IMAGING CONCENTRATION PROFILE USING LASER BASED TOMOGRAPHY

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ABSTRACT

This project describes an investigation of the use of laser based tomography in the measurement of concentration profile of flowing particles. The main purpose is to investigate the use of an optical tomography method for on-line monitoring of particles. The novelty of this method is that it can be used to provide cross-sectional image of material distribution i.e. the concentration profile. This image is formed by reconstruction of data obtained from the array of sensors. Images of the flow captured using optical sensors are digitized into a form suitable for computer processing of the flow pictures. The advantages of this method is that it is cheaper and safer than most of the current methods which mostly made use of radioactive methods. Various process industries such as petroleum and food processing can benefit from such invention to improve their products and reduce the amount of wastage. Laser diode was used as the light source and photodiode are used as the receiving sensor in this project. The laser beam will be passed through the cross sectional area of the conveyer pipe and the emitted light will strike the photodiode located across the pipe. Besides the hardware, this project will include the use of user friendly, Visual Basic program to visualize the concentration profile of the flowing particles.

ABSTRAK

Projek ini bertujuan mengkaji penggunaan laser untuk proses tomografi bagi mengenalpasti profil penumpuan untuk objek yang bergerak. Tujuan utamanya adalah untuk mengkaji penggunaan kaedah tomografi optik bagi kegunaan pengawasan partikel secara *on-line.* Keunikan kaedah ini adalah ia dapat memberi imej keratan rentas taburan bahan yang melalui satu paip penghantaran. Imej ini diperolehi melalui pemprosesan semula data yang diperolehi daripada jujukan *sensor* yang diletakkan di bahagian luar paip penghantar. Imej-imej bagi pergerakan partikel yang dikesan oleh *sensor* diubah kepada bentuk digital yang sesuai untuk diproses oleh komputer. Kebaikan kaedah ini adalah ianya lebih murah dan lebih selamat daripada kebanyakan kaedah yang digunakan kini yang mana kebanyakannya adalah menggunakan kaedah radioaktif. Beberapa industri pemprosesan seperti petroleum dan makanan boleh memanfaatkan hasil kajian ini bagi menambahbaik produk mereka dan juga pengurangan bahan terbuang. Bagi projek ini, potodiod digunakan sebagai penerima (*sensor*) dan sumber laser iaitu laser diod digunakan sebagai pemancar. Cahaya laser akan dipancarkan melalui keratan rentas paip penghantar dan cahaya yang dipancarkan ini akan mengenai potodiod yang diletak pada satu lagi bahagian yang merentasi paip tersebut. Sistem ini menggunakan dua ortogonal projeksi bersama 16 sumber laser diod. Selain dari perkakasan dan litar yang digunakan di atas, projek ini juga akan menggunakan program Visual Basic bagi tujuan penghasilan imej visual profil penumpuan bagi partikel yang bergerak tersebut.

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I	-	Transmitted intensity (Wm^{-2})
I_o	-	Initial incident intensity (Wm^{-2})
N	-	Thickness of the absorbing material (m)
μ	-	Linear absorption coefficient (m^{-1})
$V_{LBP}(x, y)$	-	Voltage distribution obtained using LBP algorithm concentration profile in unit volt) an $n \times m$ matrix where n equals to dimension of sensitivity matrix
$S_{Rx,Tx}$	-	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
$P_{\varnothing}$	-	Projection angle
x`	-	Detector position in x plane
f(x,y)	-	Coordinate (position) of real object
N	-	Total number of receiver
M	-	Total number of projections
$D_{Rx,Tx}$	-	Width of the light beam of *Tx-th* emitter to *Rx-th* receiver
$\alpha_{Rx,Tx}$	-	angle between the *Tx-th* emitter to *Rx-th* receiver
$m_{Rx,Tx}$	-	Slope of line from node *Tx-th* node to *Rx-th* node
d	-	Gap between the emitter and receiver which equals to 10 cm

$P_{(Tx8+1)}$	-	Coordinate for upper node of *Tx-th* node which consist of the x and y position
$P_{(Tx8-1)}$	-	Coordinate for lower node of *Tx-th* node which consist of the x and y position
$V_{refTx,Rx}$	-	Expected sensor voltage for projection *Tx-th* to receiver *Rx-th* during no particle flow condition in unit volt
V_{cal}	-	The calibration voltage (standardized voltage) to convert all modeling output to unit volt (V). The model assumes that it equals to 10 Volt.
$C_{MTx,Rx}$	-	the maximum number of line in the beam for light projection from *Tx-th* emitter to *Rx-th* receiver
D_{max}	-	Maximum width of the laser beam
$D_{uRx,Tx}$	-	width of the light beam of Tx-th emitter to Rx-th receiver being intersect by a single flowing object
F_{U} , F_{L}	-	Coordinate of the flowing object which have the longest perpendicular distance with light beam from T_x to R_x
$Vs_{Tx,Rx}$ (x',∅)	-	Amplitude of signal loss of receiver Rx-th for projection Tx-th
$V_{refTx,Rx}$(x',∅)	-	Reference signal of receiver Rx-th for projection Tx-th
$V_{Tx,Rx}$(x',∅)	-	Received signal from receiver Rx-th for projection Tx-th

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CHAPTER I

INTRODUCTION

As defined in one encyclopedia (Helicon 1991), the word “tomography” is derived from the Greek language, which t*omo* means “slice” and *graph* means “picture”. In another word, tomography is a method of viewing the plane section image of an object .

Process tomography provides several real time methods of viewing the cross-section of a process to provide information relating to the material distribution. This involves by taking numerous measurement from sensors which placed around the section of the process being investigated and processing the data to reconstruct an image. The process involves the use of noninvasive sensors to acquire vital information in order to produce two or three-dimensional images of the dynamic internal characteristic of process system. Information on the flow regime, vector velocity, and concentration distribution may be determined from the images. 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.

Process tomography refers to any tomographic method used to measure the internal state of a chemical process (e.g. material distribution in a reactor, multiphase flow fields in piping or concentration uniformity in mixers). By tomographic techniques, it can measure quantities such as the flow rate or solid concentration of material flowing through a pipeline and the distribution of material inside a chemical reactors or a mixer. This type of information is not usually obtainable with the sensor traditionally used by engineer, therefore these techniques gives a better understanding of the flow of material through the plant and the data can be used to design better process equipment and to control certain processes to maximize yield and quality. Basically, in a tomography system several sensors are installed around the pipe or vessel to be imaged. The sensor output signals depend on the position of the component boundaries within their sensing zones. A computer is used to reconstruct a tomographic image of the cross-section being interrogated by the sensors. Real time images can be obtained which measure the dynamic evolution of the parameters being detect at the sensors [1].

1.1 Tomography Overview

Process tomography involves the use of non-invasive sensors to acquire vital information in order to produce two or three dimensional images of the dynamic internal characteristics of process systems. 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.

At present, the usual objectives of using tomographic systems is to obtain concentration profiles of moving components of interest within the measurement section in the form of a visual image, which is updated at a refreshment rate dependent upon the process being investigated.

Basically, in a tomographic system several sensors are installed around the pipe or vessel to be imaged. A computer is used to reconstruct a tomographic image of the cross section being interrogated by the sensors [2]. The specific subsystem for flow imaging are shown in Figure 1.1 and described as follows :

1. The sensor and sensor electronics. The field sensing pattern of the sensors is also important, as it is related to the choice of image reconstruction algorithm.
2. The flow fields, which is assumed to be composed of two or more separate components. Since the flow pattern can change rapidly, fast data processing of the measured information at an acceptable cost is required.
3. Image reconstruction, which includes extraction of image characteristics and reconstruction of the image.
4. Image interpretation, to give the desired information on the flow, such as the instantaneous concentration of components from which volume flow rates can be calculated.

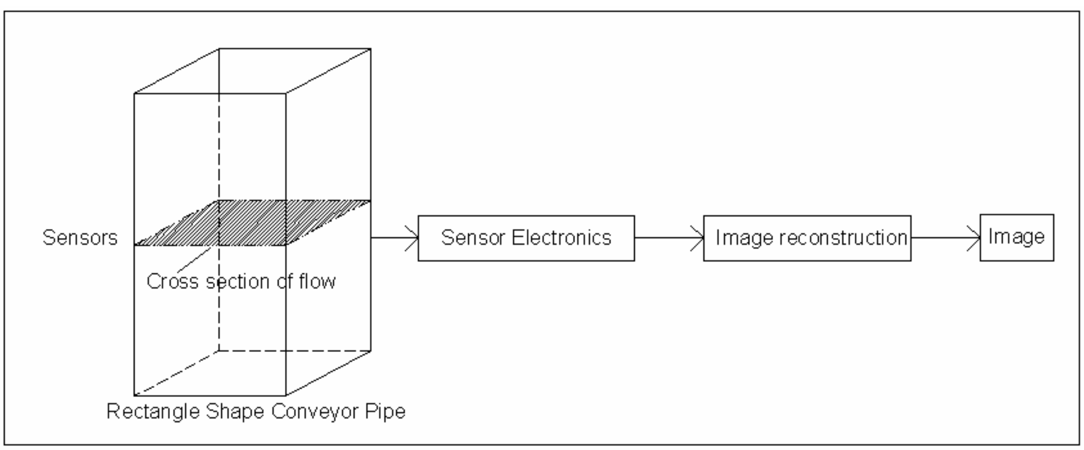

Figure 1.1 : Basic schematic diagram of tomographic system.

Basically, in a tomography system, several sensors are installed around the pipe or vessel to be imaged. The sensor output signals depend on the position of the component boundaries within their sensing zone. A computer is used to reconstruct a tomographic image of the cross section being interrogated by the sensors. Real time images can be obtained which measure the dynamic evolution of the parameters being detect at the sensor. And all that is required for a practical system is an image updated frequently enough for the smallest relevant feature of the flow to be observed [3].

1.2 Aims and Objectives of the Project

This project aims to investigate the use of tomographic measurement for on-line monitoring of two-component mixtures especially providing cross-sectional image of material distribution i.e. the concentration profile. The specific objectives of this project are :

1. To investigate the use of laser based tomography in measurement of concentration profile of flowing particles.
2. To search information regarding hardware fabrication techniques and the suitable optical sensor for measurement application.
3. To implement the using of laser diode laser as the transmitter or source.
4. To utilize photodiode as a detector.
5. To develop cross-sectional image using suitable software.
6. To measure the concentration profile and visualize an online image reconstruction using suitable software.

7. To interface the hardware & software system by using a suitable interfacing card.
8. Propose improvement & solution for the problem for future investigation.

1.3 Thesis Outline

This thesis consists of six chapters. Chapter 1 gives the introduction of the system, overview of process tomography, aims and objectives of the project and the thesis outline.

Chapter 2 provides literature review of this project. It includes the introduction about tomography, type of tomography system and type of projection can be used in tomography process. It also gives brief explanation about this project.

Chapter 3 illustrates some ideas about the emitter and receiver being used in this project.

Chapter 4 is the explanation about methodology of this project, start from the theory of the laser based tomography, overview hardware feature, signal conditioning circuit and the software development on image reconstruction.

Chapter 5 presents the process of hardware modeling and fabrication steps. It also discussed about emitter and receiver circuit and also brief explanation about the measurement steps.

Chapter 6 draws the conclusion of the whole project. This chapter also contains the suggestions for future improvement.

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