LENS INTEGRATED LASER BASED OPTICAL TOMOGRAPHY SYSTEM WITH BACK-PROJECTION ALGORITHM

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In the name of Allah, Most Gracious, Most Merciful

To my beloved and supportive parent, brothers and sisters

To my beloved wife Rosliza Jusoh and beloved son,

Muhammad Zaim Hadif

for their love and support

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ABSTRACT

This research investigates the methods of implementing switch mode parallel beam projection technique into optical tomography instrument, and observes the effects of lens in optical system tomography. In addition, the research is focused on measuring the maximum size of phantom that can be captured for concentration profile. There are two types of sources that are used in tomography system which are high and low radiation sources. In this research, low radiation source is used as a medium to measure phantom inside the pipe. There are many types of components that produce light including the light-emitting diode (LED), infrared and laser. The tests are done using laser. Pipe has 100 mm inner diameter and the convex lens is applied in front of light component to change the angle of the transmitted light. The received light is captured by the sensor for further analysis to determine phantom inside the pipe region. Result shows that the optical tomography combine with lens is easier to manage the coverage of region. The results indicate that the proposed system is suitable for object application range between 8 mm to 80 mm.

ABSTRAK

Kajian ini lebih menekankan kepada kaedah ujuran selari diaplikasikan di dalam tomografi optik dan memerhatikan kesan kanta di dalam sistem tomografi optik. Kajian ini juga memberi fokus kepada kepekatan profil yang boleh dikesan di dalam sistem yang dibina. Terdapat dua jenis sumber yang boleh digunakan di dalam pembinaan sistem tomografi iaitu radiasi yang tinggi dan rendah. Kajian ini menggunakan kesan radiasi cahaya yang rendah dan radiasi tersebut tidak akan merosakkan subjek dan dinding paip. Terdapat banyak jenis komponen yang menghasilkan cahaya termasuk diod pemancar cahaya (LED), inframerah dan laser. Sumber cahaya laser telah digunakan dalam sistem ini. Paip dengan 100 mm diameter yang dipasang dengan kanta cembung yang diletakkan di depan komponen cahaya digunakan untuk menukar kadar sudut untuk sistem cahaya. Pengesan akan mengesan cahaya yang telah melepasi kanta di dalam kawasan paip dan menentukan objek di dalam paip. Keputusan menunjukkan bahawa tomografi optik dengan menggabungkan kanta lebih mudah untuk diuruskan dan mengawal ruang paip. Keputusan yang dihasilkan menunjukkan sistem yang dibina adalah sesuai untuk aplikasi objek bersaiz 8 mm hingga 80 mm.

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LIST OF ABBREVIATION

MRI	-	Magnetic Resonance Imaging
CT	-	Computed Tomography
NMRT	-	Nuclear Magnetic Resonance Tomography
PET	-	Positron Emission Tomography
ECT	-	Electrical Capacitance Tomography
ERT	-	Electrical Resistance Tomography
MIT	-	Magnetic Induction Tomography
LED	-	Light Emitting Diode
EIT	-	Electrical Impedance Tomography
DAS	-	Data Acquisition System
LBPA	-	Linear Back Projection Algorithm
LBP	-	Linear Back Projection
BEM	-	Boundary Element Method
FEM	-	Finite Element Method
HBR	-	Hybrid-Binary Reconstruction
ADC	-	Analogue to Digital Converter
VDC	-	Direct Current Voltage
VPP	-	Peak To Peak Voltage
RP	-	Rapid Prototyping
UART	-	Universal Asynchronous Receiver Transmitter
USART	-	Universal Synchronous Asynchronous Receiver Transmitter
DAQ	-	Data Acquisition
Tx	-	Transmitter

Rx	-	Receiver
HRA	-	Hybrid Reconstruction Algorithm
FEM	-	Finite Element Method
RS232	-	Communication device

LIST OF SYMBOLS

V_{LBP}	-	voltage distribution obtained using LBPA
$S_{Tx,Rx}$	-	sensor loss voltage of transmitter and receiver (Rx)
$MA_{Tx,Rx}(x, y)$	-	normalized sensitivity maps
Δz	-	distance
f_{test}	-	focal length
f_{ref}	-	focal length of the reference lens
$T(r)$	-	radial distance
t_o	-	Centre thickness
P	-	Power
f	-	Focal length
S	-	Object distance
S'	-	Image distance
V_{rx}	-	receiver voltage
V_{max}	-	Maximum voltage when there is no object
V_{drop}	-	voltage loss
d	-	Particle size in mm unit
n_{λ}	-	refractive index (first material)
N_{λ}	-	refractive index (second material)
μ	-	Attenuation Coefficient

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CHAPTER 1

INTRODUCTION

1.1 Introduction to Tomography

Tomography comes from the Greek words *tomo*, meaning “slice”, and *graph*, meaning “picture”; in other words, a tomography system builds the image from slices of pictures. Tomography is defined as radiography in the *Oxford English Dictionary*.

Tomography is a system that can be used to check a vessel or pipeline without removing parts of the pipeline system. The system is normally a combination of hardware and software; in other words, a complete tomography system has hardware connected to a computer (interface) [1-4]. The tomography hardware part includes the mechanical and electrical parts of the electronic environment, and to complete the system, the programming must be designed will connected with the computer and display the image inside the pipeline system collected by a transmitter and receiver component. Other than that, the tomography system must also use physics theory before the system component are decides to build. The role of physics theory in the system can be to detect the phantom inside the pipeline; in other words, the transmitter source are affected the material inside the pipeline, for example unexposed the material (phantom size are accepted by a system), or the transmitter source can penetrate the material (transparency) inside the pipeline and at the same time it not affect the phantom; for example the transmitter source can be block the phantom [5, 6]. As a result of the blocking situation collected by a pair of transmitter and receiver, a measurement are taken can be used to check the size and position of the phantom in pipe region. By using the tomography system, the system will able to check the phantom characteristics, which are the size, velocity, density, and others [6-11].

The tomography systems have many names. The name of the tomography system depends on the source used to operate the system. Other aspects considered when naming the system are the theory (source are used in the system) and the application of the system in a certain environment. Popular tomography systems are X-ray, Computed Tomography (CT) scans, Nuclear Magnetic Resonance Tomography (NMRT), Magnetic Resonance Imaging (MRI), Positron Emission Tomography (PET) scans, optical tomography, optical florescence tomography, optical coherence tomography, infrared optical tomography, ultrasonic tomography, resistance tomography, capacitance tomography, Electrical Capacitance Tomography (ECT), Electrical Resistance Tomography (ERT), ultrasonic tomography , and Magnetic Induction Tomography (MIT), among others.

This thesis will focus on optical tomography and it focuses mainly on the lens effect for a straight line light source, which means a laser light source. From the word “optical”, the first expectation is that a light source will be used. From that, the system uses a light source as a transmitter and a photodiode is assigned to collect the data.

1.2 Problem statement

According to light theory, light travels for the point into other point is very fast time at a speed of 3×10^8 m/s in SI units. The optical tomography uses a light source as a medium to measure the phantom inside the pipe without damaging the pipeline. The system will be able to cover the maximum area to obtain accurate data before processing the data and proceeding to the next process, which is the reconstruction of the image. Based on a previous study [12], optical tomography is used in medical environments. Fluorescent optical tomography requires high power to produce the light because of the fluorescent itself use the electrical component, compared to optical tomography, by using electronic components to produce the light for measurement. Ohm theory shows that the current will increase when the voltage increases. From that we can assume that the brightness of the light will also increase with the voltage and current. Other than that, the research also considers the density of light for its application in biological tissue and fruit tissue [13, 14].

Lens can be use to control the angle for example in an LED [11, 15-22]. There are many types of lenses, including convex lenses, concave lenses, and many more, depending on the shape of the lens, and normally the shape of the lens changes the line of light [23-25]. Simulation software shows that the line is changed after it penetrates the lens [12, 26].

1.3 Objective of research

The main objective of this research is to develop a sensor jig with a lens installed to convert the straight line light source to light with an angle and have specific diameter light beam. The specific objectives are addressed as below:

i. To investigate the methods of implementing the combination of switch mode fan beam projection and the parallel beam projection technique into an optical tomography instrument for flow measurement
ii. To review and investigate the effects of the lens in the optical tomography system.

iii. To develop real-time image reconstruction software for an optical tomography system combining fan beam and parallel beam projection system.

1.4 Scope of research

The scope of the research consists of the following sections:

i) Fixture design

Several considerations are required concerning the sensor's physical parameters, the sensor-placement geometry, the lens used, the light emission angle and light reception angle, the material and surface reflection effect of the sensor fixture, sensor fabrication techniques, wiring spatial, and cost. Numerous studies are required on mechanical drawing, light and material characteristics, sensor fabrication, and wiring techniques as well as the budget for the material.

ii) Sensor and associated circuit design

The considerations made in the circuit design include the received signal's parameters, the sensors' signal conditions, methods of signal representation and stabilization, selection of electronic components, analogue circuit and printed circuit board (PCB) layout designs, and the signals' condition to interface with the computer.

iii) A timing controller and a synchronized data acquisition system design are involved in the design of the digital timing and control, which are used to control the parallel beam source and to synchronize operation of the data acquisition system.

iv) The limitation of the system that it only 8 until 80 mm

1.5 Organization of the thesis

This thesis is divided into seven chapters. Chapter 1 presents an overview of the research project. It will start with the introduction, cover the background of the research problems, and explain the problem statement. The aim and objectives will give clearer information on the target of this study. Lastly, the significance of the research and its contribution are discussed.

Chapter 1 presents an introduction to the environment of the tomography process, the problem statement, the importance of the study, the research objective, and the scope of the research.

Chapter 2 presents a review of the literature on tomography systems and applications and lens theory.

Chapter 3 explains the hardware used to build the system, the design of the sensor jig, and the placement of the lens inside the sensor jig without affecting the focal point. it also explains about the software programming used for the system. The programming includes the hardware programming and image reconstruction. This chapter also discusses the linear back projection and the application of data collection. Other than that the position of the object used to take the measurement value. In this chapter, the sizes of the object are discussed.

Chapter 4 discusses the results of the experiment. The discussion includes the effect of the size and position of the object. The explanation of projection by applying a lens to a straight line light is clarified further in this chapter. Other than that this chapter also present the comparison parallel beam projection and fan beam projection

Chapter 5 presents the conclusion, limitation of system and recommendation future work.

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