INVESTICE DO ROZVOJE VZDĚLÁVÁNÍ

Project „Budování excelentního vědeckého týmu pro experimentální a numerické modelování v mechanice tekutin a termodynamice“

Project registration number: **CZ.1.07/2.3.00/20.0139**

The final report of internship at the University of Leeds

Ing. Katarína Ratkovská

topic n. 6 Measurement methods TM and MT - tomography, applicability in experimental turbines

Pilsen
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EVROPSKÁ UNIE

MINISTERSTVO ŠKOLSTVÍ, MLÁDEŽE A TĚLOVÝCHOVY

OP Vzdělávání pro konkurenceschopnost

INVESTICE DO ROZVOJE VZDĚLÁVÁNÍ

Internship at the University of Leeds

Name : Ing. RATKOVSKÁ Katarína
Department: KKE – Department of power system engineering
Date of internship: 16.8.2014 – 16.10.2014
Internship was interrupted in the period 15.9.2014 – 21.9.2014 (7 days)

1. University of Leeds

The University of Leeds was founded in 1904, but its origins go back to t-he nineteenth century with the founding of the Leeds School of Medicine in 1831 and then the Yorkshire College of Science in 1874.

It wasn't long, however, before each of the cities started to consider the benefits of forming their own universities. After Manchester and Liverpool had taken the decision to establish universities, Leeds also took the leap and in 1904, King Edward VII granted the University its own Charter as an independent institution.

The university has around 33,500 students the eighth-highest number of any university in the UK.

The university is a founding member of the Russell Group of research-intensive universities, the N8 Group for research collaboration,[10] the Worldwide Universities Network, the Association of Commonwealth Universities, the European University Association, the White Rose University Consortium, the Santander Network and CDIO and is also affiliated to the Association of MBAs, EQUIS and Universities UK.

UNIVERSITY OF LEEDS

Figure 1 Logo of University of Leeds

The various schools, institutes and centres of the university are arranged into nine faculties, each with a dean, pro-deans and central functions:

- Arts (English; History; Humanities; Institute for Colonial and Postcolonial Studies; Leeds Humanities Research Institute; Institute for Medieval Studies; School of Languages, Cultures and Societies;)
- Biological Sciences (Institute of Membrane and Systems Biology; Institute of Molecular and Cellular Biology; Institute of Integrative and Comparative

Biology; Undergraduate School of Biological Sciences; Graduate School of Biological Sciences)

- Business (Accounting and Finance; Economics; International Business; Management; Marketing; Work and Employment Relations)
- Education, Social Sciences and Law (Education; Law; Politics and International Studies; Sociology and Social Policy; Graduate School)
- Engineering (Chemical and Process Engineering; Civil Engineering; Computing; Electronic and Electrical Engineering; Mechanical Engineering)
- Environment (School of Earth and Environment; School of Geography; Institute for Transport Studies)
- Mathematics and Physical Sciences (Chemistry; School of Food Science and Nutrition; Mathematics; Physics and Astronomy)
- Medicine and Health (Leeds Dental Institute; School of Healthcare; School of Medicine; Leeds Institute of Genetics, Health and Therapeutics; Leeds Institute of Health Sciences; Leeds Institute of Medical Education; Leeds Institute of Molecular Medicine; Institute of Psychological Sciences)
- Performance, Visual Arts and Communications (Institute of Communications Studies; Design; School of Fine Art, History of Art & Cultural Studies; Music; Performance and Cultural Industries; Graduate School)

Figure 2 University of Leeds

Chemical and Process Engineering is department of Faculty of Engineering where operates professor of process tomography and sensing **Mi Wang**.

The School of Chemical and Process Engineering is a multidisciplinary school, addressing a range of global and societal challenges across the areas of Chemical Engineering, Energy and Materials Science.

Process Tomography, or CAT Scanning (Computer Aidded Tomography), as a generic, non-intrusive visualisation tool, offers new opportunities for full 3-D interrogation in both medical diagnosis and industrial process monitoring. This and other new imaging technologies are far more effective than our eyes for visualising the complex internal structure and fluid dynamics previously inaccessible due to a combination of the opaque nature of surrounding materials, the presence of hazardous materials, inaccessibility and, in many cases the need to be none invasive. Mi Wang deals with this topic – Tomography.

2. Processing of internship

I was first met with professor Mi Wang during his lectures on the University of West Bohemia in Pilsen, topic was tomography.
As a Ph.D. student I spent with him the whole length of his stay in Pilsen, during this time I learned a lot informations about tomography. Since doc. Ing. Jíří Polanský, Ph.D., within the project worked closely with Professor Wang, agreed to my internship at University of Leeds.

The next step was to fix the date and duration of the internship. I communicated with Professor Mi Wang and than I consulted information doc. Ing. Jíří Polanski, Ph.D., as my supervisor and Ing. Roman Cermak, Ph.D., who co-ordinated action by the project. After approval of the internship I wrote „Príkaz na zahraničnú pracovnú cestu“ in which I asked for a deposit.

Contract for the Internship, which serves as an official document for all involved, students, University of Leeds and University of West Bohemia prepared by Ing. Roman Čermák, Ph.D.

Contact person:	Mi Wang
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http://www.engineering.leeds.ac.uk/ipse.old/people/wangmi/wangmi.shtml

With transport and accommodation helped me doc. Ing. Jíří Polanski, Ph.D., and Ing. Roman Čermák, Ph.D., because they already were situated in Leeds.

3. The course of my internship at the University of Leeds

The traineeships was to familiarize and master measurement technology PIV - Particle Image Velocimetry and tomography.

In the first week I complained through security training, so I can work in a laboratory, training in computer programs for measurement data as SCG, Fast (FICA) SYSTEM`S operation, led by Dr. Yousef Faraj and I attended lectures on tomography, prepared for us by Prof. Mi Wang.

Figure 3 Work team in Leeds

The following week I complained informed of the experiments in a lab, I attended PIV measurements with students at donktorskom program, John Vickers, his experiment. The water tank is measured by the flow of liquid by the drill bit, fluid is agitated. The measured data and at present I am working and I want to use the results of his dissertation.

Experiment of John Vickers

The rig consists of a glass testing tank which can be seen in Figure 4, with a fluid jet inlet suspended above, and this jet inlet is connected via a pump to a feed tank. The test tank has an overflow system which empties into an overflow tank which then pumps the fluid back up to the feed tank. The entire system is on a moveable frame with removable panels to shield the operator from scattered laser pulses when the rig is in operation. A schematic of the entire rig is shown in Figure 5.

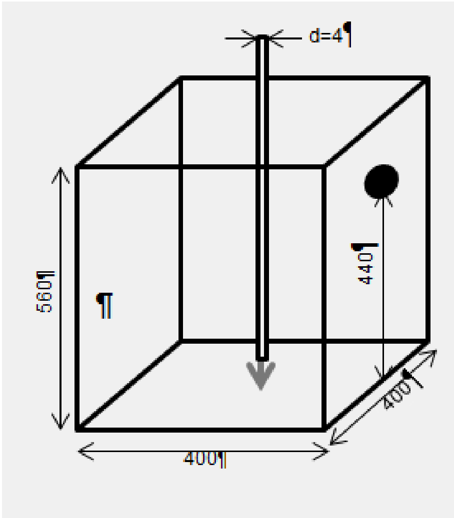


Figure 4 Diagram of test tank used

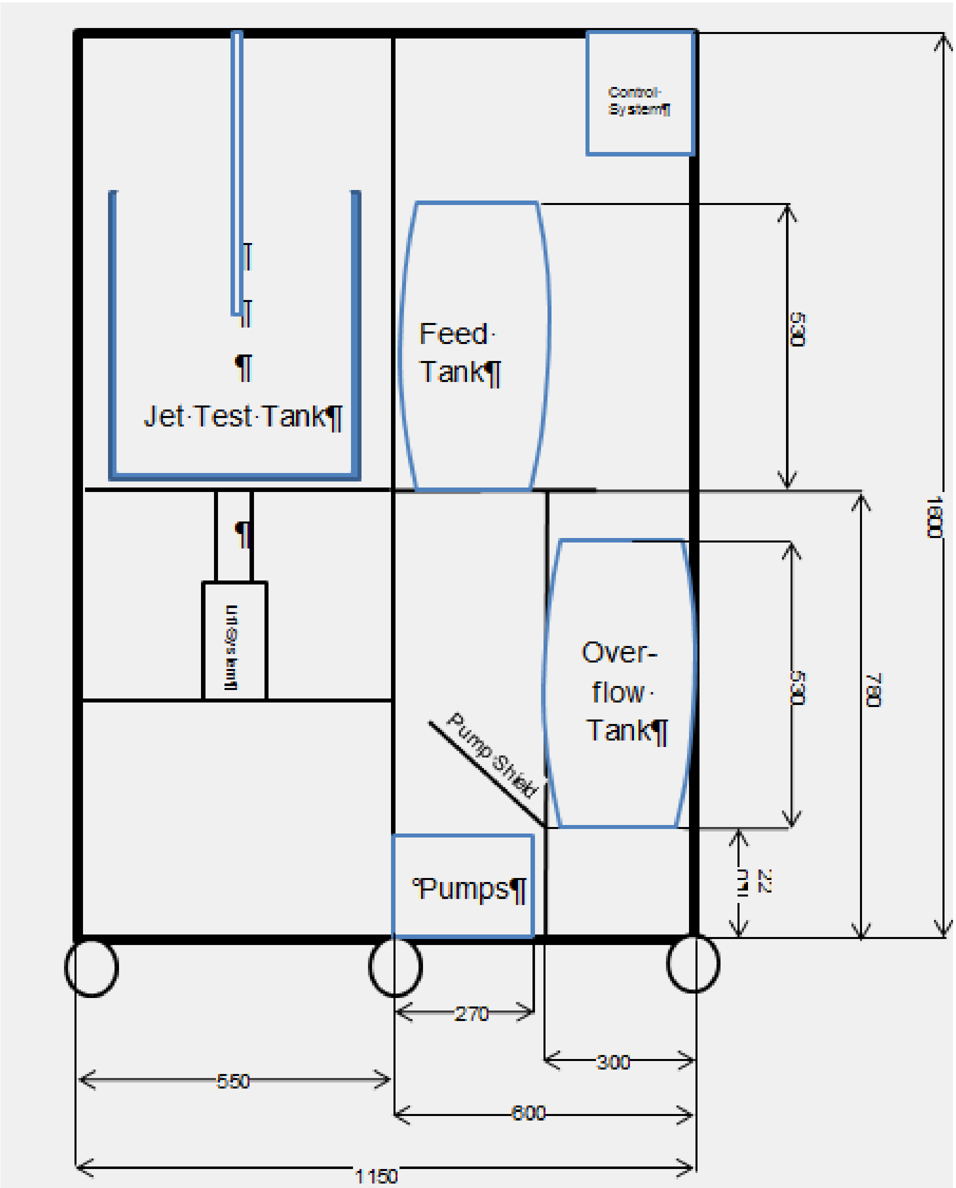


Figure 5 Schematic of impinging jet rig

Seeding particles: The focus of this investigation is into developing the techniques for fluorescent PIV, for this reason it was important that fluorescent tracer particles were used to track the fluid motion, thereby providing experience. The particles used were FPP (Fluorescent Polymer Particles), The particles are spherical with a mean particle size of 10µm over a range of 1-20 10µm and are made of Poly (Methyl methacrylate) homogenously doped with Rhodium B. The refractive index of these particles is 1.479 and they have a density of 1.19g/cm^3.

Laser: The laser used was a double-cavity Nd:YAG laser firing at a rate of 15hz, before being entering the testing tank it was diverted through a series of optics to cause the beam to diverge and form a light sheet.

Figure 6 Laser

Camera: To record the images a 12 bit cross correlation CCD camera was placed perpendicular to the light sheet, the model was a Flowsense 2M which has a maximum resolution of 1600 x1200 pixels and a buffer large enough to store 63 image pairs.

Figure 7 Camera

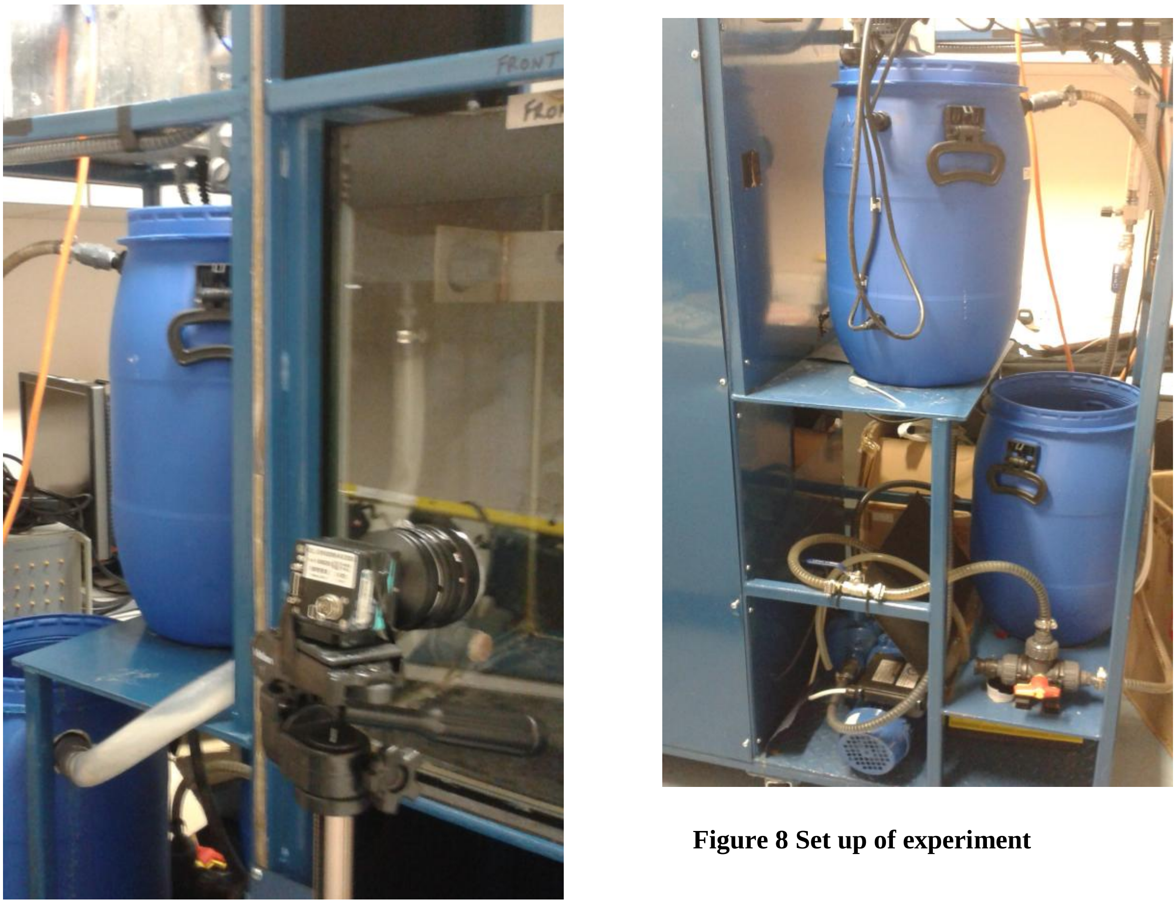


Figure 8 Set up of experiment

The next step is to actually track the movement of the tracer/solid phase particles. A function called adaptive PIV does this in Dynamic Studio. This is an adaptive method for the calculation of velocity vectors. The size and shape of the interrogation areas is iteratively adapted to account for seeding densities and flow gradients to ensure an optimal number of particles is within each interrogation area. It also has the advantage of ensuring that more time is spent processing areas of interest. This is of vital importance with limited processing time. The method allows various parameters to be defined such as the desired number of particles per interrogation area, a particle detection limit and the areas to be interrogated.

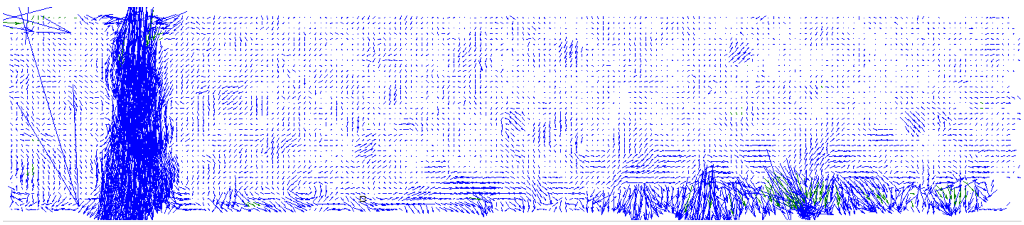


Figure 9 Initial velocity vectors after correlation performed between image pairs

For more info about the experiment you contact John Vickers. His mail address: mn09jv@leeds.ac.uk.

PIV experiment on water pipes:

I am preparing an experiment to measure PIV. The measurement results had be compared with the results of tomograph measurements. Part of the experiment was to write COSHH form, it's a safety report, which covers all possible hazards in the workplace during an experiment, also includes measures to avoid that risk and also the solution for the case that the occurrence of complications during the measurement.

As the safety work in England is very sensitive, rulemaking and subsequently approval takes a long time, during my stay in the UK experiment has not been approved.

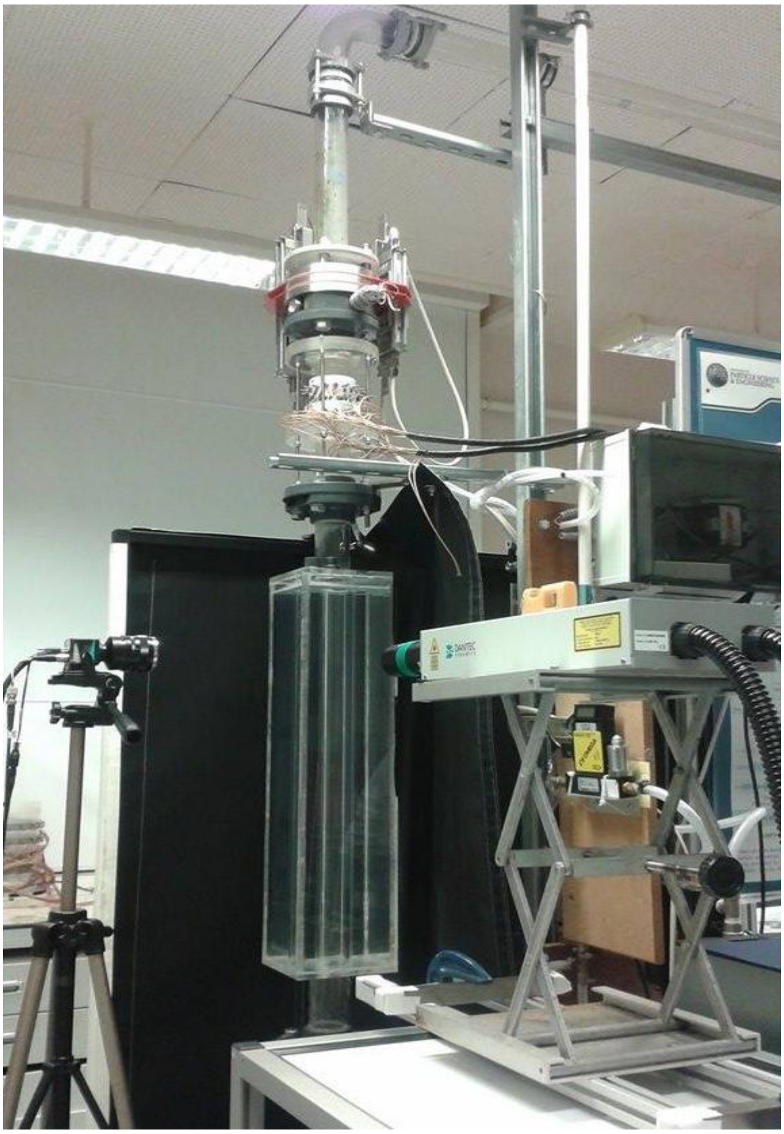


Figure 10 Set up of PIV experiment

In the closing days of internship I dealt tomography. Professor Wang Mi consulted with me this issue and the following day I experiment to verify whether it is possible to detect vapor in the air stream by tomagrafu. Experiment I as an engineer Bob Harris has prepared a measurement took place one day. The results of the measurements was filmed short message and I have participated in „4th INTERNATIONAL SCIENTIFIC CONFERENCE OF PH.D. STUDENTS AND YOUNG SCIENTISTS AND RESEARCHERS“ in Košice, 14 – 15. 5.2015. Title of paper: DETECT FLOW OF STEAM IN AIR BY ELECTRICAL CAPACITANCE TOMOGRAPHY.

Detect flow of steam in air by electrical capacitance tomography

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.

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 [3].

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 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. [3]. ECT can be used in a wide range of applications, including monitoring fluidized beds [4], flow rate measurement in pneumatic conveying systems 5], flame and combustion imaging [6] , product uniformity monitoring and sensing [7], high-speed check-weighing and the monitoring of oil-gas flows [8].

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.11.) 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 [9].

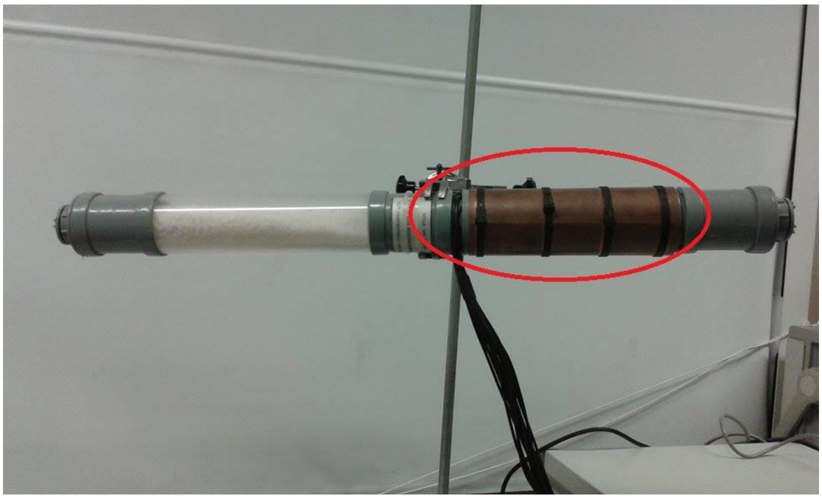


Figure 11 . An electrical capacitance tomography demo sensor

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 [9,10].

Priciple of operational

Figure 12. 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 [3].

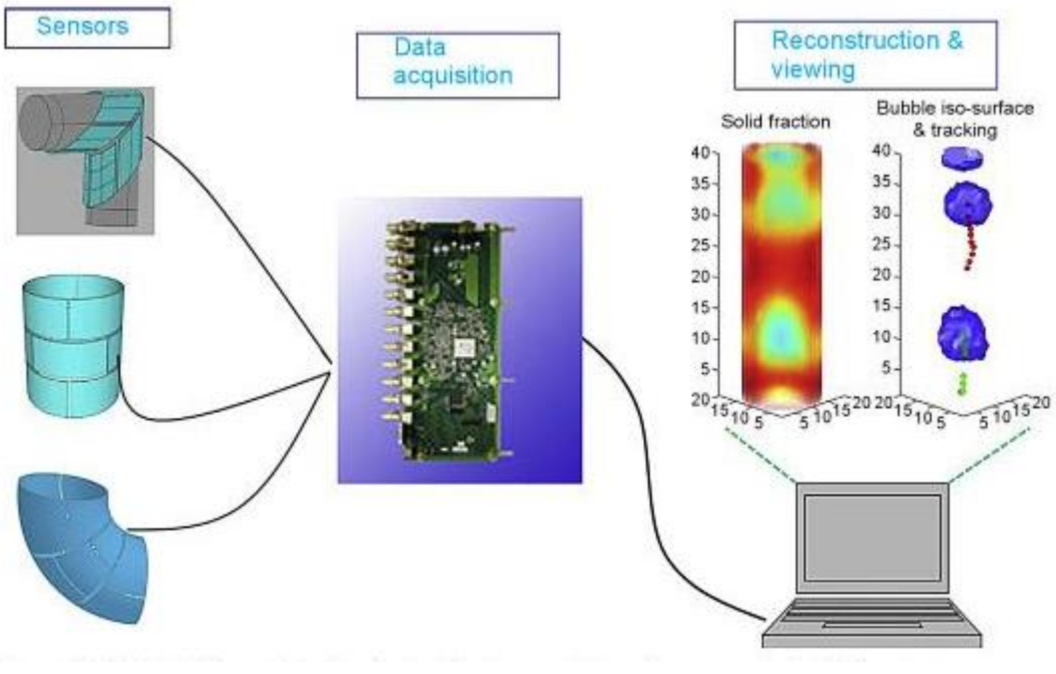


Figure 12 Illustration of the basic electrical capacitance tomography system components

Capacitance measurement principle

The basic capacitance measurement principle used in ECT is shown in figure 13. 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.

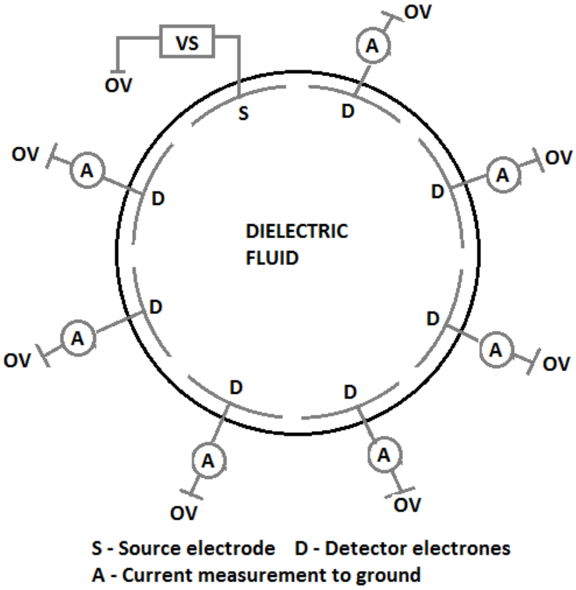


Figure 13 Capacitance measurement principle

<u>Format of permitivity images</u>

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 [9].

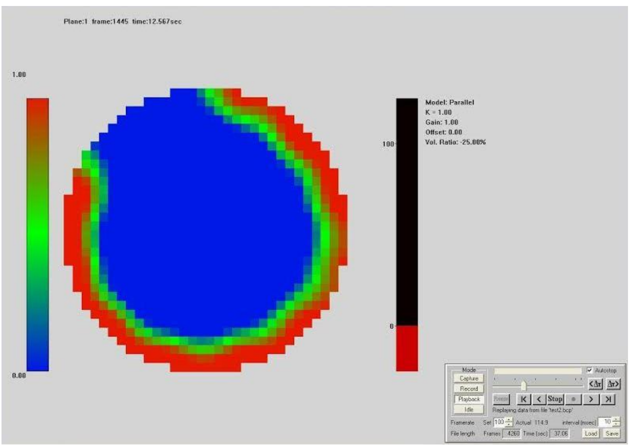
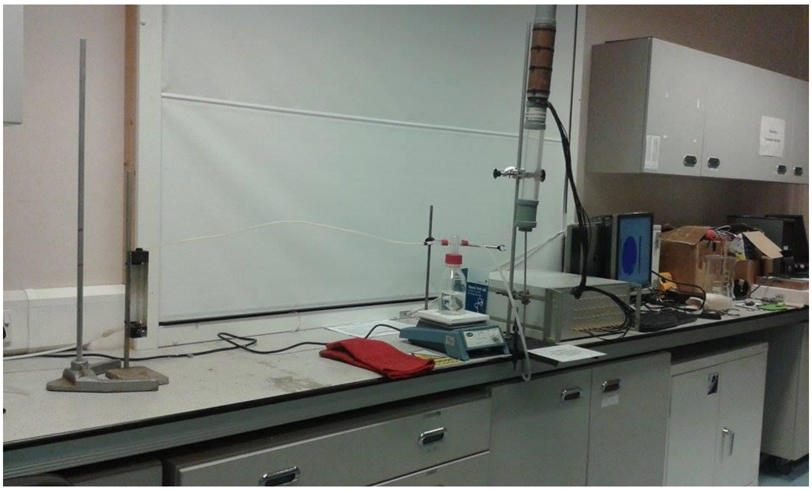


Figure 14 . ECT image for contents of a circular sensor

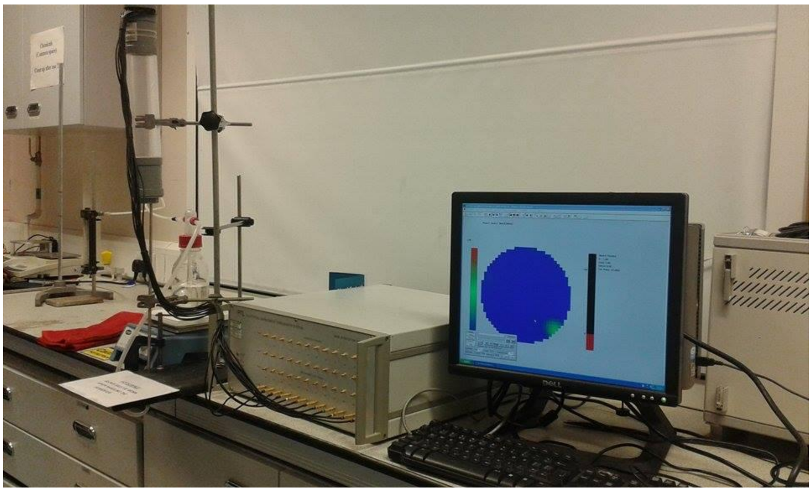
The concentration distribution is normally plotted on a fairly coarse pixel grid, because the relatively small number of available measurements limits the possible image resolution. In the sample images shown below, a red/green/blue colour scale shows areas of high concentration as red and areas of low concentration as blue – is shown in figure 14.

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

Figure 15 ***Set up of experiment A, B.***

Calibration was the first step of the experiment. Silicone beads (Figure 16.) 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.

Figure 16 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 17) 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.

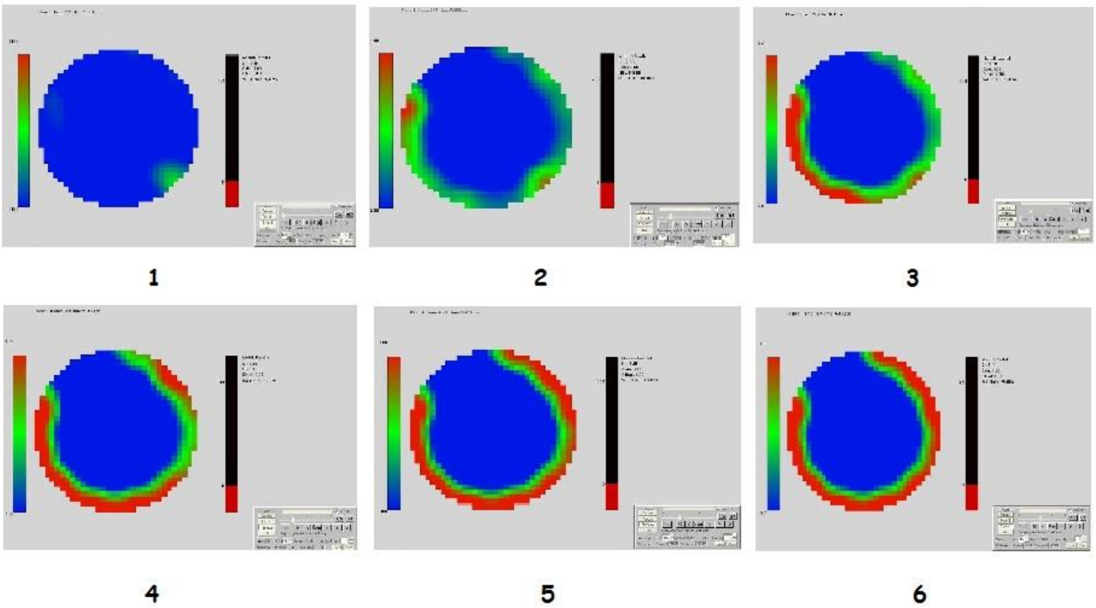


Figure 17 The measurement procedure

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.

Literature

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