

Charge coupled device based on optical tomography system in detecting air bubbles in crystal clear water

Juliza Jamaludin ^{a,b}, Ruzairi Abdul Rahim ^{a,*}, Herlina Abdul Rahim ^a,
Mohd Hafiz Fazalul Rahiman ^c, Siti Zarina Mohd Muji ^d, Jemmy Mohd Rohani ^e

^a Process Tomography and Instrumentation Engineering Research Group (PROTOM-i), Infocomm Research Alliance, Faculty of Electrical Engineering, Universiti Teknologi Malaysia, 81310 UTM Johor Bahru, Johor, Malaysia

^b Faculty of Science and Technology, Universiti Sains Islam Malaysia, 71800 Bandar Baru Nilai, Negeri Sembilan, Malaysia

^c Tomography Imaging Research Group, School of Mechatronic Engineering, Universiti Malaysia Perlis, 02600 Arau, Perlis, Malaysia

^d Faculty of Electrical and Electronic Engineering, Universiti Tun Hussein Onn Malaysia, 86400, Parit Raja, Batu Pahat, Johor, Malaysia

^e Sondotech Sdn. Bhd, 31, Jalan Mutiara Emas 5/1, Taman Mount Austin, 81100 Johor, Malaysia

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ABSTRACT

Optical tomography is one of the tomography methods which are non-invasive and non-intrusive system, consisting of emitter with detectors. Most of the available detectors systems are intrusive where sensors or probes need to be placed within the analyzed processes and this will create disturbances in the current processes. This research are conducted in order to analyze and proved the capability of laser with Charge Coupled Device in an optical tomography system for detecting air bubbles exist in crystal clear water. Experiments in detecting moving air bubbles are conducted. The images of captured data are reconstructed based on filtered image of Linear Back Projection with Hybrid algorithms. As a conclusion, this research have successfully developed an optical tomography system that capable to capture the image and measure the diameter and velocity of rising air bubbles in a non-flowing crystal clear water.

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1. Introduction

Multiphase detectors are important instrumentation in industries for the purpose of monitoring and analysis of objects behaviour in process system. Multiphase flow consists of two or three phases in one flow system. Gas, liquid and solid have different physical properties and move in different velocities [1].

Petroleum refining system, textile and fabric industries, oil and gas pipeline system, geothermal wells, steam generation in boilers and burners, and steam condensation deals with two phase flow which is in form of gas bubbles and liquid [1]. Engineers need to monitor the condensation process or the distribution of steam bubbling to avoid any damage that occurs in the high cost and high maintenance of their system. The existence of miniature gas bubbles of hydrocarbon for example, will affect the temperature and viscosity of flowing mixture. The increasing number of smaller bubbles will form an elongated Taylor's bubble. As a result, the surrounding liquid will be pushed by the gasses to the sides of the

pipe wells and damage the system [1]. In geothermal well processing system, increasing of water temperature will cause an increase in the number of air bubbles. Unfortunately, it will affect the fluid pressure. Therefore, continuous monitoring by engineers is very important [1].

Gas percentage in liquid medium, gas flow rate, appearance and disappearance of gasses, shape of gasses, and their diameters are imperative information for monitoring and process control. Generally, the wall of pipeline and vessel system are opaque. So, available gas detectors are intrusive and invasive technique such as impedance probe, optical fibre probe, ultrasound Doppler and isoknetic probe. For non-intrusive and non-invasive techniques, the examples of gas bubbles detector are pressure transducer, gamma ray density gauge technique, laser technique and tomography technique. Certain tomography technique such as Electrical and Ultrasonic tomography can deal with opaque wall but give low resolution of image results [2]. But, for Optical Tomography (OPT), they required a transparent section at the pipeline system and give high image resolution [2]. OPT has the advantages of hard field sensors [3] where the sensor does not depend on the changes of conductivity or permittivity of subjects that are being analyzed. OPT system provide a good spatial resolution where it can capture a very details image without making the pixels visible. Spatial

* Corresponding author.

E-mail addresses: lieza_ju@yahoo.com (J. Jamaludin), ruzairi@fke.utm.my (R.A. Rahim), herlina@fke.utm.my (H.A. Rahim), hafiz@unimap.edu.my (M.H. Fazalul Rahiman).

resolution refers to the number of pixels being utilized in a digital image. Greater number of pixels composed in an image will let the pixel square shape invisible [4]. OPT also provides a high speed data capturing system and it is suitable for online monitoring system applications [4].

The aim of this research project is to build an OPT system using the combination of Charge Coupled Device (CCD) linear sensor and laser diode with LabVIEW software to detect the behaviour of air bubbles in non-flowing crystal clear water. The suggested OPT system promises a non-intrusive, non-invasive and non-hazardous radiation system for online industrial inspection of multiphase flow measurement. This hardware development is capable to detect transparent objects without the help of contrast agent which can disturb the stability of multiphase flow.

Qualitative and quantitative analyses were done using the LabVIEW and Minitab software. Minitab software are used for statistical analysis, while, LabVIEW programming are developed to measure the air bubble diameter and velocity for offline data, and to produce a cross-sectional pipeline image for online data. Linear Back Projection (LBP) combined with Hybrid and filtered image algorithms were introduced and applied on 160 and 320 views image reconstruction analysis. The image captured is displayed in 64×64 image resolution but in different number of views. A view is a term for the single combination of emitter and detector which aligned in parallel array known as projection [3]. Main reason of 160 views and 320 views study is to verify the statement of higher number of sensors will generate a better quality of image reconstruction [5].

2. Research methodology

This section is divided into two main sections, which are research methodology of hardware construction and software development.

2.1. Hardware construction

This research used CCD linear sensor Sony ILX551A [6]. This type of CCD sensor can detect photons spectral range of 400 to 1100 nm [4,7]. For this flow measurement instrument, we chose low cost laser diode with a mixture of Helium and Neon gases in the ratio of 10:1. It is an atomic laser with low power device [8]. This type of laser diode emits photons with 650 nm wavelength and is suitable for the Sony ILX551A CCD linear sensor. A biconvex lens with a focal length of 0.5 was attached at the front of the laser diode source. Laser with attached lens is covered using white table tennis ball. This white table tennis ball is used as a filter to reduce the laser diode light intensity from 0.7 to 0.5 lx at air and 0.3 lx after passing crystal clear water. Low light intensity is important to ensure CCD are not saturated or damaged. Laser considered as a coherent light source because its architecture design emitted the stimulate photon [8–10]. Fig. 1 shows the details construction of laser diode subsystem.

This research applied fan beam projection methods in

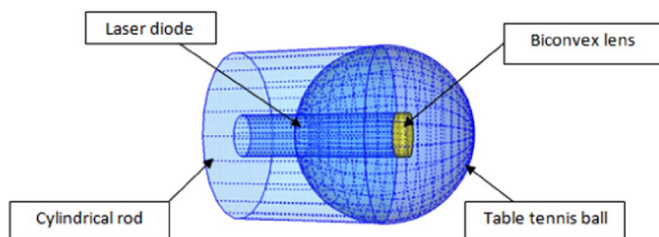


Fig. 1. Laser diode subsystem.

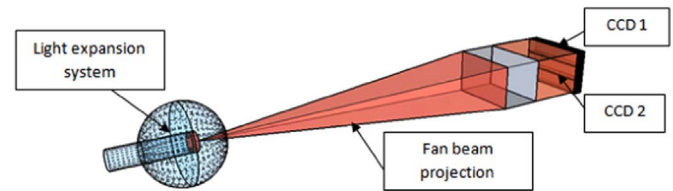


Fig. 2. Light transmitting process.

modifying its laser light beam. Fig. 2 shows the light transmitting process from laser to CCD sensors in details. lens will expand the light source in fan beam projection. the same light sources will pass the square opening which limiting the laser beam area. this square beam projection is able to cover multiple CCD sensors that aligned in parallel arrangement. in this research, the square shape beam covered both upper and lower CCD sensors.

Eight numbers of CCD sensors and four numbers of laser diodes expansion systems were arranged in octagon orientation. This arrangement of emitters and sensors helps to uniformly view the cross-sectional image of the flow system [10]. To obtain an accurate light source expansion, a laser diode was fixed to X-axis movable rod so the distance between the laser and CCD can be controlled manually. The CCD frame was used to fix the CCD sensors at a desirable level of the pipeline system. This frame provided six sockets for the CCD sensor to be attached at each column. However, this experiment used only two CCD socket in each column. The hardware construction can be seen in Fig. 3.

A 100 mm inner diameter of acrylic pipeline and sensors system were built in a closed black box because;

- Closed black box will isolated the system from interruption of external light that could affect CCD linear sensors data.
- The frames of this black box are fabricated from black powder coated mild steel. This is to ensure absorption of the laser diode light source after pass through pipeline system from scattering and reflecting unevenly inside the black box [11].
- Steel are used to assist in heat dissipation of the system. This heat is generated from the laser and other electronic components in the system. Heat built up inside the system may affect CCD accuracy and signals cable resistance values [11].

Majority of the previous OPT system especially laser diode which has fast operational speed, applied a switch mode technique [12–14]. This technique only capable to captured one projection in each measurement frame. Delay in each projection alternation will increased the time scanning per one measurement frame. The probability of data losses is high during the transition of projection. This project chose simultaneous mode for all projections. Thus, all receivers will capture the data in the same time frame without waiting for previous projection to complete. Data acquisition NI 6210 was used for the interfacing process between the hardware and software construction. The CCD linear sensor Sony ILX551A requires two signals: Read Out Gate (ROG) and a clock pulse generator to function, with both signals programmed using C language in PIC16F877A. For the clock pulse, the time per cycle was $8.80 \mu\text{s}$. Total time per scan for this optical tomography system was 18.4 ms.

2.2. Software development

There are two software programming involved in this research study; online programming for image reconstruction and offline programming.

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