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Control, Instrumentation and Mechatronics: Theory and Practice

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Preface

The 3rd International Conference on Control, Instrumentation and Mechatronics Engineering, CIM 2022 is organized by the School of Electrical Engineering, Universiti Teknologi Malaysia and supported by the Malaysian Simulation Society (MSS) and Malaysian Society for Automatic Control Engineer (MACE). The 1st and 2nd CIM have traditionally been held physically. However, the COVID-19 pandemic affects the lives and activities of many people, and this has made it necessary to organize the 3rd CIM 2022 as an online event.

The CIM 2022 conference provides a platform for knowledge-sharing and research activities in Control, Instrumentation and Mechatronics. The conference aims to bring together researchers, building a strong networking and research collaboration in the listed areas. In bringing CIM 2022 into reality, the organizing committee have made an enormous effort to maximize opportunities for our virtual discussions. Our technical program is rich and varied with five technical sessions providing key research topics in realizing Industry 4.0 vision. CIM 2022 technical program also strives for prestige by inviting distinguished speakers who are expert in their fields. We have one keynote speech and two invited speeches from three different countries, together with 73 technical papers. Furthermore, the high impact of CIM is also ensured through the spread of authors from different parts of Malaysia, as well as from other countries.

The success of the conference depends ultimately on the hard work, support and dedication of numbers of parties, who have worked with us in planning and organizing both the technical program and supporting social arrangements that make CIM 2022 a successful online event. The organizing committee have been working throughout the year to make the conference successful. Recognition should go to all CIM 2022 committee members who have all worked extremely hard for the details of important aspects of the conference programs and social activities, virtually. Special thanks to the Ministry of Science, Technology and Innovation (MOSTI) for the support and to our sponsors, SYNAPSE, MSS, AR Mechatronics, DF Automations & Robotics, JEOL and Worldbay Network System and, last but not least, to all the submitters and reviewers who are the backbone of this conference.

This Lecture Notes in Electrical Engineering entitled Control, Instrumentation and Mechatronics: Theory and Practice is a compilation of all the accepted and presented papers at CIM 2022. All the papers were peer reviewed by a minimum of two reviewers from different institutions to ensure the quality of the papers. The conference received 135 paper submissions, and only 73 papers were accepted after the review process. The articles published in this proceeding are divided into three parts which are Mechatronics (22 articles), Control Systems (27 articles) and Measurement and Instrumentation (24 articles).

We hope that the proceeding will benefit readers, in particular, researchers, academicians and practitioners in the area of Control Engineering, Mechatronics and Instrumentation.

Thank you.

Contents

Hardware Development of Dual-Modality Tomography Using Electrical Resistance and Ultrasonic Transmission Tomography for Imaging Liquid and Gas

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Abstract. In decades, single-modality technique focuses on particular application such as liquid/gas, gas/solid, liquid/liquid and liquid/solid which has drawbacks in imaging complex flow with multiple components. This paper focuses on the development of dual-modality tomography system (DMT) integrating ultrasonic tomography and electrical resistance tomography (ERT) to visualize cross-sectional images of two-phase liquid/gas in vertical column. A combination of soft-field and hard-field tomography system measures different physical parameters of two-phase liquid/gas specific of two different material properties which are conductivity (σ) and acoustics impedance (Z). A DMT system is developed with 16 units of ultrasonic transceiver sensors, and 16 units of ERT electrode positioned alternately on a single-plane arrangement to perform measurement simultaneously. The reconstructed tomographic images obtained from measurement data from these two modalities are then fused into a single tomographic image by employing discrete wavelet transform (DWT).

Keywords: Dual-modality tomography · Discrete wavelet transform

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1 Introduction

The introduction of dual-modality tomography system has gained popularity among researches in process industry. The capability of the system to distinguish between the components which are involved in a process within the object space using same measurement field has engaged researchers over the current single modality system. Nowadays, multi-phase flow is a complex mixture with both composition and flow regime have drawn attention of many researchers to identify alternative methods with the objective of producing reliable, fast, accurate, affordable and safe tomography measurement system. Many flow measurement principles have been used on single-component flow, whereas others have utilized multi-component flows. For many decades, it provides information on how the components are mixed and their relation to each other which is particularly important for the stability and effectiveness in process control systems.

There are various methods of single modality which currently being used for monitoring the two- phase process flow. This includes implementation of ultrasonic tomography (UT) and electrical resistance tomography (ERT) that have been widely used to obtain information from different medium in a wide range of industrial applications such as in multi-phase flow measurement and process monitoring [1]. Although both methods have proven their usefulness in process industry, a great number of researchers and institutions have their interest and time invested on UT and ERT development [2, 3], there are still existing more great opportunities to improve and innovate these well-known methods by the design and use of new sensing techniques, algorithms and hardware development. Dual-modality tomography has been recognized as a possible solution for the limitations on both UT and ERT methods, exploiting the best characteristics of UT and ERT. It is expected that the construction of a system with these advantages would satisfy the requirements for imaging multi-phase media.

The aims of the paper are to design and develop a dual-modality ERT and UT system for liquid/gas visualization application measuring the liquid/gas two-phase flow system for a two-phase application for non-conducting vertical column. The study focuses on the design and development of dual-modality ERT and UT which employ 16 ERT electrodes and 16 ultrasonic transceivers arrangement to increase the number of measurement. The system proposed in this study is expected to improve the performance of currently used ERT systems which deteriorate in conductive distribution at central region and to be a first step towards the integration of a dual-modality tomographic system.

2 Multi-modality Tomography Imaging in Two-Phase Flow

In decades, there were researches focusing on multi-modality tomography particularly in multi-phase flow. Deng et al. [4] conducted two-phase liquid/solid in slug flow by applying electromagnetic flow meter and ERT. This was followed by Hwili et al. [5] who conducted multi-modality tomography using ECT and electromagnetic sensors for visualizing two-phase water/oil flow. For two-phase liquid/gas, Meng et al. [6]

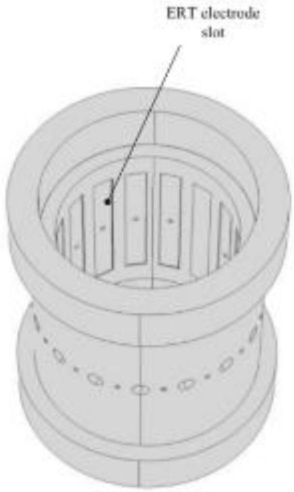

Fig. 6. ERT electrode slot inside the DMT sensor jig

The sensor arrangement of the DMT system in 2D view is shown in Fig. 7. It was assumed during the simulation that these electrodes have electrical contact (boundary conditions) with the medium inside the senor jig. Applying measurements and excitation on the same sized electrodes helps reduce loss of measurements sensitivity at minimum level [1]. In the simulation process, adjacent strategy was adapted with ac current source.

From the simulation results that has been carried out presented in [13], wide electrodes improve the evenness of the field distribution in the medium of interest, which improve signal strength. Hence. this helps to improve the ability of object detection, particularly in the central region. However, in the proposed single-plane dual-modality UT-ERT system, wider aluminium of 12 mm electrodes resulted in the reflection of ultrasonic waves during propagation in a cylindrical cell medium. Simulation results presented in Fig. 8 show that 12 mm rectangular electrodes cause the reflection of some propagated waves and cause reduction in receiving signal amplitude.

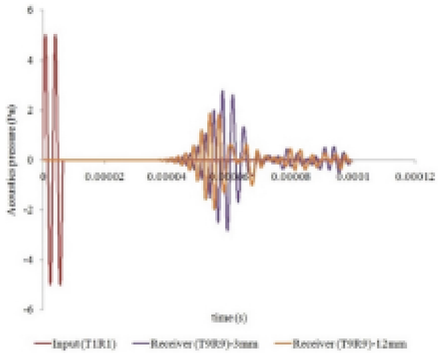

Fig. 7. Comparison received signal at Rx9 with width 3 mm and 12 mm electrode

Considering the drawback, the proposed ERT electrodes equipped with curvature at both sides on the centre electrodes. Thus, it gives centre of ERT electrode with width of 3 mm as shown in Fig. 8.

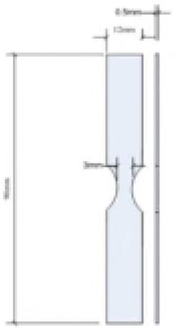

Fig. 8. Proposed ERT electrode for DMT system

From the study undergone in the sensor arrangement section, the sensor jig hardware to accommodate the ERT electrode and UT sensors has been developed as in Fig. 9. The internal and external diameter of the sensor jig column is 100 mm and 110 mm respectively was fabricated using polyvinyl chloride (PVC) material for placing ERT electrodes and ultrasonic transceivers. Both sensor types were arranged on a same plane located at the centre of the sensor jig.

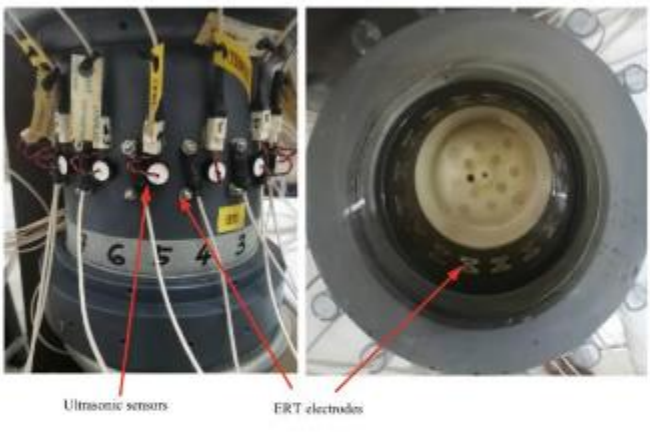

Fig. 9. Sensor jig to accommodate ERT electrode and UT sensors.

Electronic Circuit. A sufficient amount of energy is required for ultrasonic excitation operation. In producing ultrasonic transmitting signal burst tones, a low voltage of 15 V is required. The burst tone comprises of two-cycle short pulse with 328 kHz frequency generated by the microcontroller to produce ultrasonic wave. Short pulse is required to avoid longer echoes at the receiver. The burst tones were produced using excitation circuit consisting of 2N7002 N-channel MOSFET. Figure 10 shows the ultrasonic pulse excitation circuit implemented in the study. Microcontroller provides the gate

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