FLAME IMAGING USING LASER - BASED TRANSMISSION TOMOGRAPHY

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Especially for my lovely husband, Omar Mohd Faizan, my dearest son, Muhammad Hafiy Darwis , my family and friends...

"My Success Is Yours Too"

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ABSTRACT

This project describes an investigation of a flame imaging system using Laser-Based Tomography. The main purpose is to obtain the concentration profile of the flame to be incorporated in Laser-based transmission tomography measurement system for combustion on-line monitoring. The system can be applied to produce cross sectional images of flame such as that in a combustion chamber. Such a system can be employed to compare the effectiveness of different fuel additives and to monitor the onset of knock with various fuel formulations or cylinder head geometries. The ability to monitor the size, position and velocity of flame fronts in any combustion behavior and emissions. The concentration of this project is to determine the position and velocity of flame fronts in the pipeline by using photodiode (BPX 65) as sensor and Helium Neon Laser as laser sources. Laser will emit to pipe and the emitted light will strike to the photodiode through optical fiber as carry the laser light sources. To completely expand the laser light, the emitted light will collimated by a lens as is passes through the pipe walls. The system employs two orthogonal projections with one laser source. The laser source will supply 12 light beams, so the cross section of the pipe being interrogated by a total of 12 beams. In this case, we assume that the flame is placed in specific places in the measurement cross section and voltage output will calculated by the individual sensor is modeled. Besides the hardware, this project will include an interface user friendly, Visual C++ to visualize the concentration profile of the flame

ABSTRAK

Projek ini adalah berkisar berkenaan penyelidikan ke atas sistem merekabentuk imej api menggunakan tomografi berasaskan laser. Matlamat utama adalah untuk mengenalpasti profil penumpuan api bersama pengukuran tomografi berasaskan penghantaran laser bagi pempaparan pembakaran secara online.Sistem ini boleh digunakan untuk penghasilan imej keratan rentas api sebagaimana di dalam relau atau kebuk pembakaran. Sistem seperti ini boleh diimplimentasikan bagi tujuan mengesan perbezaan diantara kadar aliran minyak di dalam pelbagai pefomulasian minyak atau silinder geometri. Berkeupayaan untuk menentukur saiz, kedudukan dan kelajuan cahaya api bagi mana-mana pembakaran atau penyalaan. Projek ini bertumpu kepada untuk mengenalpasti kedudukan dan kelajuan cahaya api di dalam aliran paip dengan menggunakan pengesan potodiod (BPX 65) dan laser helium sebagai sumber pemancar. Laser akan dipancarkan ke dalam aliran paip dan cahaya yang dipancarkan ini akan dikenakan ke atas potodiod menerusi fiber optik. Untuk pencapahan cahaya laser , cahaya yang dipancarkan oleh laser akan dicapahkan dengan lensa terlebih dahulu sebelum dihantar ke paip. Sistem ini menggunakan dua ortogonal projeksi bersama satu sumber laser. Laser akan membekalkan 12 pancaran cahaya, maka keratan rentas di dalam paip akan ditentukur oleh 12 pancaran cahaya. Di dalam kes ini api akan di tempatkan dalam kedudukan yang tetap dan voltan keluaran akan di tentukur oleh setiap pengesan atau sensor yang direkabentuk. Selain dari perkakasan, projek ini merangkumi perisian Microsof Visual C++ untuk memaparkan profil penumpuan ke atas api.

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LIST OF ABBREVIATIONS/SYMBOLS

P_{ϕ}	-Projection angle
x'	-detector position in x plane
f(x,y)	-coordinate(position) of real object
N	-Total num of receiver
M	-Total num of projections
$D_{Rx,Tx}$	-width of the light beam of *Tx-th* to *Rx-th*
$\alpha_{Rx,Tx}$	-angle between *Tx-th* emitter to *Rx-th* receiver
$m_{Rx,Tx}$	-Slope of line from node *Tx-th* node $(P_{Tx\times6})$ to *Rx-th* node $(P_{Rx\times6+4})$
d	-diameter of pipe which equals to 60mm in this project.
$(P_{Tx\times6+1})$	-coordinate for upper node of Tx-th node which consist of the x and y position
$(P_{Tx\times6-1})$	-coordinate for lower node of Tx-th node which consist of the x and y pos
$V_{refTx,Rx}$	-expected sensor voltage for projection *Tx-th* to receiver *Rx-th* during non-flow condition in unit volt.
V_{cal}	-the calibration voltage (standardization voltage) to convert all modeling output to unit volt (V). The model assumes that it equals to 5Volt.

$C_{MTx,Rx}$	-the maximum number of line in the beam for light projection from *Tx-th* emitter to *Rx-th* receiver
$D_{Tx,Rx}$	-the unblocked width of the laser beam from *Tx-th* emitter to *Rx-th* receiver
$D_{\max}$	-maximum width of the laser beams
$Vs_{Tx,Rx}(x',\phi)$	-Amplitude of signal loss of receiver *Rx-th* for projection *Tx-th*
$V_{refTx,Rx}(x',\phi)$	-Reference signal of receiver *Rx-th* for projection *Tx-th* .
$V_{Tx,Rx}(x',\phi)$	-Received signal from receiver *Rx-th* for projection *Tx-th*
$\hat{f}(x,y)$	-approximation of the object functions in volt
$Vs_{Tx,Rx}(x',\phi)$	-amplitude of signal loss of receiver from Tx to Rx view that is equal to projection data
$S_{\phi}(x,y)$	-normalized sensitivity map for each projection
ϕ	-the projection angle
$\Delta\phi$	-receiver position
x'	-angular distance between projection and the summation extends over all the M-th projection

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CHAPTER I

INTRODUCTION

1.0 Discovery of Process Tomography

Normally the output of a flowmeter tell user how much material has passed through the meter in a certain time, either as a volume (amount/quality) flowrate (e.g ; liters per second) or as mass flowrate (eg; tonnes per hour). The measurement of flowrate may then be integrated to give the total amount of material delivered.

Now day, many industrial use mixture of product pumped along pipes (combination product). For example, in manufacturing process particulate materials (plastic, grain, catalysts) are blown along pipes by compressed air or pumped in liquid, but the only way to measure the amount delivered is to separate the components and meter them individually or to fill some sort of tank or vessel and measure the volume or weight of that product in the tank. The limitation is not inherent to the pumping mechanism, it is simply that the technology for measuring the flowrate is not available. So the lack of flowmeter technology for these application may adds to the cost of the operation considerably (extra piping, valves, tanks and weighing mechanism) and interferes with the process flow.

Process tomography is a method of measuring the internal density (quantity of mass per unit) distribution within process pipes and vessel. Its can be divided in to various type of tomoflow [1]

1.1 Definition of Tomography

Industrial processes are often controlled using "simple" process measurements (such as temperature, pressure, flow rate or level) at one more points in the process flow sheet. The amount of information contained is such measurement is minimal and in some cases (such as multiphase flow) there are no adequate sensors. In order to develop a better understanding of certain chemical processes, a more sophisticated approach is needed. Such an approach is provided by the interdisciplinary field of process tomography, which combines recent developments in sensor technology with tomography reconstruction techniques.

Tomography is an interdisciplinary field concerned with obtaining cross-sectional, two-dimensional images of three-dimensional objects. Its beginnings date back to 1917, when Radon demonstrated that any N-dimensional object can be "reconstructed" from an infinite number of (N-1) dimensional "projection". Such projections are analogous to ordinary radiographs, which "collapse" a 3-D object onto a 2-D image. By combining a large number of these radiographs, it is possible to determine the 3-D internal structure of the object. [2]

As defined in one encyclopedia (Helicon 1991), the word "Tomography" is derived from Greek language, *Tomo* means "slice" and "graph" means picture. In another word tomography is a method of viewing the plane section image of an object Tomography system is that doesn't have to slice nor cut through the object of interest, the word *tomo* (slice) to obtained to cross-sectional image of the object of interest .This devices used a computer to reconstruct the image from projection data, a technique now known as Computed Tomography (CT).

1.2 Technical Description of the Process

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 non-invasive 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 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 reactor 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.

In this study, the main purpose is to reconstruct the image of the internal flows in the pipeline and display it while online as the concentration profile over a cross section by using photodiode as sensors. In this project a narrow laser light is emit through the cross-section area of pipe to a receiver, by using a fiber optic as transmitter and photodiode as a receiver then the amplitude of the received light is compared with the amplitude of light that achieved with no obstruction in the light path for the same sensor. The intensity of the transmitted beam is measured by the detector and the transmittance is the ratio of the transmitted intensity to the original beam intensity. The ratio of light attenuated will be use to construct the cross-section image in the pipe. The resolution of such system is limited by the physical number of the components used as light transmitter and receiver. This will deeply discuss in the methodology part.

1.3 Aims and Objectives of the Project

1. Understand the basic concept of process tomography system for on-line visualization on the pipeline flows.
2. Modeling the whole system of the process including the fabricating, structuring and arrangement of the system.
3. To implement the fiber optic to be incorporated in Laser-based transmission tomography measurement system.
4. To implement the Helium-Neon laser as the transmitter or laser source.
5. To understand basic concept of photodiode as a detector, how its works and the sensitivity to be implemented in the system.
6. Designing the transmitter and receiver circuit.
7. To produce cross sectional images of flame such as that in a combustion chamber
8. Measuring the concentration profile and visualize an online image reconstruction using software, Visual C++.
9. Know the implementation and the effectiveness of the project.
10. Propose the solution from the forward problem to be used in the future investigation and improvement.

1.4 Scope of the study

The objectives of this investigation are:

1. To investigate the concept of process tomography
2. To study the interaction between the collimated laser light sources that are emitted to the detectors with the targeted images of flame (through the pipe), to be incorporated in laser-based transmission measurement
3. To investigate the reconstruction of flame imaging.
4. To understand the designing of the transmitter, receiver and the signal conditioning circuit for the process
5. To understand the concept and the characteristic of laser and photodiode sensor
6. To display the image reconstruction using software, Visual C++
7. Incorporating the signal conditioning (circuitry operation) with the data acquisition system by synchronized the signal conditioning with the data sampling processes
8. To analyze, verify and compare the result

CHAPTER II

LITERATURE REVIEW OF TOMOGRAPHIC TECHNOLOGY

2.0 Introduction of Technology

Process tomography actually started in the medical field when the development was used to obtain tomograms of animal and the human body. From an engineering point of view, the major difference between medical tomography imaging and process tomography imaging is that the former involves objects of interest often in the form of non-stationary flow material, and the latter takes into account the speed of the flowing material.[3]

2.1 Tomographic Imaging Process

Tomographic techniques vary widely in their instrumentation and applications, all of them can be characterized by a common two-step approach to the imaging process ; firstly gather projection data based on some physical sensing mechanism, then reconstruct a cross sectional image from the projections. The term "projection" has a specific meaning in tomography which a projection can be visualized as type of radiography of the process vessel.[4]

2.1.1 Projection Data

In tomography, that many projections are needed to reconstruct the interior volume or cross-section of an object. Projections actually can be refer as sensor arrangement .In practical systems, there are two types of projection that have been investigated and applied to measure gas/solid flow, which is parallel projection and fan beam projection. For parallel projection, the number of emitter and receiver are the same. Each pair of trans-receiver is arranged in a straight line and the receive signal only correspond to its emitter source, while for fan beam projection, the number of emitter and receivers can be unequal [5]. Nevertheless, 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 several projections are needed to reduce aliasing which occurs when two particles intercept the same view.[6]

However from the both method its can be illustrated into a various techniques of arrangement which all of that has been widely investigated to implement into flow imaging of conveying system .The various arrangement can be illustrated in to six types of projection, there are [7] :-

(a) Two orthogonal projections (figure 2.0)
(b) Two rectilinear projections (figure 2.1)
(c) Three rectilinear projections (figure 2.2)
(d) A combination of two orthogonal and two rectilinear projections (figure 2.3)
(e) Three fan-beam projections (figure 2.4)
(f) Four fan-beam projections (figure 2.5)

Figure 2.0 – 2.5 shows the types of sensor arrangements of parallel projection and fan beam projection.

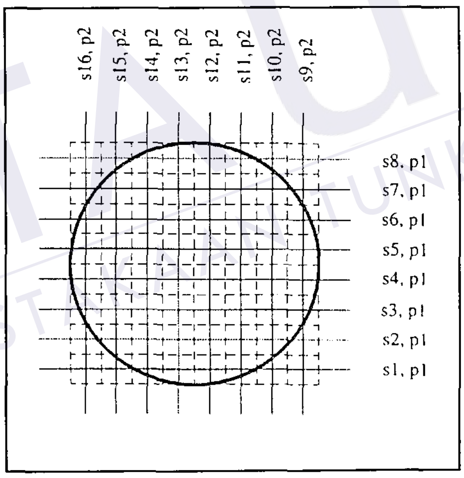

Figure: 2.0: Two Orthogonal projections

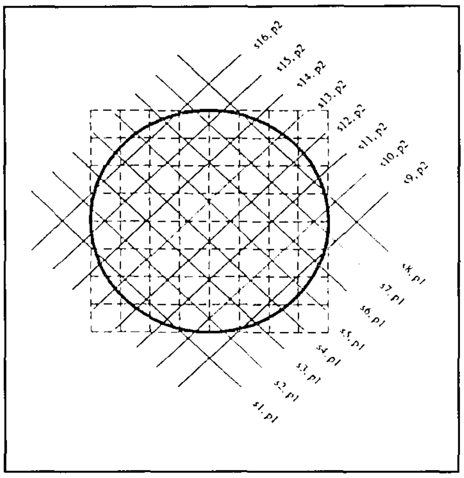

Figure 2.1:Two rectilinear projection

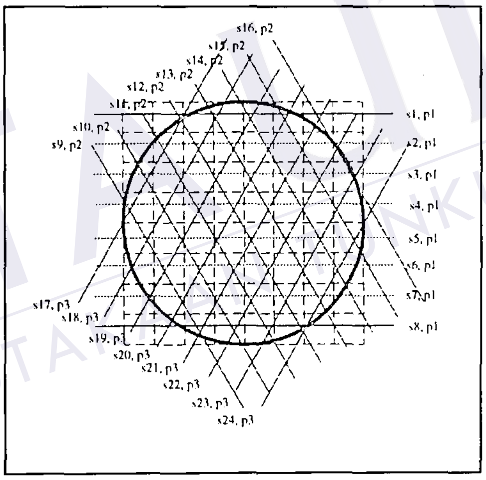

Figure 2.2: Three rectilinear projections

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