A TOMOGRAPHY IMAGING SYSTEM USING TWO TYPES OF SENSORS

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ABSTRACT

Process tomography is a technique to realize flow imaging in a process vessel or pipeline by using the sensor system. This technique involves using tomographic imaging methods to manipulate data from sensors in order to collect sufficient information about the flow in the pipeline. This project is about the construction of a simple imaging system using two types of sensors namely optical sensors and electrodes (forming electrodynamic sensors) with halogen bulbs as light sources. These sensors complement each other. The images from both sensors can be analyzed to determine the precise distribution of objects in the pipe. The sensors are suitably arranged around an 80mm x 80mm x 40mm transparent square pipe. The amount of sensors must be sufficient so that the accuracy and resolution of the image is good. The more sensors used the better as it enhanced the resolution and provide an accurate image of the object distribution. The sensors are connected to simple signal conditioning circuits which are then linked to a data acquisition system (DAS). The DAS is then connected to a computer which then displays the images of objects flowing in a pipe detected by the system.

ABSTRAK

Proses tomografi adalah suatu teknik untuk mendapatkan imej aliran dalam sebuah paip atau talian paip menggunakan system penderia. Teknik ini melibatkan penggunaan kaedah-kaedah pengimejan tomografi untuk memanipulasi data daripada penderia-penderia untuk memungut maklumat yang secukupnya tentang aliran dalam paip. Projek ini adalah tentang pembinaan system pengimejan ringkas menggunakan dua jenis penderia yakni penderia optik dan elektrodinamik (yang membentuk penderia elektrodinamik). Lampu halogen menjadi sumber cahaya. Penderia-penderia ini saling melengkapi antara satu sama lain. Imej-imej daripada kedua-dua penderia boleh dianalisis untuk menentukan agihan yang jitu tentang objek dalam paip. Penderia-penderia diatur dengan sesuai di sekeliling paip segiempat 80mm x 80mm x 40mm yang transparen. Bilangan penderia mesti secukupnya supaya ketepatan dan kebezajelasan imej adalah elok. Lebih banyak penderia yang digunakan adalah lebih baik kerana ia menguatkan kebezajelasan dan mendapatkan imej yang tepat tentang agihan objek. Penderia-penderia itu disambung ke litar-litar penyesuaian isyarat yang ringkas yang disambungkan ke system perolehan data (DAS). DAS disambungkan ke sebuah computer yang kemudian memaparkan imej-imej objek yang mengalir dalam paip yang dikesan oleh system.

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CHAPTER 1

INTRODUCTION

1.1   Process Tomography

There are various definition ns for the word 'Tomography'. The word is derived from the Greek words; 'Tomo' which means 'to slice' or 'cutting' section, and 'Graph' that means 'image' or 'drawing'. The Oxford English defines tomography as: Radiography in which an image of a predetermined plane in the body or other object is obtained by rotating the detector and the source of radiation in such a way that points outside the plane giving a blurred image. Most people associate tomography with complex systems which are used to obtain images of internal parts of the human body. The development of tomography instrumentation started in 1950's, and has led to the invention of a number of imaging equipments for processes in the1970's. The concept of tomography is not restricted to the medical field only, but exceeded to include industrial applications, where tomography has been developed, over the last twenty years, to be a reliable tool for imaging various industrial applications, such as chemical, oil, gas, food processing, biomedical, pharmaceuticals, and plastic products manufacturing. This field of application is commonly known as Industrial Process Tomography (IPT) or simply Process Tomography (PT). In addition to the use of tomography in the medical and industrial fields, it is also used in the fields of archaeology, biology, geophysics, materials science and other sciences. In most cases it is based on the mathematical procedure called tomographic reconstruction.

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 multi-projections of the same observation. Such information can assist in the design of process equipment, verification of existing computational modelling and simulation techniques, or to assist in process control and monitoring.

Currently, there are several tomography techniques available for studying complex multiphase phenomena. These include for example, infrared, optical, X-ray and Gamma-ray tomography systems, positron emission tomography (PET), magnetic resonance imaging (MRI), and sonic or ultrasonic tomography system. Although 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 modelling a multi fluid flow system.

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 other than 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).

The electrodynamic models basically relate the charge on a particle to the voltage on a sensor. These models are developed based on the fact that many flowing materials pick up charge during transportation, primarily by virtue of friction of fine particles amongst themselves and abrasion on the wall of the conveyor.

Although charge generation on solids is well know from electrostatics, it is not generally possible to calculate the magnitude of charge generated solely based on the properties of the material and the process in which it is involved.

However, it is known that the magnitude of charge generated depends on different parameters. It has been established that the magnitude of charge acquired by solids depends upon the moisture content of the atmosphere, the particles size distribution and the velocity with which the particles move and/or impinges onto surface.

1.2   Project background

Process tomography provides several methods of obtaining the concentration profile of a process. It has become one the vast growing technologies nowadays, and it can be applied to many types of processes and unit operation, including pipelines, stirred reactors, fluidized beds, mixers, and separators. Depending on the sensing mechanism used, it is non-invasive, inert, and non-ionizing.

The main target of this project is to develop a tomography system by using optical sensors with two halogen bulbs as light sources for visualization of solid flow, the extracted results then will be compared with the results obtained from electrodynamic sensors on the same process. Several researches had been carried

out to investigate the performance of 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 (Soh, 2000) had proved that such problems may be minimized with the application of fan beam projection technique. The technique will produce a significant number of data and this will improve the accuracy of the image obtained (R. Abdul Rahim et al., 2004b)

For this project, the image reconstruction is based on Linear Back Projection (LBP) algorithm. The LBP algorithm was originally designed for x-ray tomography, and then became the simplest and most common used in image reconstruction.

Flow imaging measurements can be either done using on-line (real time) or off-line. For on-line measurements, many performance aspects must be considered such as hardware performance, data acquisition system, and algorithm performance. The quality of images obtained depends on the number of sensors used in measurements. The input channel of the data acquisition system has to be increased with the increase in the number of sensors used.

1.3   Problem statement

Nowadays, various pipes and vessels are used in process, and it is difficult to know what type of flow is inside them. Systems have to be developed whereby the controller is able to view objects within these pipes without interrupting the flow.

The 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.

The way around this problem would be to place sensing electronics around the actual pipe or vessel, where the system having two types of sensors; eg optical and electrodynamic enable comparison to be made. By using these sensing electronics, we are able to take measurements and recreate an image of what is contained within. Electronics of this nature needs to be created such that it is affordable and easy to operate. A voltage-to-current converter is used to inject the input current source, while other pairs of electrodes are able to pick this up and convert this signal into a voltage measurement. Various types of voltage-to-current converters need to be built, implemented and tested for suitability and sensitivity. Thereafter, a synchronous detection systems needs to be tested together with the voltage-to current converter via the sensing electrodes.

This project to investigate the process tomography, and how can be used to construct an image of a solid object in a transparent square pipe. In selecting the appropriate optical sensor, the characteristics of the light source and sensor must be investigated. Based on this, the transmitter, receiver and signal conditioning circuit of the system will be designed and realized physically. The signal conditioning circuit will be combined with the data acquisition system. Image reconstruction will be done using MATLAB.

The process involves projecting a light beam through some medium from one boundary point and detecting the level of light received at another boundary point. The Electrodynamic transducer was constructed by using a copper rod as a sensor in order to detect the electrostatic charges of the flowing objects through the pipe.

1.4   Objective of the Project

   i.   To search for material about the optical and electrodynamic sensors and hardware fabrication.

  ii.   To design and implement signal conditioning circuits that are effective for receiving and processing the signals.

 iii.   To understand the image reconstruction algorithm.

 iv.   To obtain data for image reconstruction.

  v.   To display the concentration profiles for object flow using MATLAB Software.

 vi.   To analyze the data so as to understand the flow regimes.

1.5   Scope of work

In order to achieve the aim of this project, that is to investigate the flow regimes (image reconstruction) due to dropping particles in pipe based on tomography concept, the scope of this project need to be understood, where it includes the following points:

   i.   Familiarization with the operation and performance of electrodynamic and optical tomographic systems.

  ii.   Construct an 80mm x 80mm transparent square pipe for system evaluation.

 iii.   To design an electrodynamic system and an optical system prototype that can be used to measure the solid object flow.

 iv.   To design, construct, and test signal conditioning circuits to process the signals obtained from sensors.

  v.   Compare images from electrodes and optical tomography data.

vi.   Reconstruction of cross sectional images by using MATLAB Software in order to determine the concentration profiles of the solid object flowing inside the pipe.

1.6   The Thesis Outline

The layout of this report is as follows:

Chapter 1 gives a brief introduction to process tomography. Next, project background, problem statements, objective of the project and scope of the study are presented in this chapter.

Chapter 2 mainly discusses the literature review that is related to this study. It consists of an overview of process tomography, the significance of developing the system and a historical review about the evolvement of the process. Typical sensors used in process tomography are also discussed. This chapter provides a brief insight on the optical and electrodynamic tomography systems.

Chapter 3 describes the hardware development process which includes the fabrication of a transparent pipe to house the fibre optic cables and sensors, the specification of the optical sensor and the design of the signal conditioning circuits in order to obtain vital output signal.

Chapter 4 gives a thorough explanation on software development. This includes the modelling of the process, the sensitivity models of optical and electrodynamic sensors and a description 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.

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.

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