Sensors & Transducers Journal, Vol. 140, Issue 5, May 2012, pp. 45-52

www.sensorsportal.com

Sensors & Transducers
ISSN 1726-5479

http://www.sensorsportal.com

A Study on Optical Sensors Orientation for Tomography System Development

[1] M. Fadzli B Abdul Shaib, [2] Ruzairi Abdul Rahim, [1] Siti Zarina M. Muji, [2] Leow Pei Ling, [1] M. Mahadi Abdul Jamil

[1] Faculty of Electrical and Electronic Engineering, Universiti Tun Hussein Onn Malaysia, 86400 Parit Raja, Batu Pahat, Johor, Malaysia

[2] Process Tomography & Instrumentation Research Group, Cybernetics Research Alliance, Faculty of Electrical Engineering, Universiti Teknologi Malaysia, 81310 UTM Skudai, Johor, Malaysia

E-mail: fadzli@uthm.edu.my, szarina@uthm.edu.my, mahadi@uthm.edu.my ruzairi@fke.utm.my

Received: 2012 /Accepted: 23 May 2012 /Published: 31 May 2012

Abstract: This paper describes the investigation of optical sensors performance towards the development of optical tomography system. The orientation of the transmitters has been set from 0° until 180° and then the receiver's responses were analyzed. Hence, sensors capabilities were tested further by placing blockage object in between the transmitter and receiver and the effect of this arrangement were observed. Finally, new designs of sensor jig were introduced based on the results achieved. *Copyright © 2012 IFSA.*

Keywords: Optical tomography, Fan beam projection, Light intensity.

1. Introduction

Process tomography is an online imaging technique to observe dynamic flow characteristics of moving material inside the vessel without need to invade the flow. This technique mainly used to observe concentration location, velocity and mass flow rate of material flow in the vessel or pipeline [1]. Optical tomography is one of the branches in process tomography areas which generally applied in pneumatic conveying system or gravity chute conveyor in a process vessel or pipeline. This technique has its own advantages compared to other modality which are safe (not involve radioactive source such as gamma ray or x-ray [2], less complicated, inexpensive and straight forward where the parameter measured is equally sensitive throughout the measurement volume [3].The main concept in this type of modality involves the attenuation of light when flowing particle obstructs the light beam projection [4]. The optical tomography is a preferable measurement technique for particle flow imaging in gas [1-4, 6-8] instead of electrical tomography. The later technique is commonly use for observing the mixture of different types of liquid or the combination of solid and liquid [5, 11-12]. The key factor in this selection relies on the penetration capability of both modality techniques. The electrical properties manipulation is applied in electrical tomography technique with higher penetration factor but relatively low spatial resolution [5]. Meanwhile, the blockage of light propagation effect is used in optical tomography system to produce high resolution image despites of low penetration capabilities. In developing optical based tomography system, there are several initial step need to be considered before moving further. Firstly, type of receiver and transmitter needs to be determined depending on its applications. After determining type of component for transmitting and receiving signals, transmission and receiving angle also need to be considered. Furthermore, the applicability towards the effectiveness of observing the material blockage needs to be verified.

2. Projection Coverage for Transmitter & Receiver

Infrared Light Emitting Diode (IR LED) is chosen as transmitting and receiving element. The choice of this type of sensors is to avoid visible light to interrupt the measurement [6]. The angle of transmission or receiving angle depends on the type of projection that needs to be constructed. For parallel type of projection, the smaller angle is preferred while the larger angle for fan beams type. The main reason is that for parallel type of projection only, one receiver correspond to each projection while for fan beam type, several receivers will correspond to one projection. The example arrangement of IR LED for parallel [7] and fan beam projection [8] is shown in Fig. 1.

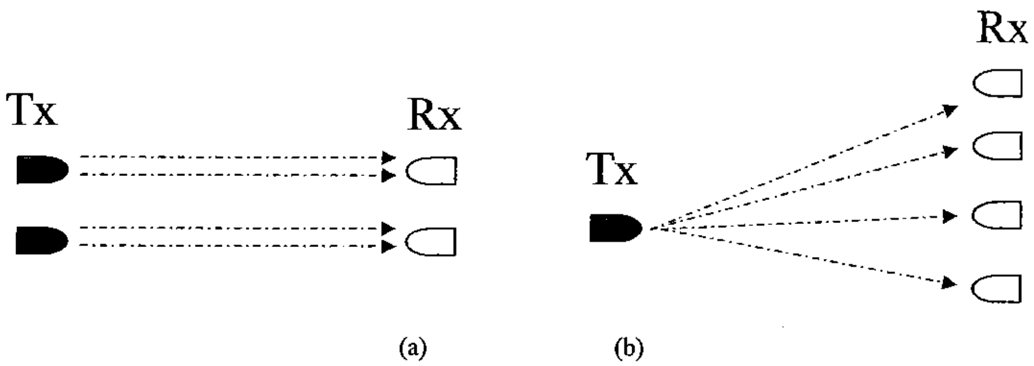


Fig. 1. Different projection type optical tomography system, (a) Parallel Projection; (b) Fan Beam Projection.

IR LED transmitter and receiver have its own characteristics in terms of radian intensity, wavelength and coverage areas. In terms of coverage areas, it can be referred from the data sheet as "half angle". Full angle of transmission or receiving angle of coverage can be determined by multiplication of "half angle" by 2. In this study the theoretical value of the sensor from the datasheet will be verified through experimental work as a comparative analysis. For transmitter model OSRAM-SFH 485P, theoretically, angle of projection can cover up to 80^0 and for receiver model OSRAM-SFH203 PFA, the receiving angle can cover up to 150^0 [9].This wide angle range capabilities fulfill the needs for fan beam projection in optical tomography where larger angle are at utmost important.

2.1. Experimental Set Up

It is important to have the correct experimental set up in order to determine maximum angle can be covered by the transmitter and receiver. The transmitter and receiver circuit is constructed to drive IR LED by referring to Fig. 2[10]. Simple programming using C Language is embedded into PIC 18F4550 giving pulse signal to IR LED transmitter. This pulse signal ensures transmitter to activate and deactivate alternately for some period of time. The signal from transmitter is detected by receiver will be amplified before being measured.

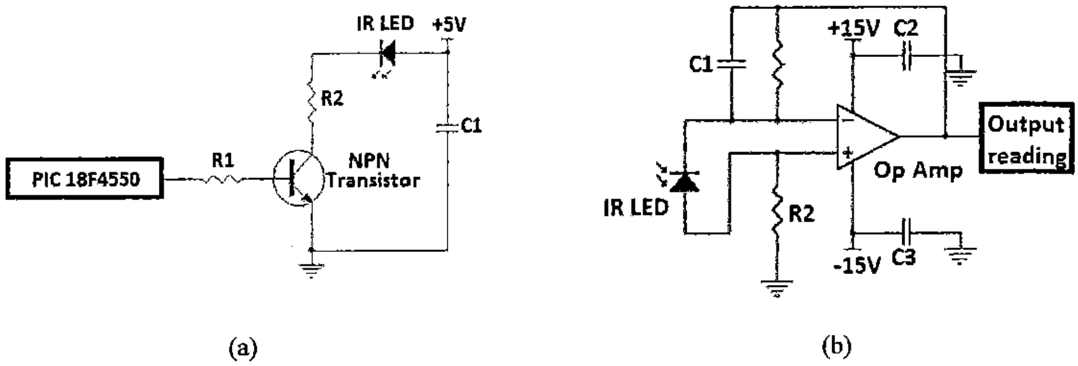


Fig. 2. Arrangement for transmitter and receiver circuit, (a) Transmitter Circuit; (b) Receiver circuit.

As shown in Fig. 3, transmitter's IR LED is positioned at centre of the circle and receiver's IR LED is placed at the edge of the circle radius. The value of the circle radius depends on the radius of cylinder used to develop the whole optical tomography system. Receiver's IR LED arranged between 0° to 180°. The reason for this arrangement is because the maximum angle of the transmitter and receiver in real implementation of optical tomography system is 180°.

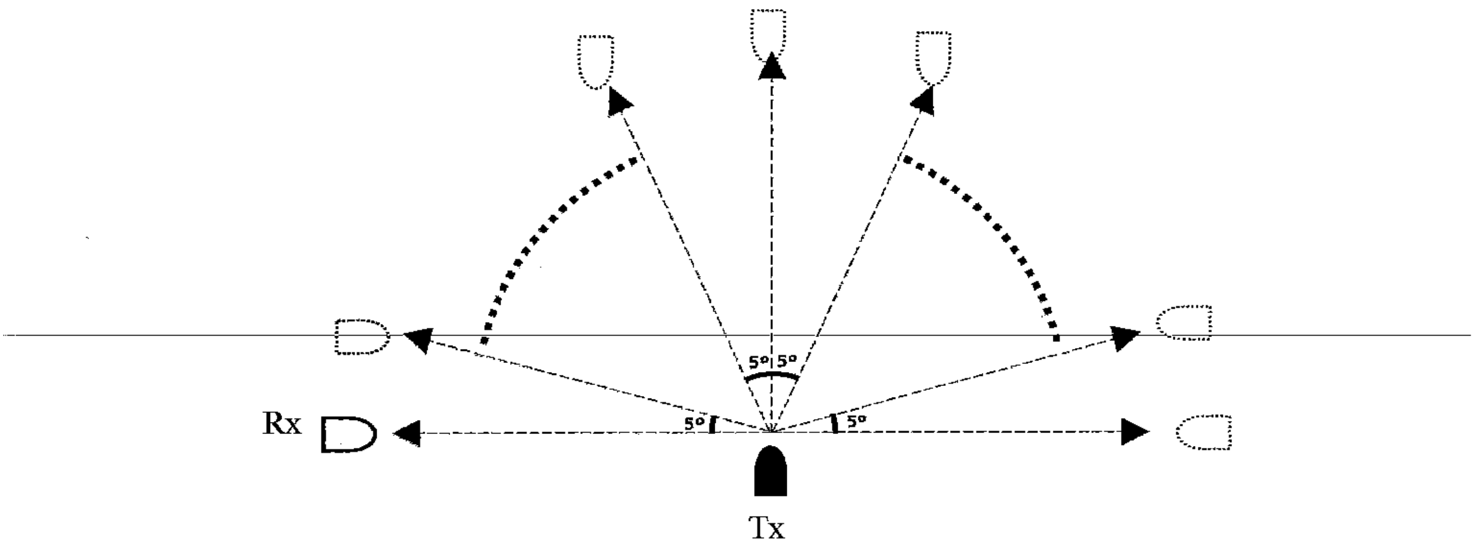


Fig. 3. Diagram of angle for transmitter and receiver's IR LED.

The receiver's response in voltage is recorded for incremental angle of 5°. Fig. 4 shows responses from one of the receiver corresponding to each transmitter projection. The input signal is set to operate at frequency of 33 kHz or 30 µs for one cycle of projection and the output signal obtained is 4.24 V. For each activation of transmitter's projection, voltage at the output of the receiver gradually increased until steady state condition is achieved before gradually reduces to zero voltage as deactivation of transmitter projection. The graph for each receiver's response base on two difference radius is shown as in Fig. 4.

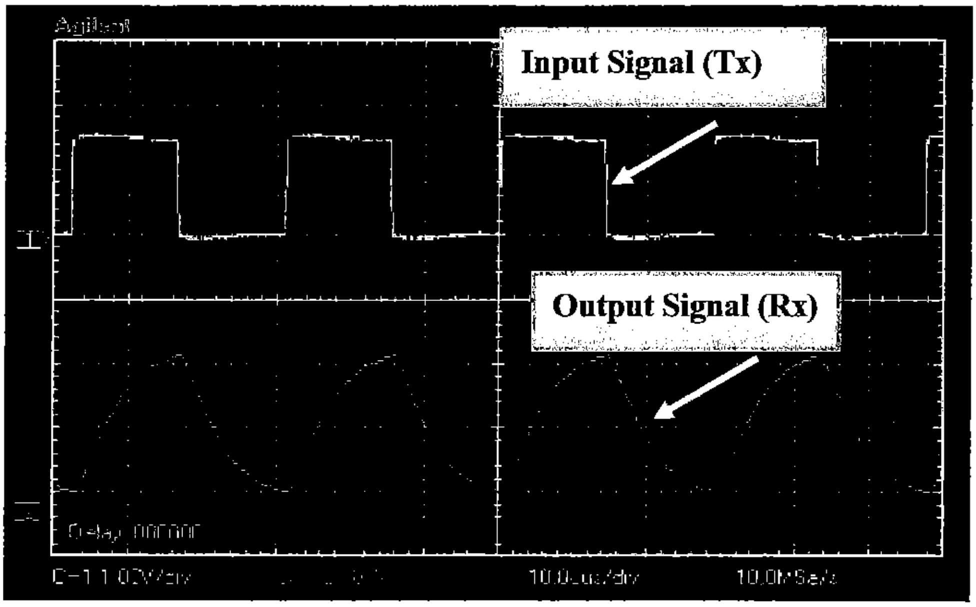


Fig. 4. Graph showing signal from transmitter and receiver.

Based on the observation from the graph pattern as shown in Fig. 5 and 6, the receiver can give response up to 180° angle compared to theoretical values which can only covers up to 80° for transmitter and 150° for receivers. The intensity based on the voltage reading gradually increase and decrease depends on location of the receiver. The voltage reading is higher when the location of the receiver between 75° and 125° but the rest of the location shows lower value of voltage but still can be measured. This proves that for certain condition, the coverage of transmitter and receiver can be optimized in comparison to theoretical value.

2.2. The Effectiveness of the Sensors Configuration

After determining the sensors projection coverage, sensor needs to be tested on the actual sensor jig. The main reason for this procedure is to examine the response of the sensor either jig constructed suitable for sensor configuration or need to be modified further. In this set up, acrylic cylinder with 100 m in diameter is drilled to suite 16 pairs of receivers and transmitter which will be placed alternately. Even though receiver's response is better when smaller diameter is used as shown in Fig. 5, but 100 m is most preferred based on wide application in industry and also the availability of the cylinder. As illustrated in Fig. 7, the sensors with 5 mm in diameter were placed alternately with 11.25° angle difference. 16 sets of transmitter labeled starting from Tx0, Tx1, Tx2, until T15. 16 sets of receiver were also labeled starting from Rx0, Rx1, Rx2 until R16. The actual figure of sensors arrangement embedded on the acrylic cylinder is shown in Fig. 8 (a).

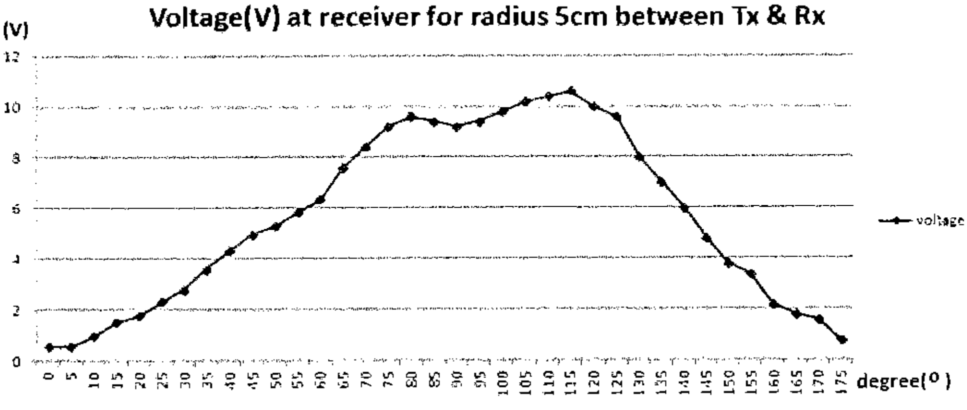


Fig. 5. Graph showing receiver's response for radius of 5 cm.

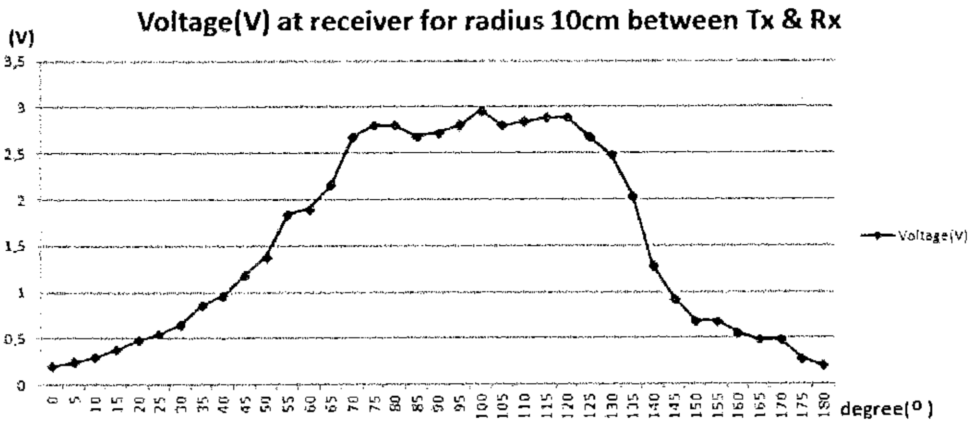


Fig. 6. Graph showing receiver's response for radius of 10 cm.

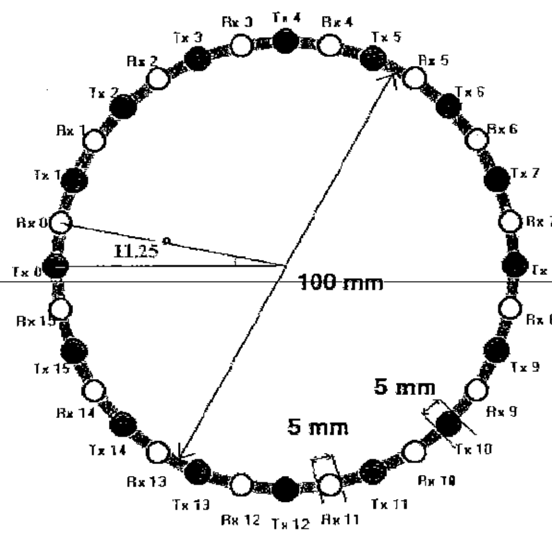
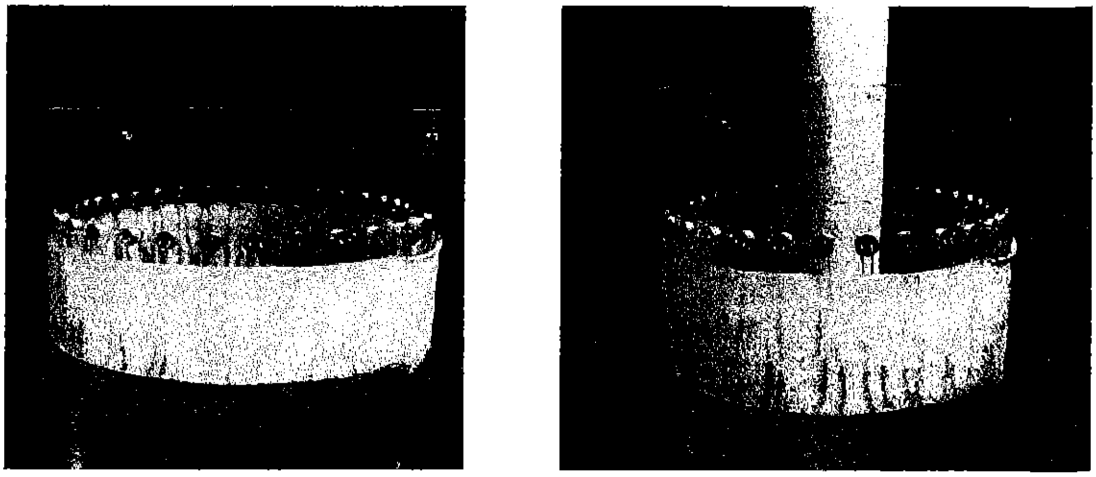


Fig. 7. Diagrammatic representation of sensors configuration.



(a) (b)

Fig. 8. Actual figure for sensors arrangement, (a) Sensors embedded on acrylic cylinder; (b) Piece of white colored paper placed at the middle of cylinder

In order to observe the effectiveness of this arrangement, one of the transmitters, Tx0 is activated and the values of the voltage for each receiver were measured. Then, followed by a piece white colored of paper is placed at the middle of the cylinder as shown in Fig. 8(b) and the same measurement is repeated. The collected data shown in Fig. 9.

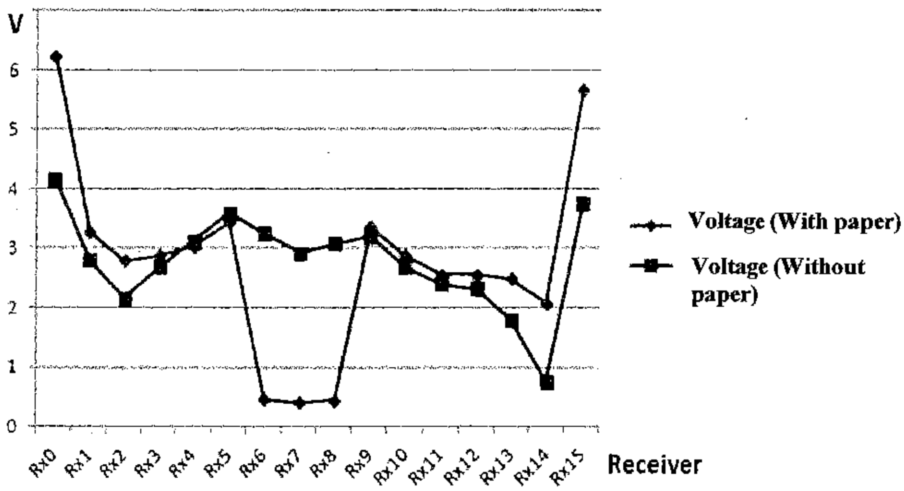


Fig. 9. Voltage comparison for sensors performance with and without blockage.

From the graph shown in Fig. 7, when there is no blockage at the middle of the cylinder, the voltage is higher at the location of Rx0 and Rx15. This is due to the location of the transmitter Tx0 which is located between receivers Rx0 and Rx15 where the light intensity is higher. Other than that, the reflection between the sensors and the acrylic cylinder wall potentially contribute to this higher voltage. When the sensors are blocked by the paper, the voltage is higher at the Rx0 and Rx15. This is also due to the reflection of acrylic pipe wall and also from the paper which has white colors properties potentially enabling some additional reflection. However, there is sudden drop of voltage observed at Rx6, Rx7 and Rx8 due to covering of white paper. The reason for this sudden drop of voltage is due to the light being obstructed from transmitter to the receiver.

3. The Proposed New Design of Sensor Jig for Optical Tomography System Development.

From this preliminary study, new designs for sensor jig were introduced. As shown in Fig. 10, this jig builds separately from the acrylic cylinder and made from different material (PVC type). This method could possibly reduce the reflection of the light from the cylinder. Thus, inaccuracy could be reduced. In term of mechanical side, the difficulty for the drilling process of the acrylic cylinder can be avoided. Besides, this new design only uses "plug-in" method to attach it with the acrylic cylinder. In this design, two different cylinder with the same dimension is inserted on the upper part and the lower part of the sensor jig as shown in Fig. 10(b). Thus, the proposed new jig demonstrates the simplicity in design.

(a) (b)

Fig. 10. New design for sensor jig, (a) Single jig design; (b) Jig embedded on acrylic cylinder.

4. Conclusion

Based on the testing of sensors performance as in coverage angle were proven to be expandable. In addition, the preliminary study has triggered new idea of sensor jig design for future investigation in optical based tomography. Besides, the capabilities of each sensor can be maximized based on the studies focused on the sensors performance with selective configuration.

References

[1]. Ruzairi Abdul Rahim, Pang Jon Fea, Chan Kok San, Leong Lai Chen, Real time image construction for various flow regimes using optical tomography sensor in a gravity flow *conveyor, Advanced Powder Technology*, Vol. 16, Issue 4, 2005, pp. 399–411.

[2]. M. S. Beck, R. G. Green and R. Thorn, Non-intrusive measurement of solids mass flow in Pneumatic Conveying, *J. Phys. E: Sci. Instrum.*, Vol. 20, 1987, p. 835.

[3]. S. Ibrahim, R. G. Green, K. Dutton, K. Evan, R. Abdul Rahim, Optical sensor configurations for process tomography, *Meas. Sci. Technol.* Vol. 10, 1999, p. 1079.

[4]. Green R. G., Horbury N. M., Abdul Rahim R, Dickin F. J., Naylor B. D. and Pridmore T. P., Optical fibre sensors for process tomography, *Meas. Sci. Technol. Meas. Sci. Technol.*, Vol. 6, 1995, pp. 1699-1704.

[5]. Tomasz Dyakowski, Laurent F. C. Jeanmeure, Artur J. Jaworski, Applications of electrical tomography for gas–solids and liquid–solids flows — a review, *Powder Technology*, Vol. 112, 2000, pp. 174–192.

[6]. Muji, S. Z. M., Morsin, M., Rahim, R. A., Criteria for sensor selection in optical tomography, *IEEE Symposium on Industrial Electronics and Applications (ISIEA' 2009)*, October 4-6, 2009, Kuala Lumpur, Malaysia.

[7]. Ruzairi Abdul Rahim, Pang Jon Fea, Chan Kok San, Optical tomography sensor configuration using two orthogonal and two rectilinear projection arrays, *Flow Measurement and Instrumentation*, Vol. 16, 2003, pp. 327–340.

[8]. Yingna Zeng, Qiang Liu, Yang Li, Nabil Gindy, Investigation on concentration distribution and mass flow rate measurement for gravity cute conveyor by optical tomography system, *Measurement*, Vol. 39, 2006, pp. 643-654.

[9]. Datasheet from OSRAM Opto Semiconductors datasheet, model SFH 203PFA and SFH 485P.

[10].R. Abdul Rahim, K. S. Chan, J. F. Pang, L. C. Leong, A hardware development for optical Tomography system using switch mode fan beam projection, *Sensors and Actuators, A*, Vol. 120, 2003, pp. 277–290.

[11].Elmy Johana, Fazlul Rahman Mohd Yunus, Ruzairi Abdul Rahim & Chan Kok Seong, Hardware Development Of Electrical Capacitance Tomography for Imaging a Mixture of Water and Oil, *Jurnal Teknologi Keluaran Khas*, 54, Januari 2011, pp. 425–442.

[12].Norpaiza M. Hasan, Barry J. Azzopardi, Imaging stratifying liquid–liquid flow by capacitance tomography, *Flow Measurement and Instrumentation*, Vol. 18, 2007, pp. 241–246.
