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A Novel Electrical Cpacitance Sensor Design For Dual Modality Tomography Multiphase Measurement

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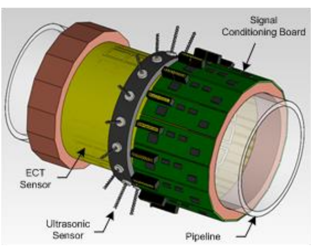
Graphical abstract



Abstract

Electrical capacitance tomography (ECT) is one of process tomography technique which is developed rapidly in recent years. ECT is an imaging technique to obtain the internal permittivity distribution of a vessel or pipe by using capacitance electrodes sensor. This method has been integrated with ultrasonic tomography as multimodality system to perform multiphase flow measurement such as crude oil separation and oil process industry. In the present paper, a novel type of ECT sensor was developed using copper FR4 material. The electrode sensors can be flexibly bend or curve to fit the pipe surface for optimum measurement. Thus, every single sensor strip is designed to be functioned independently. Such system has lower sensing capability in the central of the sensing area which often contributes to poor imaging result. This problem can be overcome by combining the ECT with ultrasonic tomography to form a dual modality tomography system. By implementing the new ECT sensor, multiphase flow measurement image results can be achieved. The reconstructed image results are presented in this paper.

Keywords: ECT tomography; electrical capacitance; sensor; multiphase flow measurement

■1.0 INTRODUCTION

A multi-modality tomography system is widely applied in medical field such as the emergence of positron emission tomography (PET) along with computerized tomography (CT) [1]. The aim of multi-modality tomography is to address the need for multiple measurement data whereby a single-modality is not sufficient enough to provide for a process [2]. The range of possible application for multiphase flow measurement is widely extended when several modalities are integrated to perform the required measurement [3]. This research has emerged electrical capacitance tomography (ECT) with ultrasonic tomography (UT) to integrate a dual modality tomography system (DMT) for multiphase flow measurement. Such combination has high capability to visualize liquid-gas pipeline flow processes [4, 5, 12]. This research proposed a DMT system with ECT-UT integration. The basic diagram of a single modality tomography system and a dual modality tomography (DMT) system are illustrated as below Figure 1.

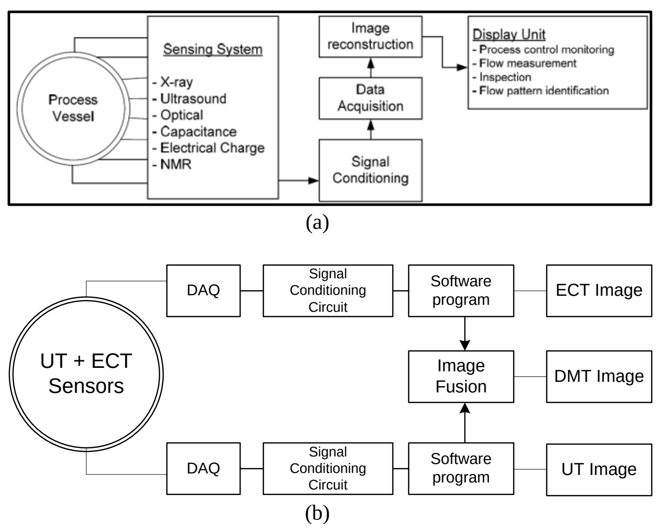


Figure 1 Tomography system block diagram; (a) single modality tomography (b) dual modality tomography

To achieve the optimum reconstructed measurement result is to have an appropriate sensor design for a specific application such as multiphase flow measurement. The electrical capacitance tomography (ECT) in this research has been developed for visualizing the distribution of dielectric materials. In this paper, a new type of ECT electrode sensor is proposed. Related key issues such as effects of driven guard electrodes, earthed screens were considered for DMT system [6]. The proposed DMT hardware system is shown in Figure 2.

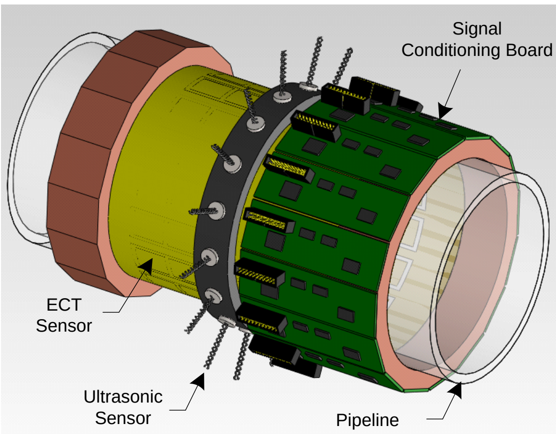


Figure 2 Dual Modality Tomography (DMT) hardware system

■2.0 ECT SENSOR

ECT is used to obtain the spatial distribution of dielectric materials inside a pipeline. This was done by measuring the electrical capacitances between the electrodes placed around a pipe. The collected data will then be converted into an image visualizing the distribution of permittivity as a pixel-based plot [7] or tomogram images. The concentration distribution of the two components over the cross section of the vessel can be obtained from the permittivity distribution.

2.1 Electrode Design

The material of the electrode must be highly conductive. Flexi Copper FR4 material has been used to fabricate ECT sensors. A total of 16 ECT sensor strips are implemented for the DMT system.

The diameter and the length of the electrode strip will determine the capability of the sensor to measure smallest capacitance value. The length of the electrode strip (sensing zone) was designed to be 110 mm which is equal to the diameter of the pipeline. Any length shorter than 110 mm pipeline will reduce the sensitivity of these sensors [7]. This is also to avoid serious fringe effect in both axial ends of the electrode strip [6].

A driven guard is located surrounding the sensor strip as in Figure 3. By doing so, the electric field can be prevented from spreading in the axial dimension. An earthed screen was also implemented in this sensor design where the top layer of the flexible copper strip will act as earth screens which cover the surface of the sensor. This is to shield the sensor system from air disturbance occurrence in the acquired signal [8]. The ECT electrode strip is shown below in Figure 3.

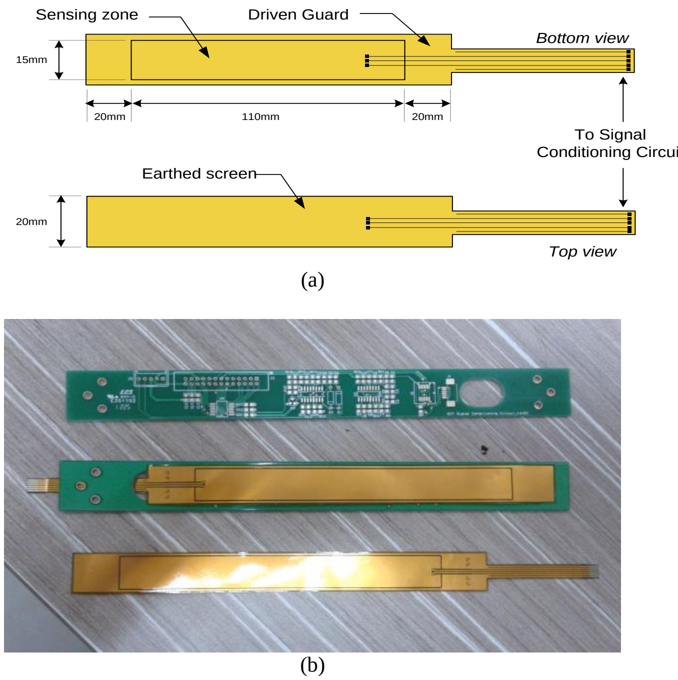


Figure 3 ECT copper electrode strip design

2.2 ECT Electrode Location

The ECT sensors are mounted symmetrically outside an insulation pipe. Commonly, non-invasive and non-intrusive method is more preferable as it does not cause damage to the pipeline. Somehow, the wall thickness will contribute negative effect on the measurement [6].

There are three ways to install the electrode plate sensors: (1) internal method where the sensors will be invasively contact with the internal measurement, (2) embedded method where the sensors are mounted inside the pipe surface which does not expose to the exterior nor the interior of the pipeline, and (3) external method where the sensors are non-invasively located outside the pipeline.

The advantage of internal electrodes is the components of capacitance due to the electric field inside the sensor will always increase in proportion to the material permittivity regardless of the pipeline's material or thickness factor. Somehow, internal electrodes are usually merged in [9] highly conductive liquid such as oil and water. Cases of short circuit have high potential due to the high conductivity. Therefore, the sensor should be placed externally.

To obtain proper measurement results, all 16 electrodes must be attached to the pipe surface without any air gap as in Figure 4.

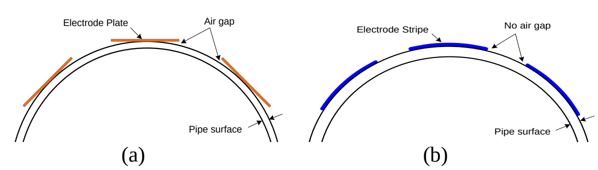


Figure 4 ECT electrode: (a) hard plate electrode (b) copper strip

3.0 RESULTS AND DISCUSSION

The ECT electrode strips are tested in ECT single mode of the DMT system. The image results are reconstructed using linear back projection (LBP) algorithm to overcome inverse problem [10]. Somehow, the forward problem needs to be solved to determine the two dimensional tomogram images [11]. This was done by dividing the cross sectional of the sensing area into 32 x 32 pixels as in Figure 5.

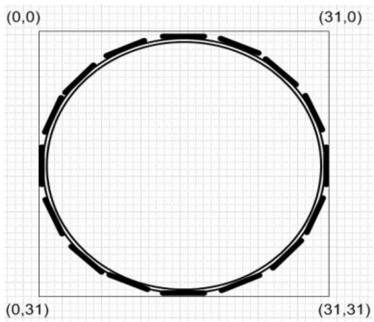
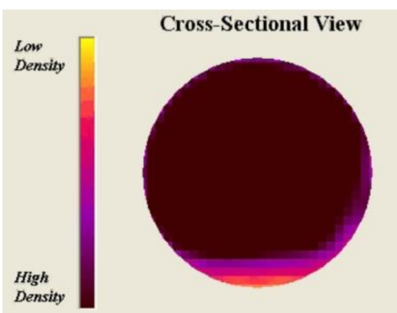
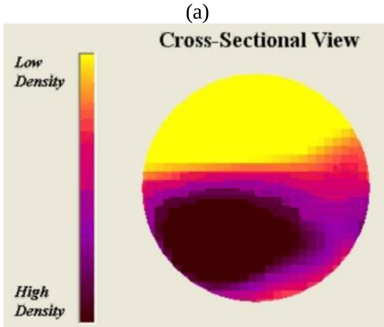


Figure 5 32 x 32 pixel image plane

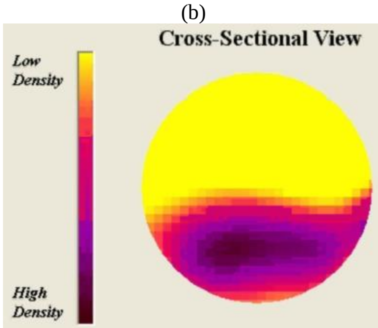
Three types of multiphase flow was measured using water-gas as the measurement subject; i) full water flow, ii) half water flow and, iii) quarter water flow. The reconstructed image results are presented below as in Figure 6.



(a)



(b)



(c)

Figure 6 Reconstructed image (a) full flow (b) half flow (c) quarter flow

The reconstructed images are visualized in color ranging from higher density ($\boldsymbol{p_{water}}$ = 80.0) to lower density ($\boldsymbol{p_{air}}$ = 1.0). The higher densities the material is, the darker the color will be visualize.

4.0 CONCLUSIONS

The implementation of the new ECT electrode strip in multiphase flow measurement for DMT system managed to produce adequate results. The flow measurement in the pipeline was successfully visualized using LBP algorithm.

Acknowledgement

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