	Electrical Impedance Tomography
ECT	-	Electrical Charge Tomography
LBP	-	Linear Back Projection
EMT	-	Electromagnetic Tomography
MRI	-	Magnetic Resonance Imaging
Hz	-	Hertz
PET	-	Position Emission Tomography
NMR	-	Nuclear Magnetic Resonance
TV	-	Television
PCB	-	Printed Circuit Board
LV	-	LabVIEW
VI	-	Virtual Instruments
DDK	-	Driver Development Kit
NI	-	National Instrument
DAQ	-	Data Acquisition

CHAPTER I

INTRODUCTION

1.0 Introduction

Wilhelm Roentgen discovered x-rays in the year 1895, his discoveries contributed to the most important diagnostic methods in modern medicine. Since then, it is possible to look through into both non-living and living things without cutting the certain area of the subject by taking X-ray radiography (Ellenberger et al., 1993). This method of projection is far from being a perfect image of the real subject since the images were a superposition of all planes normal to the direction of X-ray propagation. In the 30's conventional tomography was the tomographic method using the X-ray radiation and gave possibility to restore information of 2D and 3D images (William and Beck, 1995).

The word ‘tomography’ is derived from the Greek words, where ‘tomo’ meaning ‘to slice’/’section’ and the word ‘graphy’ means image. In the year 1970 all the possibilities in the 30’s became true when this technique utilized the x-rays to form images of tissues based on their x-ray attenuation coefficients. However, this technique does not stop at the medical studies area and it was successfully developed into the industrial field and commonly known as the Industrial Process Tomography (IPT). This technique aims to measure the location concentration, phase proportions, and velocity measurement (Chan, 2003) retrieved from the quantitative interpretation of an image or, more likely, many hundreds of images corresponding to different spatial and temporal conditions using direct measurement/real time due to the dynamic changes of internal characteristic.

In general, process tomography is a field to investigate the distribution of objects in a conveying pipe by placing several sensors around the vessel without interrupting the flow in the pipe; to acquire vital information in order to produce two or three dimensional images of the dynamic internal characteristics of process systems. The output signal from the sensors will be sent to the computer via an interfacing system. The computer will receive the signal from the respective sensors to perform data processing and finally construct a cross-section flow image in the pipe through image reconstruction algorithms. With further analysis, the same signal can be used to determine the concentration, velocity and mass-flow rate profile of the flows over a wide range of flow regimes by providing better averaging in time and space through multiprojections of the same observation. Such information can assist in the design of process equipment, verification of existing computational modeling and simulation techniques, or to assist in process control and monitoring.

There are many parameters such as 2D and 3D images, velocity, and Mass Flow Rates (MFR) which can be retrieved from the tomography visualizing techniques within the processor or unit operation. Hence, the latter parameters give the information of the distributions of material in a pipeline. Therefore, from the knowledge of material distribution and material movement, a mathematical model can be derived and it can be used to optimize the design of the process (Tapp *et.al*, 2003).

1.1 Background of problems

Process Tomography has become one of the vast growing technologies nowadays The tomographic imaging of objects offers a unique opportunity to unravel the complexities of structure without the need to invade the object (Beck and Williams, 1996). It is a diversification from the original research on x-ray tomography, which focused on how to obtain 2-D cross-section images of animals, human, and non-living things (Syed Salim, 2003). Process Tomography can be applied to many types of processes and unit operation, including pipelines (Neuffer *et al.*, 1999), stirred reactors (Wang *et.al*, 1999), fluidized bed (Halow and Nicoletti, 1992), mixers, and separator (Alias, 2002). Process tomography is an essential area of research involving flow imaging (image reconstruction) and velocity measurement. For example in the research that was carried out by Ibrahim (2000), the Linear Back projection (*LBP*) algorithm which was originally designed for x-ray tomography was used to obtain the concentration profiles of bubbles in liquid contained in a vertical flow rig. This project investigated the two-phase flow (solid particle and air) using a vertical pneumatic conveyor flow rig.

Flow imaging usually involved obtaining images of particles and gas bubble (Yang and Liu, 2000) and the measurements can be either done using on-line (real time) or off-line. For on-line measurement, there are many performance aspects that must be considered such as hardware performance, data acquisition (signal interfacing), and algorithm performance. Limited numbers of measurement affect the quality of images obtained. The input channel of the data acquisition system has to be increased with the increase in the number of sensors used.

LBP algorithm is the most popular technique that was originally applied in medical tomography. Research conducted by Chan (2003) improved flow imaging using 16 alternating fan-beam projections with an image reconstruction rate of 20 fps, but this image reconstruction rate not is sufficient to achieve an accurate measurement of velocity. Generally, this project performed an investigation on how to improve the sensing method developed by Abdul Rahim (1996) which used fiber optics in flow visualization. Instead of using one light source, this project focused on using individual light source meaning one infra-red LED emitter for one photodiode. This method was then combined with an infra-red tomography system which consist of a hardware fixture, a signal conditioning system, and a data acquisition system by synchronizing the whole process operation.

Furthermore, image reconstruction in the spatial domain and frequency domain were investigated for this project. Generally, the information retrieved from the measurement system can be used to determine both the instantaneous volumetric and velocity of solids over the pipe cross section.

1.2 Problem Statement

Now days, various types of tomography pipeline are used in process, and it is mostly using harmful radioactive that might be effect the usage and also dangerous to handle. Not only that, the data can only be viewed offline which is also difficult to the user.

With this project, it changes from the offline to real time and makes it become friendly user to be operated. Furthermore this project is using infra-red based that is much cheaper compare with photodiode or phototransistor.

This process tomography system requires the knowledge of various disciplines such as instrumentation, process, and optics to assist in the design and development of the system. Generally, the solutions to the problems that were carried out in this project are:

- Development of a suitable sensor configuration for the selected infra-red emitter and receiver. Design of the fixture must be able to avoid the infra-red sensor from being exposed to any kind of ambient light (day light, lamp etc) and placed around the boundary of pipe so that light emitted from the emitter will be the only one that is in contact with the solid particle in the pipeline.

- Selecting the suitable signal conditioning and electronic controller. The characteristic of the component used will determine the whole measurement result, such as power consupmtion, offset current, input impedance, slew rate, and common mode input voltage range (Tan, 2002).

- Increasing the number of sensor measurement (32 pairs of infra-red transmitter and receiver for upstream and downstream planes). The number of measurement and projection angle subsequently affect the quality of the image reconstructed (Ibrahim, 2000).

- Synchronization of the data acquisition with the circuitry operation.

1.3 Objective of the Project

The objectives of this investigation are:

- To construct hardware and software for real time infra red based tomography system in order to obtain cross section profile of conveying pipe.
- To create a low cost and an unharmful tomography system.

1.4 Scope of study

The aim of the study is to investigate the image reconstruction in pipe due to dropping particles. The scope of study includes:

- Design and fabricate infra-red based signal conditioner circuit.
- Design and fabricate prototype of infra-red based tomography system with conveying pipe.
- Design and construct software to obtain cross section profile of flowing object inside the conveying pipe using LabVIEW.
- Integrate signals data from hardware and processing software via Data Acquisition System (DAQ) card in order to obtain cross section profile.

1.5 Methodology

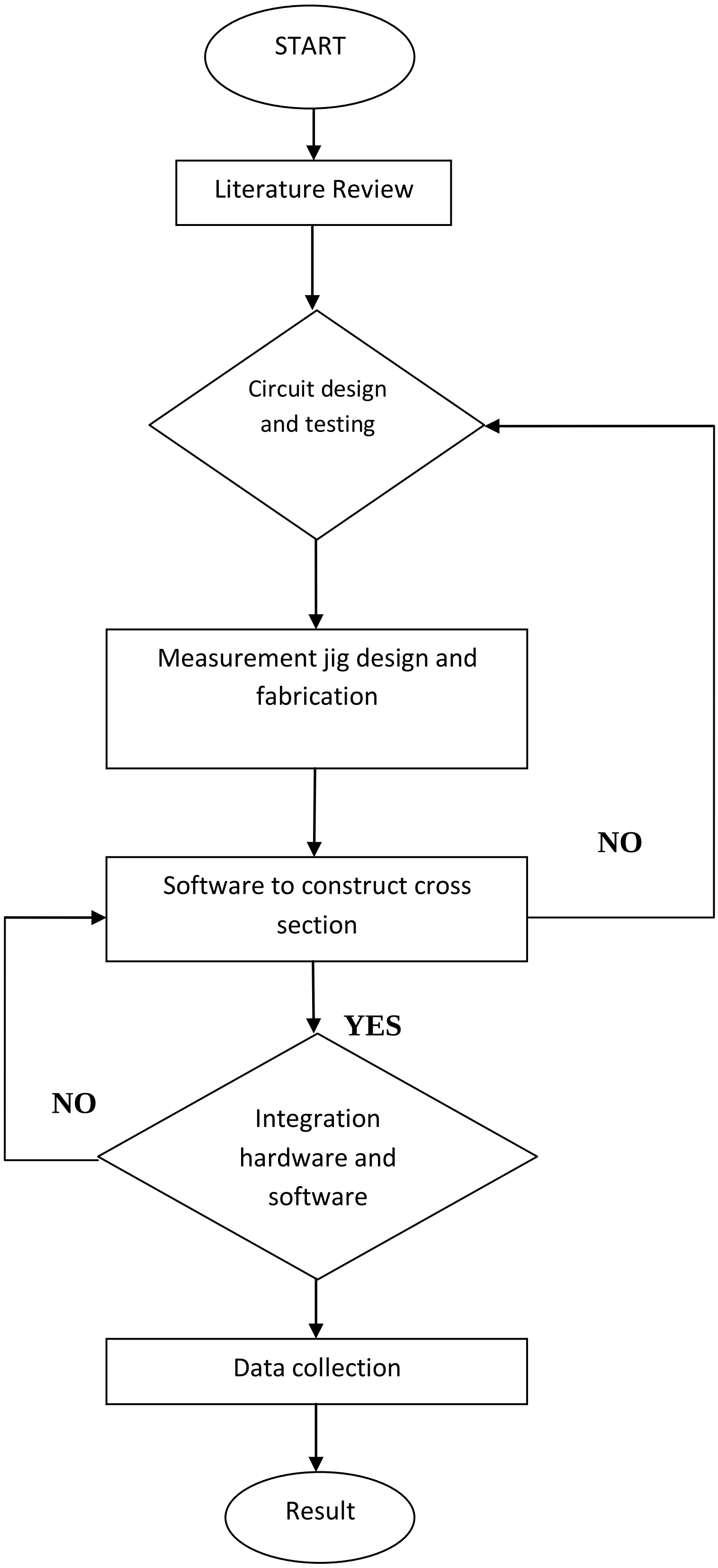

Figure 1.1: Flow Chart of Research Methodology

CHAPTER II

LITERATURE REVIEW

2.1.0 What is Process Tomography?

The use of "Process Tomography" is analogous to the application of medical tomographic scanners to examine the human body, but applied to an industrial process (tank, pipe, etc.) because there is a widespread need for the direct analysis of the internal characteristics of process plants in order to improve the design and operation of equipment. The computerized tomography (*CT*) methods used in medical imaging provide useful means for obtaining instantaneous information on distribution of components on a cross section of the pipe, and thus lead to the possibility of a much more accurate measurement (Beck *et al.,* 1986).

Process tomography can be applied to many types of processes and unit operations, including pipelines, stirred reactors, fluidized beds, mixers, and separators. Depending on the sensing mechanism used, it is non-invasive, inert, and,