Sensors & Transducers Journal, Vol. 135, Issue 12, December 2011, pp. 20-26

www.sensorsportal.com

Sensors & Transducers

ISSN 1726-5479

http://www.sensorsportal.com

An Overview: Effectiveness of Different Arrangement for Electrode Guard in Electrical Capacitance Tomography

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Received: 7 September 2011 /Accepted: 16 December 2011 /Published: 28 December 2011

Abstract: Electrical capacitance tomography (ECT) system is useful to obtain information about the spatial distribution of a dielectric materials mixture inside a vessel. It has been suggested by many researchers previously to use guard electrode in ECT sensors. This paper describes various types of design for guard electrode in Electrical Capacitance Tomography (ECT) sensor. The design of these electrode guards is vital to reduce crosstalk (undesired signals) between the adjacent electrodes (positioned at the outside of the measured pipe) since the crucial signals are only inside the pipe. There are three types of electrode guards designed by various researchers which are radial guard, axial guard with end guard and driven guard. The configuration and the effectiveness of each designed electrode are discussed. Other than that this paper introduced new design of electrode guards which are embedded on electrode sensor instead of placing separately between or around adjacent measuring electrodes as the previous design. *Copyright © 2011 IFSA.*

Keywords: Guard, Electrode, Arrangement, Effectiveness, ECT.

1. Introduction

Even though ECT is considered as matured technology, this technique is still remaining popular among the industries and researchers. This is due to its capabilities for multiphase flow imaging based on variety of measurement using permittivity properties for material to be imaged. Besides, it is also known as low cost, fast imaging speed, robust, non invasive and non-intrusive tomography technique [1]. There are various types of flow that can be observed based on this technique which are: (1) mixture of two different fluid (2) fluid and gas (3) water and oil and lastly (4) solid and gas flow [2].

The basic principle of this technique is to measure the capacitance changes between multiple of electrode sensors. The image is reconstructed base on the data collected via appropriate algorithm e.g. Linear Back Projection. In Fig. 1, common ECT sensor constructions among the researchers were referred. The multiple electrodes made from highly conductive materials are mounted symmetrically around the periphery of the vessel or pipe. A sine wave signals from the function generator is injected to one of the electrode (act as transmitter) while the rest of the electrodes are considered as a receivers. The changes of the capacitance at each of the receivers are measured. The same experimental sets up were performed on the other electrodes. Generally, the total numbers of independent measurements is given by N(N-1)/2, where N is the total number of electrodes. By referring to Fig. 1, N =12 electrodes, thus the total number of capacitance measured are 66 [3].

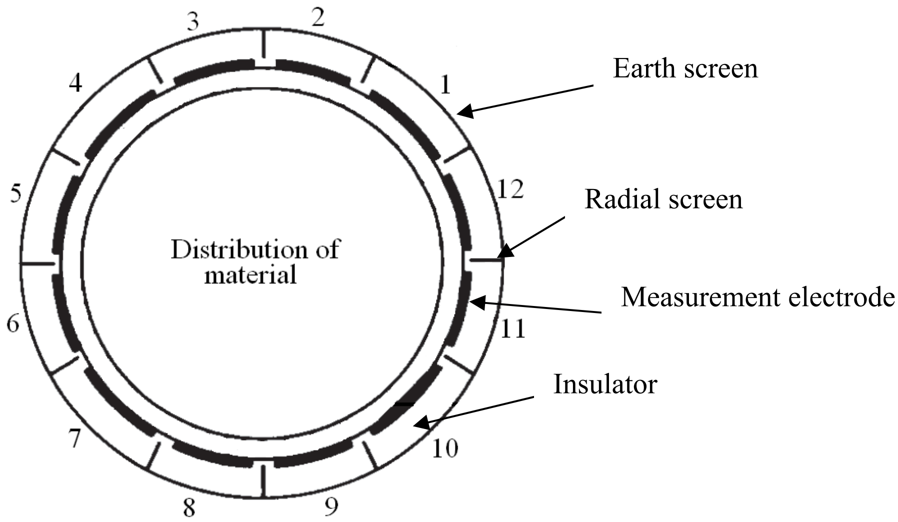


Fig. 1. Cross sectional view for ECT sensor with 12 electrodes.

2. Standing Capacitance in ECT System

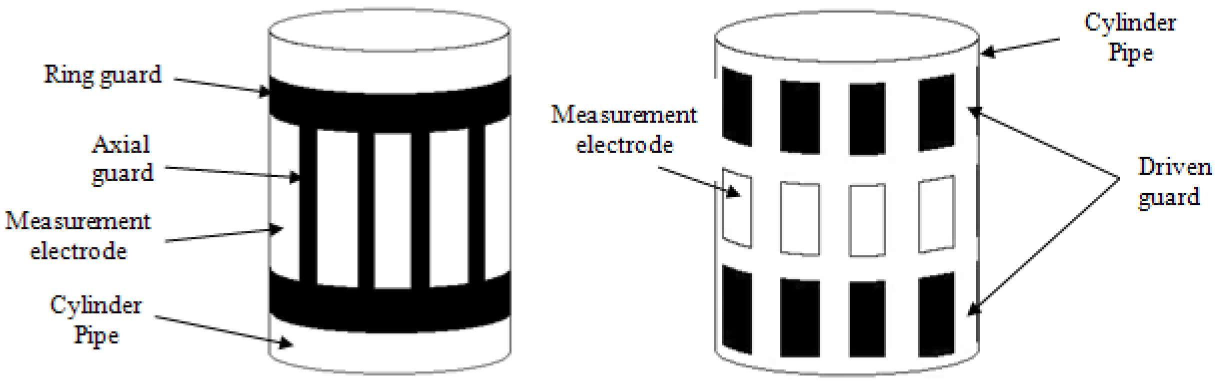
Standing capacitance in ECT system is the effective capacitance between electrodes that been measured supposed one of the electrode is injected with a certain signal e.g. sine wave signal. When the flow of dielectric materials perturb the signals between the two electrodes, the standing capacitance value will change but in small magnitude (typically 0.01 to 0.5 pF) [4]. This value should be small to ease the measurement on the changes of the effective capacitance value by the material distribution inside the sensing zone [5]. The high value of standing capacitance (typically 150 pF) can be reduced by placing earth screen and electrode guards in ECT system [4]. This can limit or reduce the standing capacitance value which arises from ambience noise and capacitance effect from adjacent electrode outside the vessel’s boundary. This is vital since only the capacitance effect inside the pipe is taken into consideration.

3. Variety Design of Electrode Guard

In determining which electrode guard is suitable for ECT sensors, several aspects needs to be considered before sensors been constructed such as: (1) Difficulty in mechanical construction (2) The sensitivity and (3) Material flow type which need to be imaged. There are varieties designs of electrode guard which are: (1) Radial guard (2) Axial guard with end guard and (3) Driven guard. These three types of electrode guard have their own advantage and disadvantage in term of its construction and performance towards ECT sensors.

The drawing shown in Fig. 1 previously is an example of construction of the radial guard protruding inwards the pipe liner. For mechanical construction, radial guard is known as the most difficult set up [1]. The length of radial guard and driving electrode should be equal in the axial direction. In this design, radial guard is kept at zero potential and driving electrode is driven by excitation signals.

There is another design of guard electrode called axial guard [5]. In this design, the earth strip act as axial guard is placed between the measurement electrodes with ring guards at zero potential [6] as shown in Fig. 2. The length of axial guard and measurement electrode should have the same length. Both axial and ring guard has its own purpose. For ring guard, the capacitance between the electrode and ambience noise can be reduced while inter electrode capacitance between the external earth screen and electrode can also be reduced [5].



(a) (b)

Fig. 2. (a) ECT sensors with end guard and axial guard, (b) ECT sensors with driven guard.

An alternative construction of different electrode guard is called driven guard. Both segmented driven guard are mounted onto the cylinder pipe between the measurement electrodes as shown in Fig. 3. In this design, when the measurement electrode acts as excitation terminal, the corresponding driven guard electrodes is also injected with the same excitation source, while at receiver terminal guard electrode will be connected to earth [1].

4. Performance of Different Type of Electrode Guard

The diversity in the designed techniques of the electrode guard in ECT system is determined by its practicality and environment or its material which need to be imaged. Undeniably, the performance in electrode guard designed is also an important factor to construct good ECT sensor. Generally, electrode guard restrain field lines were produced by electrode excitation travelling towards measuring electrode outside the pipeline. Only capacitance due to electric field line within interior of the pipe is taken into consideration [7].

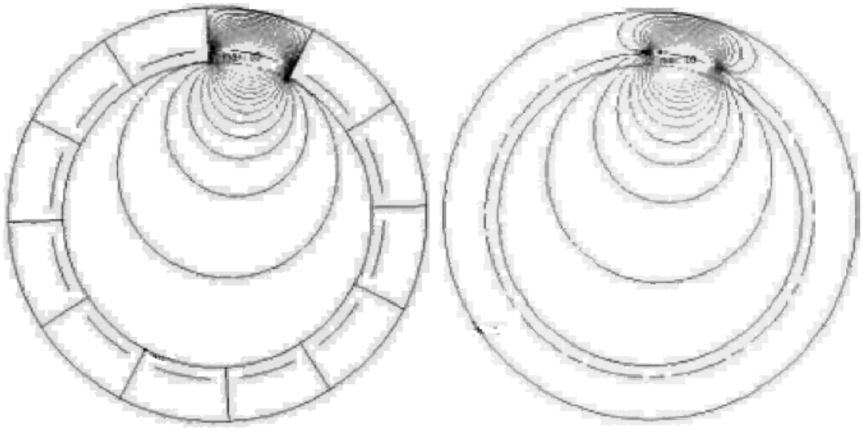
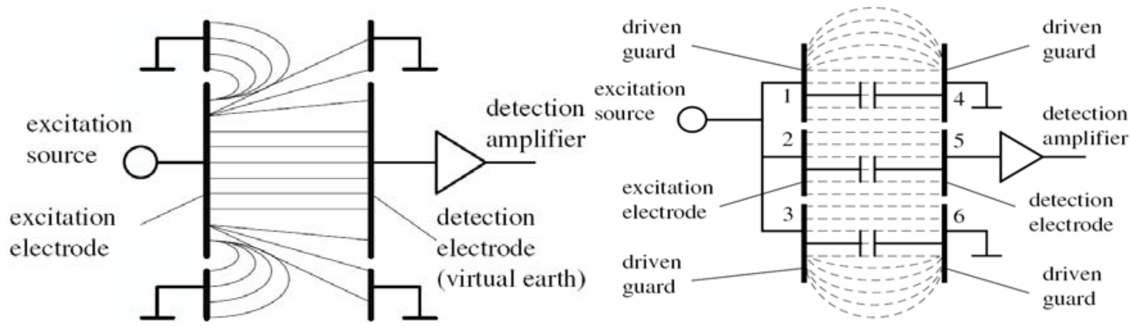


Fig. 3. Equipotential contour plot: (a) sensor with radial guard (b) sensor with plain axial guard.

The pattern arrangement of radial guard will isolate one electrode with another. Hence, shield the field line from adjacent electrode excited by measurement electrode as shown in Fig. 4(a). Due to this, standing capacitance greatly decreased when capacitance between two electrodes is being measured, in comparison with ECT sensors with no electrode guard [5]. Even though radial guard offers an excellence performance in term of shielding the field line, but it might be impractical for many cases [8]. This may be due to its sizes, installation technique onto the cylinder pipe and mainly the complexity in construction.

Fig. 4(b) demonstrates an axial guard with ring guards which is another alternative to confine field line even though it is not the best shielding technique [5]. In result, the technique may reduce standing capacitance even though not as good as radial guard. This method still has negative impact towards capacitance measurement where the small amount of field line is pulled towards axial earth screen despite its ability to reduce the standing capacitance as shown in Fig. 4[1].



(a) (b)

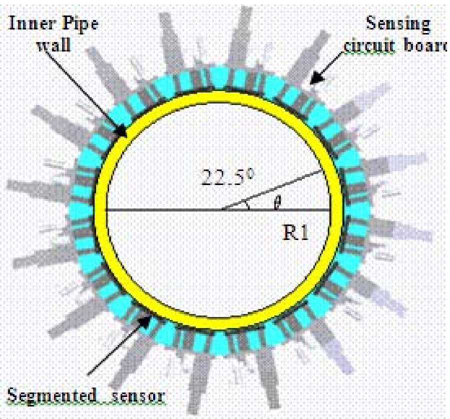
Fig. 4. Electric field distributions in ECT sensors (a) axial guard, (b) driven guard.

Driven guard in ECT sensors is one of the options for those wish to use shorter electrode. This is due to elimination of fringe effect occurred at the end of electrode. This driven guard will help field line parallel towards corresponding driven guards which connected to zero potential. As illustrated in Fig. 4(b), field line from the excitation electrode does not deviates to the adjacent driven guard, thus higher signals could be detected with shorter electrode [1]. However, there are several factors which could possibly limit the use of this technique such as (a) Its only applicable for flow of single material and axially symmetry, (b) Total capacitance between the driven guards and measured electrode exists, (c) Complexity for wiring & data acquisition [5].

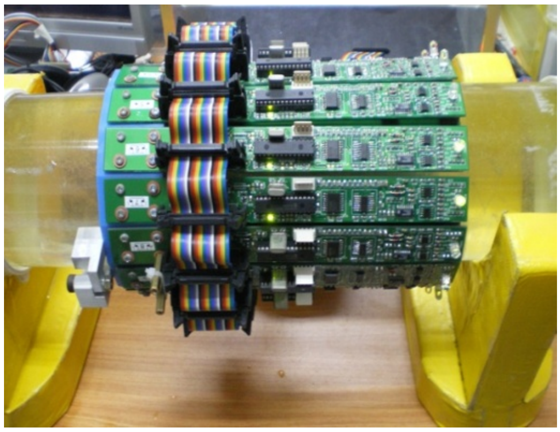
5. Embedded Electrode Guard

A segmented capacitance tomography system for real-time imaging of multiphase flows is developed and presented in this work. The earlier research shows that the Electrical Capacitance Tomography (ECT) System is applicable in flow visualization (image reconstruction) [1]. The acquired concentration profile obtained from capacitance measurements able to imaged liquid and gas mixture in pipelines meanwhile the system development is designed to attach on a vessel. The electrode plates which act as the sensor previously has been assembled and fixed on the pipeline, thus it causes obscurity for the production to have any new process installation in the future.

The new approach of this sensing module proposed a new design of electrode guards which is designed embedded on the segmented electrode sensor plate instead placed between the adjacent measuring electrodes previously. The new design of driven guard has been intergraded onto electrode sensor in order to prevent the electric field lines from spreading at the ends of the measuring electrodes. Fig. 5 (a) shows an arrangement of 16 electrodes sensor on pipelines that has been designed to cover an acrylic pipe 11 cm in diameter with wall thickness of 0.5 cm, R1 is inner pipeline radius 5 cm, R2 is an outer pipeline radius, 5.5 cm and electrode stretch angle θ is 22.5° and Fig. 5 (b) shows the complete module of the Portable ECT [10, 11].



(a)



(b)

Fig. 5. A sixteen segmented electrodes sensor array: (a) illustration of 16 sectors of portable ECT, (b) complete portable ECT sensing module.

These driven guard electrodes will surround the circumference of the pipeline once all the 16 electrodes have been installed on pipeline. The length of the guard electrodes is 33 mm on the left, and 43 mm on the right, as shown in Fig. 6. The measuring electrodes must be completely surrounded by an earthed, metal screen so that the signals obtained in the signal conditioning circuit will not be influenced by the disturbance in the air. In this research, the earth screen is located on the top layer of the electrode PCB as shown in Fig. 7. These sensing plates are covered by an insulated metal screen called the earth screen. The material used for the sensing and screen layers is a copper surface designed using double layer Printed Circuit Board (PCB) [12].The earth screen covers the all the surface on the top layer as shown in Fig. 8.

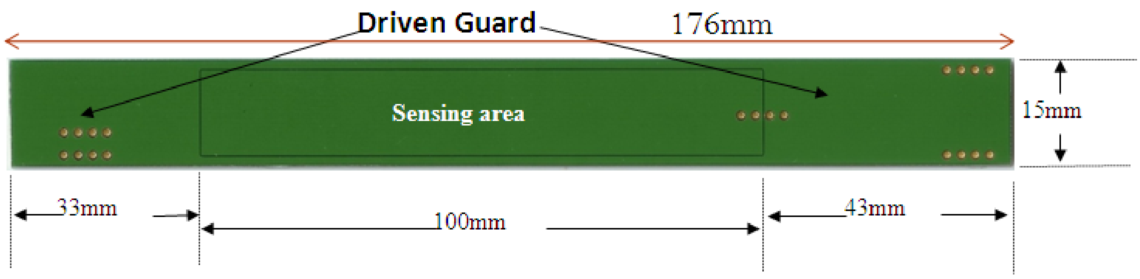


Fig. 6. Electrode's dimension.

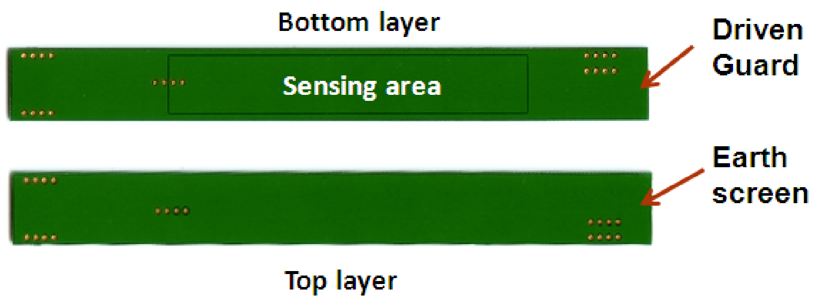


Fig. 7. An overview of a complete electrode sensor design.

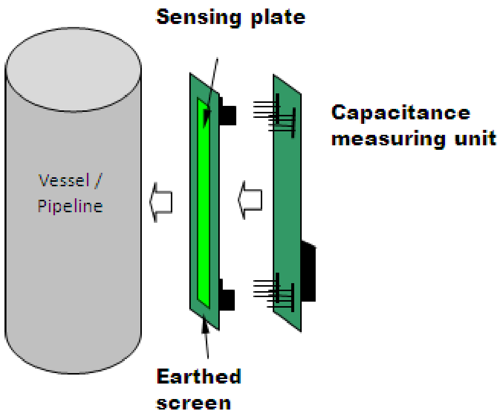


Fig. 8. The electrode guards and sensors design mounted on pipe wall.

6. Conclusions

A segmented electrode sensor offers a new design of electrodes guard and idea on ECT system which is portable to be assembled in different diameter sizes of pipeline, and it is flexible to apply in any number due to different size of pipeline without the need of redesigning the sensing module. The new approach of this sensing module contains the integration intelligent electrode sensing circuit on every each of electrode sensors. Not even electrode guards, a microcontroller unit and Data Acquisition (DAQ) system has been integrated on the electrode sensing circuit and USB technology was applied into the data acquisition system making the sensor able to work independently. The new design of embedded guards gives more flexibility and portable to be expand or reduced depends on the electrode sensor that going to be used.

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