IMAGING CONCENTRATION PROFILE OF MULTIPHASE FLOW BY USING INFRARED BASED TOMOGRAPHY

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ABSTRACT

Optical tomography is one of the methods of process tomography, which is less expensive, has a better dynamic response and is more portable for routine use in process plant than other radiation-based tomographic methods. This project aim to implement infrared (IR) sensor arrange in orthogonal beam projection based tomography for measurement of concentration profile of multiphase flow. The flow being used in this project consists of water and bubbles flow. The image is formed by reconstruction of data obtained from the array of sensor. Then the data will be converted into voltage readings in signal conditioning circuit. The data acquisition system is to collect and digitalize the analog system from the sensor input which is manipulated by a computer in off-line mode. Finally, imaging of tomogram is visualized on computer processing used by Visual Basic 6.0 software.

ABSTRAK

Tomografi optikal adalah satu cara dalam proses tomografi dimana ia lebih murah, mempunyai tindak balas dinamik yang lebih baik dan boleh digunakan di dalam pelbagai proses berbanding radiasi yang lain berasaskan kaedah tomografi. Projek ini bertujuan menggunakan penderia infra merah dalam susunan orthogonal untuk mengukur tumpuan bentuk daripada gabungan aliran. Alirann yang digunakan di dalam projek ini terdiri daripada air dan aliran gelembung. Imej ini akan ditunjuk dengan membina semula daripada data yang dipeolehi daripada susunan penderia. Kemudian, data ini akan ditukarkan kepada bacaan voltan melalui litar penukaran isyarat. Sistem data perolehan digunakan untuk mengumpul dan digitaliskan masukan analog daripada sistem penderia dimana ia dimanipulasi oleh komputer di dalam cara *'off-line'*. Akhir sekali, imej tomogram akan dipaparkan kepada computer dengan menggunakan perisian Visual Basic 6.0.

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LIST OF ABBREVIATIONS

PCB	-	Printed Circuit Board
IR	-	Infrared
IC	-	Integrated Circuit
DAS	-	Data Acquisition System
LBP	-	Linear Back Projection
LED	-	Light Emitter Diode
VB	-	Visual Basic

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CHAPTER 1

INTRODUCTION

1.1 Process Tomography

The challenge of the efficient design and flexible operation of many industrial manufacturing processes is coupled closely to the availability of high-quality information concerning their actual internal state. Many process systems are incompletely understood or are designed for operation under specific conditions or with particular grades of raw materials [3].

Process tomography is an emerging imaging technique which encapsulates a wide variety of sensor types, design principles and performance goals [6]. This technique still in its infancy, but it has potential for enabling great improvement in efficiency and safety in process industries, while minimizing waste and pollution in a range of applications. It can be used to obtain both qualitative and quantitative data needed in modeling a multi-fluid flow system. In tomography, multiple projection are used to obtain sets of data from various views (typically, across a pipeline or a process vessel). These data are used to provide tomographic images representing the content of the pipeline or vessel. The tomographic imaging of objects provides an opportunity to unravel the complexities of structure without invading the object [5].

Process tomography involves the acquisition of measurement signals from sensors located at the periphery of an object. To construct cross-sectional image, the sensor signals are amplified, filtered, digitized and finally be processed in a computer using certain image reconstruction algorithm. Normally, most of the flow information is based on the cross-sectional image. For example, the cross-sectional image itself already provides flow material's concentration. On the other hand, hundreds set of upstream and downstream images can provide flow velocity when correlation function is applied in this case. As a result, process tomography will provide an increase in the quantity and quality of information when compared to many earlier measurement techniques [7].

Basically, tomography system has several sensors are installed around the pipe or vessel to be imagined. A computer is used to reconstruct a tomographic image of the cross section being interrogated by the sensor. The specific subsystem for flow imaging describe as follows:

i. The sensor and sensor electronic. The field sensing pattern of the sensor is important, as it is to the choice of image reconstruction algorithm.
ii. 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.
iii. Image reconstruction, which include extraction of image characteristics and reconstruction of the image.
iv. Image interpretation to give the desired information on the flow such as instantaneous concentration of components from which volume flow rated can be calculated.

1.2 Aim and Objective of the thesis

This project aim is to implement infrared (IR) sensor arrange in orthogonal beam based tomography in measurement of concentration profile of multiphase flow. The specific objectives of this project are:

1. To construct a system based on tomography by using IR that able to get structure for one process or flow in Industrial with combined the software and hardware part.
2. To design a system that can measure of concentration profile and display it using by Visual Basic 6.0 software.

1.3 Problem Statement

The challenge of the industry is the cost of manufacturing and purification of the products. Considerable capital and operational investment is required to manufacture a relatively small volume but highly effective product. It is difficult measurement if two or more phases present in flow process. The end of result, a product has lower quality, lower productivity, or low data collection. With this project, the measurement will become faster, easily and quality.

1.4 Scope project

The scope of this project consists of two parts:

i. Hardware

This part is focus of development for sensor circuit and signal conditioning circuit. These circuits are used 16 pair of infrared and the output of voltage will transfer to data acquired system (DAS card) and displayed on computer.

ii. Software

Visual Basic 6.0 software is used in this project to obtain the tomogram and perform calculation by using Linear back projection algorithm.

1.5 Organization of the thesis

This thesis consists of five chapters. Chapter one is an introduction to process tomography and multiphase flow.

Chapter two mainly discusses the literature review. It consists of several sensing mechanisms such as capacitance, ultrasonic and optical tomography.

Chapter three presents methodology of the project. The process and procedure are discussed here.

Chapter four presents the results of concentration measurement for a range of bubble flow.

Lastly, chapter five discusses the conclusion from this project and makes suggestions for future work.

CHAPTER 2

LITERATURE REVIEW

2.1 Basic of tomography

Tomography is one process or technology to provide cross-sectional profile for one process or flow. A typical optical tomography system consists of a sensor, an electronic circuit, a data acquisition system, and a host computer as data processing and display unit. For the developed system, the block diagram of Figure 2.1 is applied.

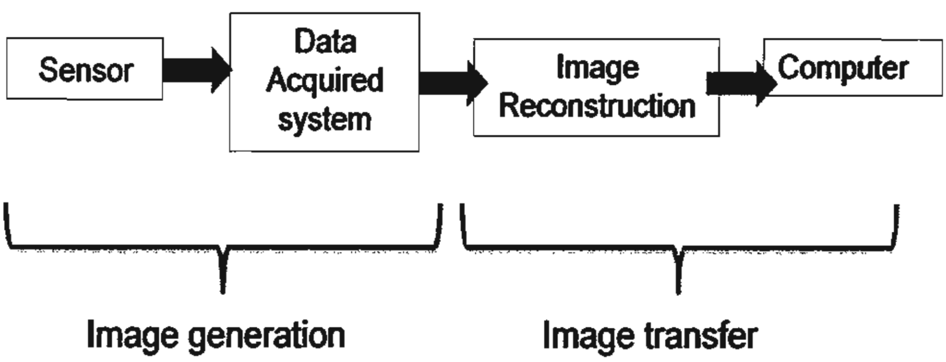

Figure 2.1: The tomography system

The design of a tomography system process depends on how the measurement is made. The benefit of process tomography as below:

i. Can be unravel the complexity of a structure without invading the object
ii. Can be obtain exact information of the internal flows in the process equipment
iii. The process can be lead to the approximation of the mass flow rate measurement.

In optical tomography system, the two types of sensor arrangement techniques that have been investigated and applied to measure gas/solid flows are parallel beam projection and fan beam projection. For parallel beam projection, the number of emitter and receiver are the same. Each pair of transmitter-receiver is arranged in a straight line and the received signal only corresponds to its emitter source. While for fan beam projection, the number of emitters and receivers can be unequal. The fan beam projection technique provides a higher resolution system compared to the same number of sensors used in parallel projection due to high obtaining information [6]. However, it has the weakness like hard to model the sensitivity map of each sensor projection in forward problem and a longer time to reconstruct the cross-sectional image compared to parallel beam projection technique.

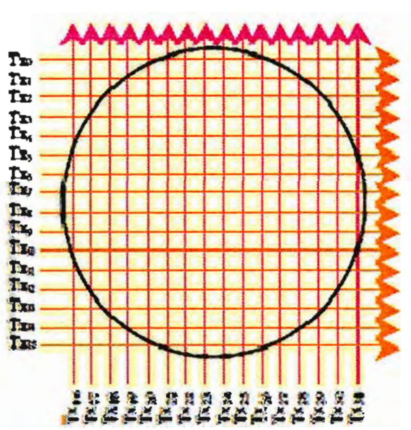

Figure 2.2: Two orthogonal projection

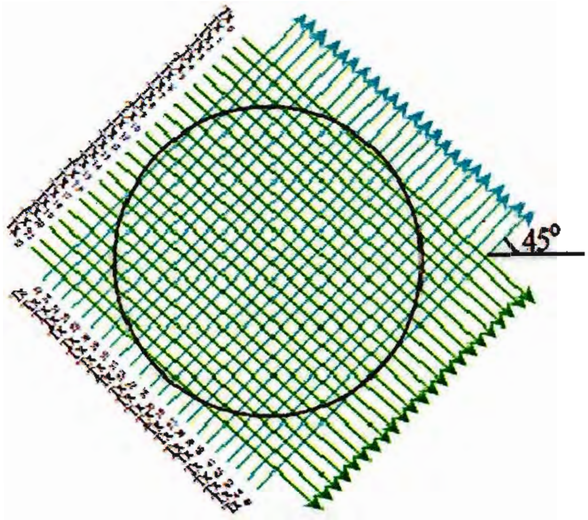

Figure 2.3: Two rectilinear projection

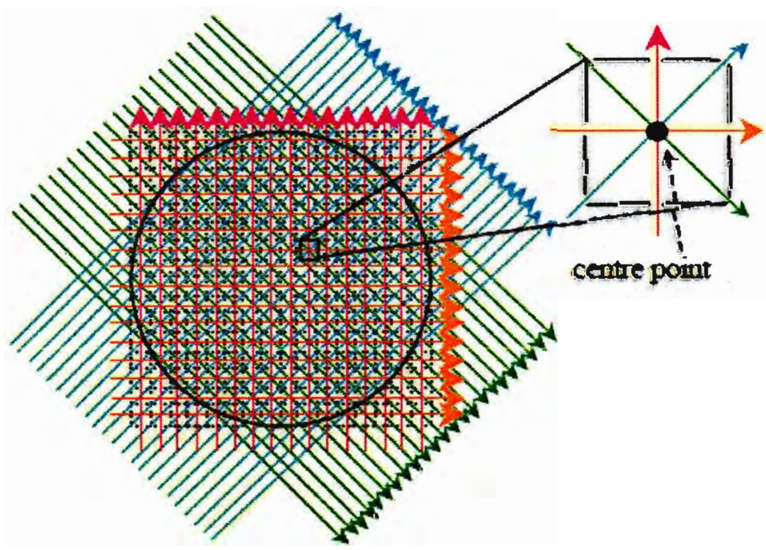

Figure 2.4: Combination of two orthogonal and two rectilinear projections

2.2 Sensor of tomography system

For a specific application, the sensor modality will be the most critical design choice, since it must be sensitive to the variations of interest in the process and offer suitable noise properties. The choice of a particular technique is usually dictated by many, often contradictory factors. These include the physical properties of the process, the desired spatial and temporal resolution of imaging, cost of the equipment, its physical dimensions, human resources needed to operate it and the potential hazards to the personnel (e.g.,radiation) [3].

2.2.1 Electrical Capacitance Tomography

In an electrical capacitance tomography (ECT) system, a number of electrodes are mounted around the process of interest. These electrodes can be mounted either inside or outside the vessel depending on the wall material and the conveying fluid. The measured capacitance between two electrodes depends on the dielectric constant of the medium in between. The changes in the capacitive value are due to the variations in the permittivity of the material inside the process vessel.

ECT is suitable for imaging industrial multi-component processes involving non-conducting fluids, but it is difficult to obtain accurate quantitative information. The electrode length required to provide measurable capacitances means that its resolution is limited and it result in 'smearing' and 'averaging' effects. It cannot produce meaningful images when the conveyed component loading decrease below approximately 5% due to the relatively low signal to noise ratio of the capacitance to voltage transducer and non-uniform sensing fields [5].

Where the process contents of interest are non-conducting, an ECT instrument can image the 2D or 3D permittivity (ε) distribution by sensing the capacitance between electrodes mounted in the boundaries of the subject. Typical examples of measurement subjects here include minerals in liquid and solid forms, such as oils and powders. Specific designs have been proposed to enhance performance in term of speed of data acquisition, sensitivity and low noise [3].

2.2.2 Electrical impedance tomography (EIT)

EIT stands for Electrical Impedance Tomography and these measure both resistive and capacitive components of materials. This allows discrimination of conducting materials to be differentiated based on their properties. For example organic material in suspension has a significant capacitive component and can be differentiated from ionic nutrients.

EIT is a novel imaging technique with applications in medicine and process control. Compared with techniques like computerized x-ray tomography and positron emission tomography, EIT is about a thousand times cheaper, a thousand times smaller and requires no ionising radiation. In the medical field, the most studied applications for EIT are measurement of gastric emptying and lung function. In the industrial field typical applications are imaging the distribution of oil and water in a pipeline and imaging the flow of substances in a mixing vessel. In some ways industrial applications are more favorable for EIT because it is usually possible to use a rigid, fixed array of electrodes. The fixing of electrodes on the human body is one of the residual problems facing medical EIT [9].

The accuracy of the technique is restricted by its complexity in sensor modeling, noise reduction and image reconstruction. The limited number of measurements and presence of electrical noise cause difficulties in obtaining solutions. Additionally, the applied electrical field are 'soft' so that the complex (e.g iterative) reconstruction algorithms may be needed to reduce image distortion [5].

2.2.3 Ultrasonic tomography

Ultrasound waves are acoustic waves of the order of 1 to 100MHz wherever there is an interface between one substance and another, the ultrasound wave is strongly reflected. Ultrasound has been successfully used for ocean tomography at the scale of hundreds of kilometers [5].

Ultrasonic process tomography is potentially useful for imaging process where difference in object density and elasticity offer the most significant sensing