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DETECT FLOW OF STEAM IN AIR BY ELECTRICAL CAPACITANCE TOMOGRAPHY

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Abstract:*.In practice, the steam can also occur in cases where there not be formed, and then affect the composition of the air flow and adversely affect the process. Therefore, it would be useful to detect steam in the air flow. Tomography is a non invasive technique for measuring and displaying the concentration distribution of a mixture of two nonconductive fluids and it requires no direct contact between the sensor and the object or domain of interest. The article analyses steam in air by electrical capacitance tomography and describes a specific experiment made in a laboratory at the University of Leeds.*

Abstrakt: *Para sa môže v praxi vyskytovať aj v prípadoch, kedy by vznikať nemala a následne tak ovplyvniť zloženie prúdiaceho vzduchu a negatívne ovplyvniť daný proces. Z toho dôvodu by bolo užitočné detekovať paru v prúdiacom vzduchu. Tomografia je neinvazívna meracia metóda, ktorá určuje priestorové rozloženie zmesi dvoch izolačných kvapalín a nevyžaduje si priamy kontakt medzi snímačom a objektom alebo objektom záujmu. Daný článok analyzuje problematiku zameranú na detekciu pary vo vzduchu elektrickým odporovým tomografom a je popísaný konkrétny experiment uskutočnený v laboratóriu na University of Leeds.*

Key words: *Electrical capacitance tomography, steam, air, detection.*
Kľúčové slová: *Elektrický kapacitný tomograf, para, vzduch, zistenie.*

INTRODUCTION

Multiphase flow systems are of a critical element in many industrial processes as they constitude the medium through which basic ingredients are processed to yield the final product. Examples of their use include energy generating processes, food processeing and drug manufacturing, among others. The ability to image multiphase flow interaction in real time has always been a highly desirable capability to further understand the complex dynamics among interacting phases in any flow system. Such understanding is critical, for examlple, to effectively model, optimize and scale up the reactors that host the process. From early on, electrical sensing techniques have attracted much attention as a noninvasive means for imaging of multiphase flow systems, in addition, the rates in which phase interactions occur often demand fast imaging modalities, again making electric sensing techniques a natural choice [1].

Electrical capacitance tomography (ECT) is an electric sensing modality that easily meets the high – speed demands of multiphase flow real – time imaging. ECT has also a noninvasive characteristic, a feature much desirable in industrial applications as noted. The basic system components used for ECT then, and still used today, are a set of capacitance

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plates constituting the ECT sensor, data acquisition system for measuring the mutual capacitance between different plate pairs, and a processing device for image reconstruction and visualization. Each of these individual components has been further developed over the years in terms of both hardware and software capabilities. Most notable are the efforts aimed at developing new imaging reconstruction techniques to extract better images from the limited set of capacitance data. [1]. ECT can be used in a wide range of applications, including monitoring fluidized beds [2], flow rate measurement in pneumatic conveying systems [3], flame and combustion imaging [4] , product uniformity monitoring and sensing [5], high-speed check-weighing and the monitoring of oil-gas flows [6].

1 ELECTRICAL CAPACITANCE TOMOGRAPHY

ECT is used to obtain information about the spatial distribution of a mixture of dielectric materials inside a vessel, by measuring the electrical capacitances between sets of electrodes placed around its periphery (Fig.1.) and converting these measurements into an image showing the distribution of permittivity as a pixel-based plot or image averaged over a volume whose length is equal to that of the measurement electrodes [7].

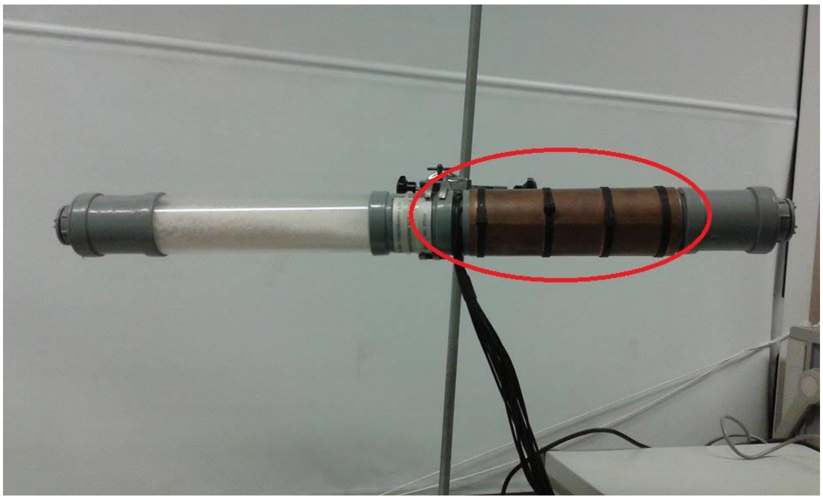


Fig.1. An electrical capacitance tomography demo sensor

The images are approximate and of relatively low resolution, but they can be generated at relatively high speeds. Although it is possible to image vessels of any cross section, most of the work to-date has been carried out on circular vessels. ECT can be used with any arbitrary mixture of different non-conducting dielectric materials such as plastics, hydrocarbons, sand or glass. The permittivity image resolution achievable depends on the number of independent capacitance measurements, but is generally low [7,8] .

1.1 PRINCIPLE OF OPERATION

Figure 2. shows a schematic view of the basic components of an ECT, consisting of capacitance sensors, data acquisition electronics, and image reconstruction/visualization software. The capacitive sensors are used here to blanket the region to be imaged with a static electric field, from which sensitivity maps indicate the regions in the imaging domain from where the changes on the mutual capacitances are being affected. The data acquisition electronics measure the capacitance variations as changes in dielectric material distribution that take place inside the imaging domain. The set of mutual capacitance data measured by the acquisi¬tion system is one dimensional (ID). Nevertheless, imbedded in such data is the spatial information per the sensor design and relative spatial arrangement among the electrode plates. The reconstruction algorithm essentially aims at decoding such two-dimensional (2D) or three-dimensional (3D) spatial information from the ID capacitance measurements [1].

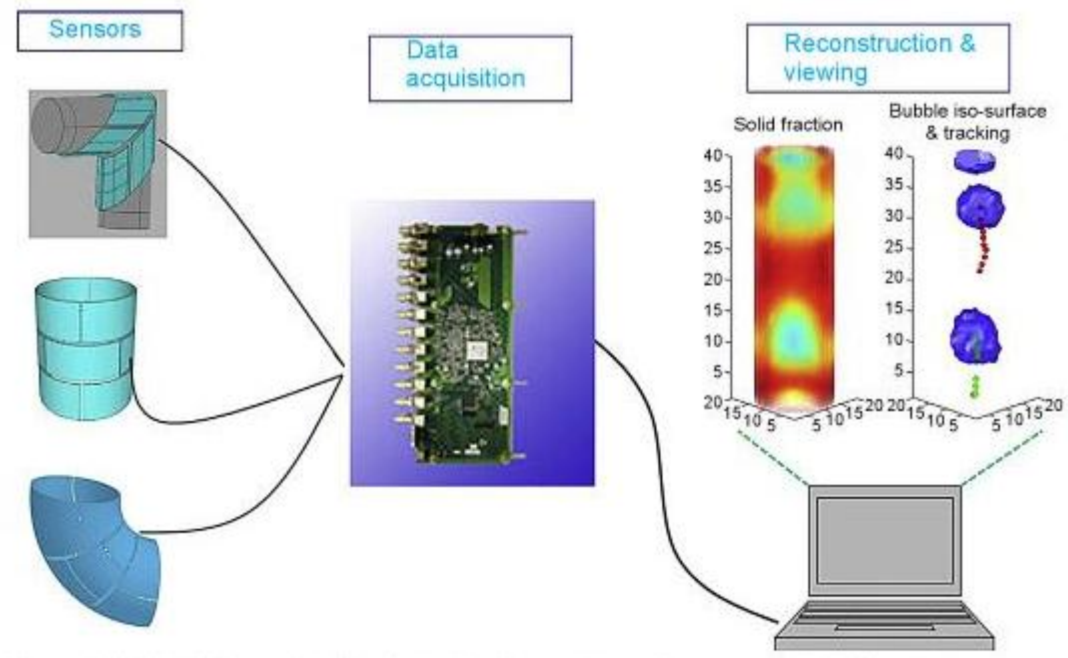


Fig.2 Illustration of the basic electrical capacitance tomography system components

1.2 CAPACITANCE MEASUREMENT PRINCIPLE

The basic capacitance measurement principle used in ECT is shown in figure 3. An alternating voltage (Vs) is applied betwen one electrode (the source electrode) and ground and the resulting currents A which flow between the source electrode and the remaining electrodes to ground are measured. These currents are directly proportional to the capacitances between the source and detector electrodes. The set of capacitance measurements made when one electrode is excited as a source is known as a projection.

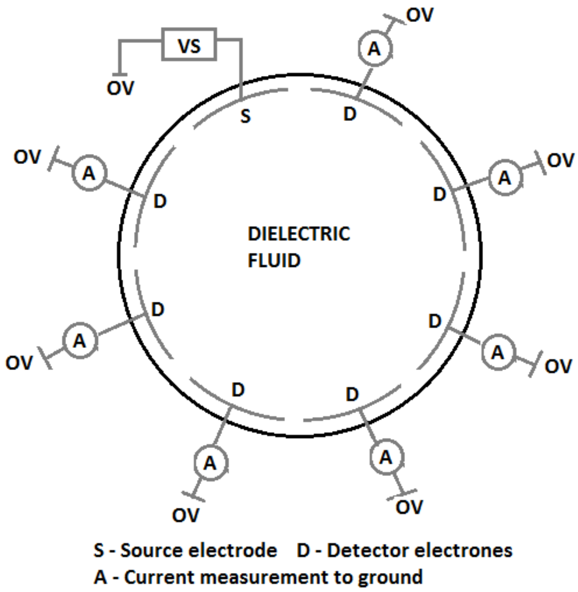


Fig.3. Capacitance measurement principle

1.3 FORMAT OF PERMITIVITY IMAGES

Images can be generated at high frame rates, typically up to 5000 frames per second. Successful applications of ECT include imaging 2-phase liquid-gas mixtures in oil pipelines and solids/gas mixtures in fluidised beds and pneumatic conveying systems. Where the mixture is flowing along the vessel, measurements of the concentration distributions at two axial planes permit the velocity profile and the overall flow rate to be found in some cases. A typical ECT permittivity image format uses a square grid of 32 x 32 pixels to display the distribution of the normalised composite permittivity of each pixel. For a circular sensor, 812 of the available 1024 pixels are used to approximate the cross-section of the sensor [7].

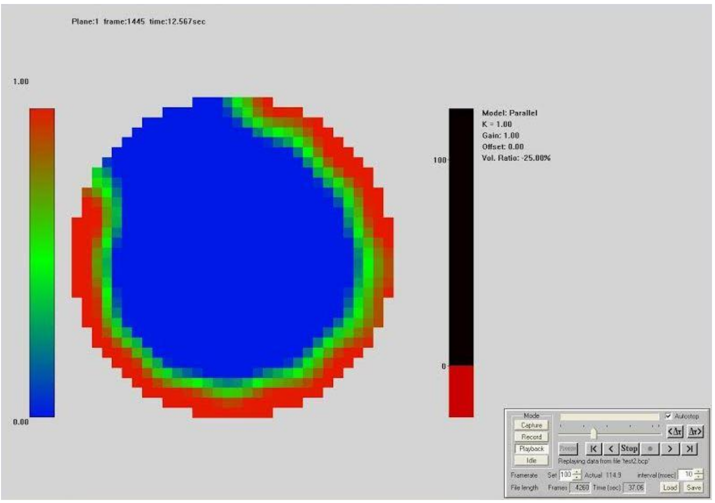
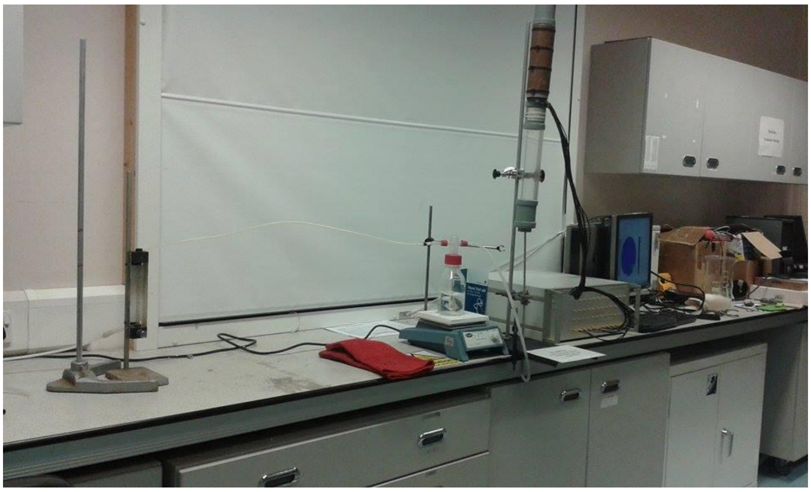


Fig.4. ECT image for contents of a circular sensor

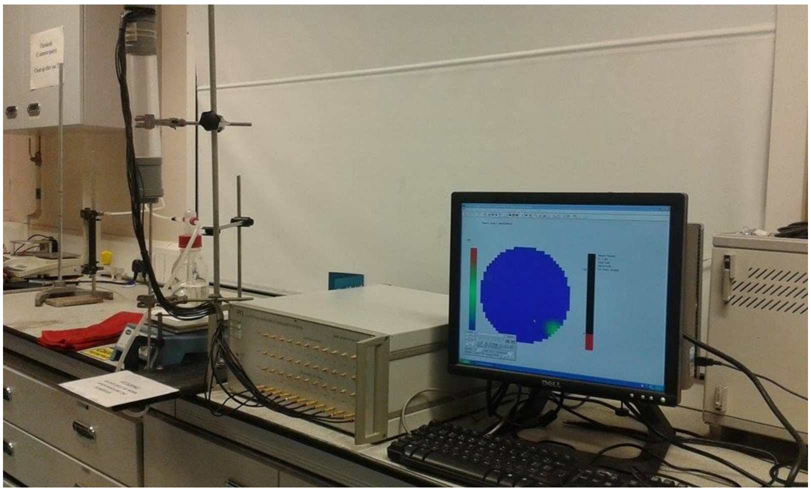
The concentration distribution is normally plotted on a fairly coarse pixel grid, because the relatively small number of available measurements limits the possible image resolution. In the sample images shown below, a red/green/blue colour scale shows areas of high concentration as red and areas of low concentration as blue – is shown in figure 4.

2 EXPERIMENT

The experiment as the set up shown in Figure 5 A, B - consists of manometer, a humidifier with heated water in a glass container. The glass container has an inlet and an outlet on its top. The inlet is for pressurised air supply via the manometer, which guides the air into the water and the other is for steam extraction, which will guide the steam to the test tube. An electrical capacitance tomography sensor with 12 electrodes and computer is installed to the central location of the test tube.



A



B

Fig.5. Set up of experiment A, B

Calibration was the first step of the experiment. Silicone beads (Figure 6.) were used to fill the sensing volume where an electrode-based ECT sensor was installed. The concentration distribution was drawn in a colour pallette the high concentration areas shown in red and low concentrations shown in blue.

Fig.6 Silicone beads in ECT area

Then we tried to find out whether it is possible to detect the steam flow in air by ECT. The steam from the water contaner passes through a tube directly inside a vessel with electrical capacitance tomography sensors. The next six pictures (Figure 7) show the measurement procedure. successively red area increased around the edge of the measuring area due to the big contrast from the image of condenser water layer, because was a big temperature difference between steam and construction ECT. This has led toand that the steam can not be visualised, because measurements were affected by the condensation of steam on the wall.

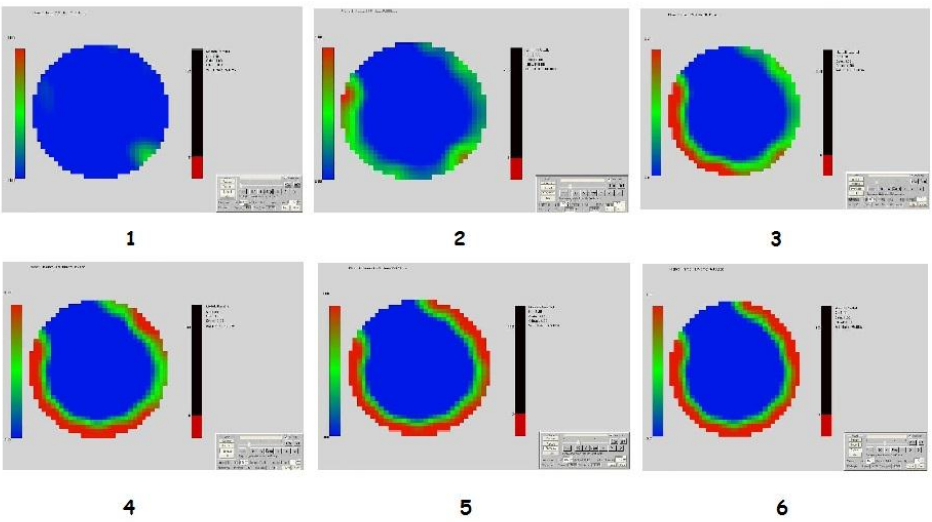


Fig.7. The measurement procedure

3 CONCLUSION

During the experiment, an effect of condensation on the wall of the ECT sensor was found, which resulted in the steam flow could not be visualized due to a big contrast from the condensed water layer and air-steam mixture flow. Therefore, it is necessary to gather comments and carry out further research to overcome the problem. One of the proposals is on the set up of experimental devices and other issues should also be improved in the future, for example, the suitable calibration materials and the method of forming and motiving steam in future. Condensation could be avoided by the use of a heated ECT sensor or – an ECT with a new concept sensor .

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