CHAPTER 1

INTRODUCTION

1.1 Introduction to Process Tomography

The word "tomography" is derived from Greek language, "Tomo" means cutting section and "Graph" means picture. Tomography is a field of interdisciplinary that is concerned with obtaining cross-sectional images of an object. Therefore, the tomography process can be defined as a process of obtaining plane section images of an object (Williams and Beck, 1995). Figure 1.1 illustrates the process of obtaining the reconstructed cross-sectional image of a pipe in process tomography.

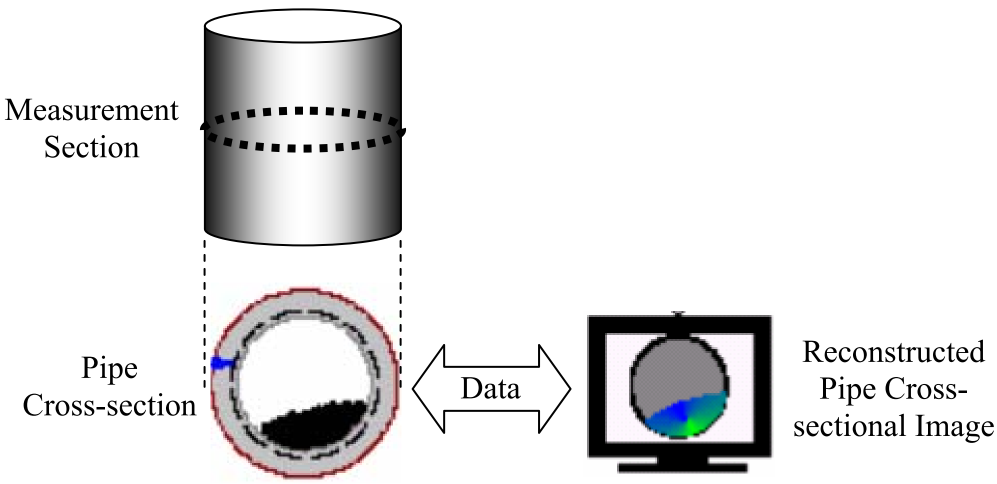

Figure 1.1: Overview of process tomography.

Process tomography had been widely used in the medical field. The important factor featured by this process is the ability of unraveling the complexities of a structure without invading the object. Furthermore, this method is able to explore the spatial distribution of the contents of a process vessel in an intrinsically safe manner and non-invasively (Sallehuddin *et. al*, 2000). Due to that fact, numerous sophisticated medical equipments were designed by applying this method such as Magnetic Resonance Imaging (MRI), Computed Tomography Scans (CT) and Positron Emission Tomography (PET). These equipments are very expensive due to the application of sensors that are capable of producing high-resolution image with high accuracy.

The tomography was first applied in industrial field in the middle of 1980's. The tomography system can increase the productivity and the efficiency of a process that uses material transportation through pipes such as in oil industry. Pipes flow visualization is often to be the first step in experimental analysis in order to improve the pipe flows and performs the process control. This makes the tomographic measurement becomes more important in industrial process nowadays (Williams and Beck, 1995).

A full understanding of process behavior requires knowledge of the direction of material movement as well as its distribution. The ability to interrogate the dynamic internal characteristics of a process plant by using conventional instrumentation is severely limited for most practical conditions (S. Ibrahim *et al.*, 2000). Tomography provides several real-time methods of obtaining the cross-section of a process to obtain information relating the material distribution. This involves taking numerous measurements from sensors placed around the section of the process being investigated and processing the data to reconstruct an image. Tomography can be used to provide feedback information on the process for the objectives of process control.

Optical tomography is an attractive method since it may prove to be less expensive, have a better dynamic response, and more portable for routine use in process plant than other radiation-based tomographic methods such as positron emission, nuclear magnetic resonance, gamma photon emission and x-ray tomography. Its performance is also independent of temperature, pressure and viscosity of fluid (S. Ibrahim *et al.*, 2000).

A simple tomography system can be built by mounting a number of sensors around the circumference of a vertical pipe or horizontal pipe. Multiple projections are used to obtain sets of data from various views across the process vessel. These data are used to provide tomographic images representing the contents of the pipeline or vessel.

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. The tomographic imaging of objects provides an opportunity to unravel the complexities of structure without invading the object (Dyakowski, 1995).

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 multi-projections of the same observation. Tomography will provide an increase in the quantity and quality of information when compared to many earlier measurement techniques (Abdul Rahim, 1996).

Process tomography is a technique still in its infancy, but it has the potential for enabling great improvements 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.

1.2 Background Problems

The main objective of this project is to develop an infrared optical tomography system which is able to capture cross-sectional image of solid flow inside the pipeline. Several researches had been carried out to investigate the performance of optical process tomography in obtaining the data from the process pipeline. The accuracy of the image obtained is dependant on the number of sensors used and the projection technique applied. Parallel beam projection technique produced limited number of data obtained and may had a problem with beam convergence and aliasing effect. A research conducted by Soh in 2000 had proved that such problems may be minimized with the application of fan-beam projection technique. The technique will produced a significant number of data and this will improve the accuracy of the image obtained (R. Abdul Rahim et al., 2004b)

Regarding the optical sources used in the measurement, numerous researches had been carried out to investigate the feasibility of using visible light source in many projection techniques. Unfortunately, the application of the previous mentioned light sources are very limited. For example, the application for measuring the opaque liquid tends to give erroneous result due to the flow residue that will block the beam. Even though the residue is in form of thin film, it is sufficient to block any visible light from being transmitted. To solve this problem, the infrared light source is preferable. It overcomes the above mentioned limitation.

1.3 Problem Statements

Optical tomography involves projecting a light beam through some medium from one boundary point and detecting the level of light received at another boundary point (Ruzairi, 1995). This procedure provides information from which a profile of the flow can be gained. In practice, several projection views are required to minimize aliasing effect that occurs when two particles intercept the same view (Saeed, 1988).

The optical sensor emission implemented with switch mode fan beam projection is a new investigation in process tomography. The first implementation of switching principle with optical sensors for tomography research had been carried out by Dugdale in year 1992 in parallel beam optical tomography projection (Ruzairi, 2004b). The research has followed by Soh in 2000 to investigate the divergence effect of optical beam to an array of optical receivers. The initial stage of her research has shown that with switching principle implemented with two pair of optical sensors, four independent measurements obtained. The fan beam projection has proved to provide higher efficiency of measurements from the same number of optical sensors compared to parallel beam projection system. 'Fan beam' is a term used when a series of angular projections of the light sources and detectors are applied to interrogate the measurement section.

This project will utilize a switch-mode fan-beam projection technique which consists of 4 pairs of infrared optical sensors. There are several factors that must be considered during the project implementation such as:

i) To develop a process tomography system that is applicable to perform a fan-beam projection, the suitable sensor should be selected considering on the wavelength of the emitter-receiver pair and the projection angle of the emitter. The emitter should be able to project a light beam to every receiver during data acquisition process.

ii) Since infrared wavelength possessed high electromagnetic energy, several experiments will be conducted to investigate the effect of the infrared beam to the sensing system itself such as the reflection effect and the penetration limit. Further experiments will be performed to investigate the effect of the surrounding towards the system performance such as the effect of the infrared signal that is emitted by other objects.

1.4 Significance of Study

1) Numerous researches had been carried out to investigate the interior condition and changes of the substances being conveyed inside the pipeline or process vessels. In this project, a non-invasive instrument to perform real-time image reconstruction process has been realized.
2) There are several numbers of researches had been carried out on optical process tomography. This project utilized infrared beam as a sensing system for a pipeline having a diameter of 50 mm. The response of infrared tomography system has been identified.

1.5 Objectives

1) To obtain an online concentration profile of solid particles conveying in a pipeline.
2) To apply the switch mode fan beam projection technique in order to increase the optical sensor ability in imaging the solid conveying system.
3) To investigate the response of employing infrared sensors in optical process tomography.

1.6 Scope of project

1) To construct a small-scale flow rig consists of a pipeline with a diameter of 50mm for system evaluation.
2) To build an image reconstruction algorithm in order to display the concentration profile of the solid particles in a pipe.
3) To develop an application program to display the concentration profile of the solid.

4) To interface between the hardware and software to realize the real-time application.

1.7 Organization of the Thesis

Chapter 1 introduces the process tomography. Background problems, problem statements, importance of the study, research objectives and scope of the study are presented here.

Chapter 2 mainly discusses the literature review that is related to this research. It consists of the introduction to process tomography, the significance of developing the system and some historical review about the evolvement of the process. Typical sensors used in process tomography are also discussed. The chapter content is basically give prior attention to the optical tomography system. Readers are presented with the techniques previously applied and some techniques that are still at ongoing research. The application of process tomography is very rare in our country but yet it has been applied to several applications elsewhere. In this chapter, some examples of the application were reviewed to provide the readers with some knowledge of applied tomography.

Chapter 3 discusses on the hardware development process where the criteria of the sensors are presented. This chapter also gives an explanation about the development process started from drafting to the precautions taken in order to minimize the error that may affect the data taken.

Chapter 4 gives a thorough explanation on software development stage. This includes the modeling of the process, the algorithm flowcharts and some presentation of the developed software.

Chapter 5 presents the results obtained from the experiments done on the developed system. The results obtained are discussed and a conclusion was drawn based on the analysis. Several experiments had been carried out in order to investigate the system performance in many aspects such as the accuracy of the system, the environmental effect towards the system performance and to identify the limitation of the system.

Chapter 6 contains the conclusions from this project and some suggestions for future work and development are given in order to improve the system ability.