# FLOW REGIME IDENTIFICATION OF PARTICLES CONVEYING IN PNEUMATIC PIPELINE USING ELECTRIC CHARGE TOMOGRAPHY AND NEURAL NETWORK TECHNIQUES

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# ABSTRACT

A plastic beads (solid particles) flow in a pipeline is a common means of transportation in industries. Monitoring and controlling materials flow through the pipeline is essential to ensure plant efficiency and safety of the system. The pipeline transportation used in this project makes use of electrodynamic sensors which are charge to voltage converters. The process flow data is captured fitting an array of 16 sensors around the circumference of the pipe to capture the inherent charge on the flowing solid materials. A high speed data acquisition card DAS1800HC is used as the interface between the sensors and a personal computer which processes the data. A Radial Basis Function (RBF) neural network based flow regime identifier program is developed in Matlab environment. Baffles of different shapes are inserted to artificially create expected flow regimes and data captured in this way are used in training and evaluating the network's performance. The results of this work show significant improvments, the dataset which was check as the input gave good results, especially for full flow, three quarter flow and inverse quarter flow are 100%, and 95% has been succeed for each of quarter flow inverse three quarter flow and inverse half flow, and for the others flow regimes (center half and half flow) 90% succeed.

# ABSTRAK

Aliran zarah pepejal mengunakan saluran paip merupaksan salah satu medium pengangkutan biasa di dalam industri. Pemantauan aliran bahan-bahan yang melalui saluran paip adalah penting untuk memastikan kecekapan dan keselamatan sistem. Pengangkutan saluran paip yang digunakan di dalam kajian ini menggunakan pengesan elektronik yang menukar cas kapasitor kepada voltan elektrik. Data melibatkan aliran zarah pepejal direkodkan mengunakan 16 jenis pengesan elektronik (sensor) yang berbeza. Pengesan-pengesan elektronik ini disusun disekeliling paip. Kad perolehan data berkelajuan tinggi DAS1800HC digunakan sebagai kad antara muka di antara pengesan elektronik dan komputer peribadi yang memproses data tersebut menggunakan Algoritma unjuran linear kembali (Linear Back Projection Algorithm -LBPA) dan Algoritma unjuran belakang yang ditapis (Linear Back Projection Algorithm - FBPA). Program pengesan rejim aliran berasaskan Rangkaian Neural (Neural Network) beteraskan Fungsi Asas Radial (Radial Based Function - RBF) telah dibangunkan mengunakan Matlab. Sesekat tiruan dengan bentuk yang berbeza dimasukkan untuk mewujudkan rejim aliran yang dijangka dan data yang diperolehi dengan cara ini telah digunakan dalam melatih dan menilai Program pengesan rejim aliran. Hasil eksperimen berdasarkan dataset ini memberi keputusan yang baik, terutamanya bagi aliran penuh, aliran tiga suku dan aliran songsang adalah 100%. Keputusan 95% telah berjaya diperolehi untuk aliran tiga suku songsang dan aliran 1/2 songsang. Manakala bagi aliran rejim lain, keputusan diperolehi ialah 90%.

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| | | |
|---|---|---|
| **RBF** | - | **Redial Basis Function** |
| **IPT** | - | **Industrial Process Tomography** |
| **PT** | - | **Process Tomography** |
| **PC** | - | **personal computer** |
| **ECT** | - | **Electrical Capacitance Tomography** |
| **OT** | - | **Optical tomography** |
| **OFPT** | - | **Optical Fiber Process Tomography** |
| **GA** | - | **Genetic Algorithm** |
| **ECHT** | - | **Electrical Charge Tomography sensor** |
| **DAS** | - | **The Data Acquisition System** |

| | | |
|---|---|---|
| **LBPA** | **-** | **Linear Back Projection Algorithm** |
| **FBPA** | **-** | **Filtered Back Projection Algorithm** |
| **ART** | **-** | **Algebraic Reconstruction Technique** |
| **ANN** | **-** | **Artificial Neural Network** |
| **RBF** | **-** | **radial basis function** |

# CHAPTER 1

# INTRODUCTION

## 1.1 An overview of process tomography

The word tomography is derived from the Greek word tomos which means section, while the word graphy means image. According to the Oxford English Dictionary, the word tomography can be described 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 give a blurred image"( R A William et al, 1995)

This description is based on the new technique in diagnostic medicine during the early 1970s by utilizing X-rays to form images of tissues based on their X-rays attenuation coefficient. Over the last decade, the concept of tomography imaging was not restricted to medical field only; it has been successfully developed into a reliable tool for imaging numerous industrial applications. This field of application is commonly known as Industrial Process Tomography (IPT) or simply as Process Tomography (PT). However, techniques of tomography used in the industry and medical fields are different from each other due to the different aim of application. Normally medical tomography aims to measure the location of objects in space, while process tomography aims to measure the location concentration, phase proportions, and velocity of movement.

The use of process tomography is not limited to only obtaining cross-sectional image of processes. It can also be used to obtain mass-flows rate or volume flow rates and velocity profiles. Depending on the mechanism of the process tomography sensor can be used in processes involving solids, liquids, gases and any of their mixtures.

For process tomography, direct analysis and measurement of the internal characteristics of process plants in real time are carried out. A number of sensors are placed around the peripheral of a process vessel, pipeline, and multiplexed. By using a data acquisition system, the signal is converted to digital signal and fed into a computer in which a cross-section of the measured parameter will be reconstructed to produce images of concentration and movement of the components in the process vessel. Measurements are reconstructed to form two or three dimensional images, providing information to monitor processes and improving yields, quality, efficiency, and overall control. Process tomography can be applied to many types of processes and unit operations, including pipelines, stirred reactors, fluidized beds, mixers and separators.

Electrical tomography is one of the most investigated fields in process tomography. It is non-invasive, cost effective, safe and easy to implement technique. Electrical charge tomography is a system used in imaging particulate flow in pipelines using Electrodynamic sensors (charge-to-voltage transducer).It’s a passive transducer where the field is generated by the flowing solid particles.

The motivation for using Electrodynamic sensors as the sensing device in tomography arises from 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 walls of the conveyor.

Based on the above fact Electrodynamic sensors can be used to measure the charge on the flowing materials and convert it to voltage so that spatial information of the flowing material in the cross-section of the conveyor could be obtained.

In this project, 16 Electrodynamic sensors are fitted around the circumference of the conveying pipe to sense the inherent charge on the flowing particles. Each Electrodynamic sensor detects the charge on the flowing particles in its sensing zone and converts the detected charge into electrical signal (Small voltage) level. In the same manner all the 16 Electrodyanmic sensors yield the level of sensed signal. The signals from the array of Electrodyanmic sensors are filtered and amplified to a level suitable form for data acquisition system. The data acquisition system then converts the simultaneously captured data to a digital format. The data acquisition system is used as an interface between the sensors and the personal computer (PC) used in data storage and processing. These data are then manipulated using image reconstruction algorithms techniques to obtain tomography images in an offline method. The flow data are used in obtaining concentration. An overview of process tomography block diagram is shown in Figure 1.1.

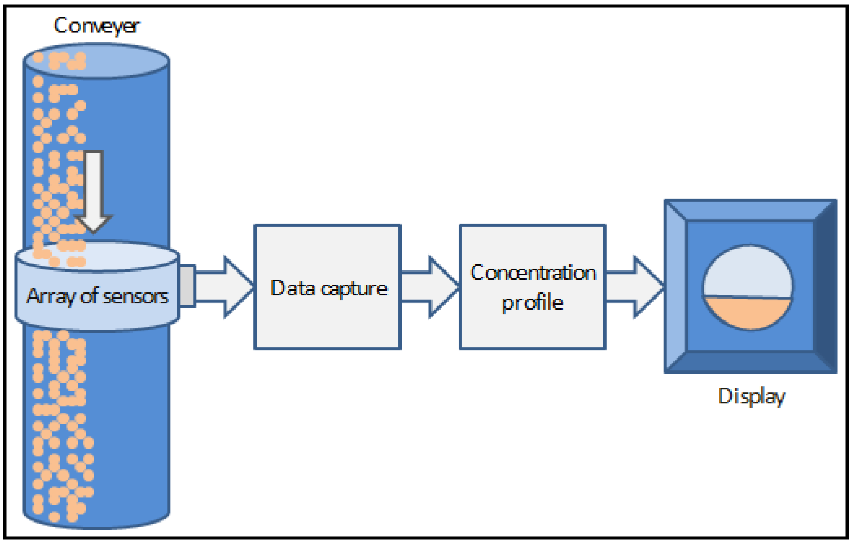


**Figure 1.1:**An overview of Process Tomography System

## 1.2 Problem statement

The Electrodynamic sensors are excellent in sensing flowing materials in close proximity to their location. However, when flowing material are far-off from the sensors location their accuracy diminishes. To improve this accuracy, there is the need to reconstruct the tomograms. This is done using the linear back projection image reconstruction algorithm.Another image reconstruction algorithm called filtered back projection algorithm can also be used and both methods give good accuracy of the image of flowing material.

In this project 16 Electrodynamic sensors will be used to detect flowing material with a view to using the above mentioned algorithms to improve the accuracy of the tomograms.

## 1.3 Objectives

1) To measure voltage around the circumference of the pipeline using 16 Electrodynamic sensors and to capture the data.
2) To identify flow regimes in pneumatic pipeline using Electrodynamic sensors and neural network techniques.
3) To verify the flow regime using image reconstruction algorithms.

## 1.4 Scope of Work

The scopes of the project are:

1) To study the strategy of process tomography.
2) To reconstruct image of the flowing particles in the conveyer pipe.
3) Identify 8 different types of flowing particles.

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