Further study on multiphase flow measurement with wire-mesh sensors

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ABSTRACT

Abstract. A relatively new tomography system in the process tomography, wire-mesh sensor is an intrusive and invasive type of sensor used for flow measurement. Several research have been conducted previously to improve the design and accuracy factors of the sensor and still undergoing some changes. Using copper as the medium of electrodes and having two layers of measuring unit transmitter and receiver in a closer distance this sensor proves it is still a viable option in the process tomography for multiphase flow measurement. A 16 x 16 wire-mesh sensor was designed and applied in this study to obtain the raw data from the target flow. The sensor worked together with transceiver circuit and data acquisition and image reconstruction software to visualize the flow condition and void fraction.

Keywords: Wire-mesh, tomography, void fraction, multiphase

1. Introduction

Wire-mesh tomography was first introduced by H.M. Prasser [1] as a different type of measurement unit for fluid flow measurement. Then several experiments on wire-mesh conducted with mostly similar sensor design with a different approach on soft-ware. Unlike other tomography methods, the image reconstruction for wire-mesh sensor is still 2-D. While there are experiments with wire mesh sensors that involves 3-D image reconstruction, these sensors would be used as a secondary or back-end system for the tomography system used. Recent studies on wire-mesh sensors had used Python as the programming platform for image reconstruction. Accuracy, temporal resolution and other image reconstruction factors were considered to improve the sensor. This paper would discuss several similar experiments and the improve-ment made from a pre-built wire-mesh sensor.

2. Wire mesh sensor

The basic principle of wire-mesh tomography in different experiments are similar. The basic construction is to have 2 layers perpendicularly located where one is transmitter and the other is receiver. This sensor has two types of operating principle which measured using conductivity and permittivity value through investigation area. Measurement occurs when fluid passes through the sensors which make current flow from one plane to another causing change in conductivity or permittivity.

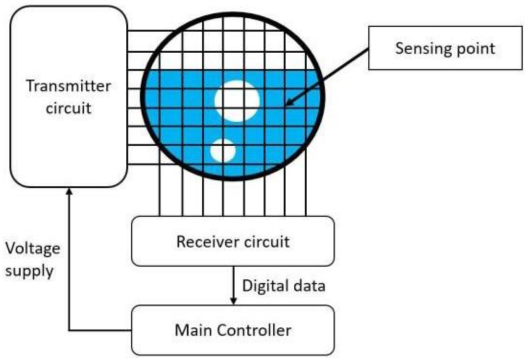

Figure 2: Simplified design of wire mesh tomography system

Figure 2 shows simplified design of wire mesh tomography system. Wire mesh tomography system can be split into 3 main parts, wire mesh sensor, electronic system and image reconstruction. Wire-mesh sensors measure characteristic multiphase flow parameter by a grid of fine wire electrodes in the flow cross-section. Each crossover of wires on transmitter and receiver plane will be forming a sensing point and each of them represent one pixel on the reconstructed image. This project is focusing on a wire mesh tomography using fluid conductivity approach to measure the instantaneous distributions of phases of conducting fluids. The data captured by the wire mesh sensor will be analysed and converted to an image in showing the void fraction of the flow.

16 channels wire mesh sensor is used in this project as it is sufficient to analyse liquid gas interface. Doubled the channels will increase the time required in reconstructing tomogram results and increase the cost of the project. Hence, 16 channels provide the best cost-effective solution.

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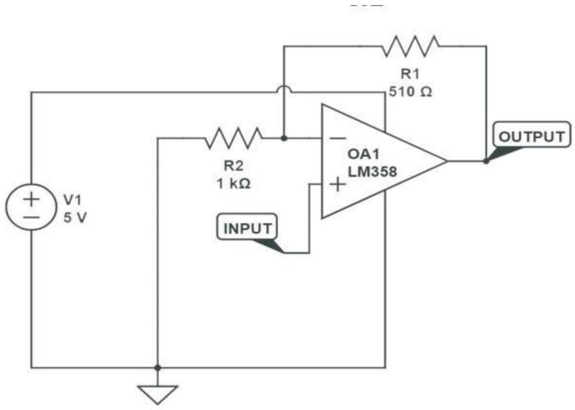

Figure 3: Level shifter circuit

The op amp used is LM358 and which is a dual pack op amp in one single unit. A total of eight LM358 dual op amps are used to provide sufficient connection between 16 receiver channels. Resistors, R_1 and R_2 should be as low as possible to reduce the resistor noise or thermal noise generated by themselves which might cause noisy or inaccurate result [6]. Op amp tends to be nosier at low frequency due to the existence of 1/f noise from the op amp itself. Thus, it is importance in selecting low noise op amp.

For this project, a simple image reconstruction technique is used to avoid complex image reconstruction algorithm reducing system framerate [2]. Excitation signal is sent to the transmitter plane from wires to wires orderly. Each wire on the transmitter plane will be supplied with constant voltage supply in sequence and image reconstruction started.

3. Data Analysis

One of the current research on wire-mesh studied on the multiphase liquid flow and a simulation had been done to compare the results to study the flow behaviour. A 2D asymmetric model had to be created to investigate the liquid flow for multiphase flow. 2 types of liquid had been tested, first is transformer oil and the second one is water. The figure 6 shows initial value which is nearby 0 in velocity and there was some movement in liquid.

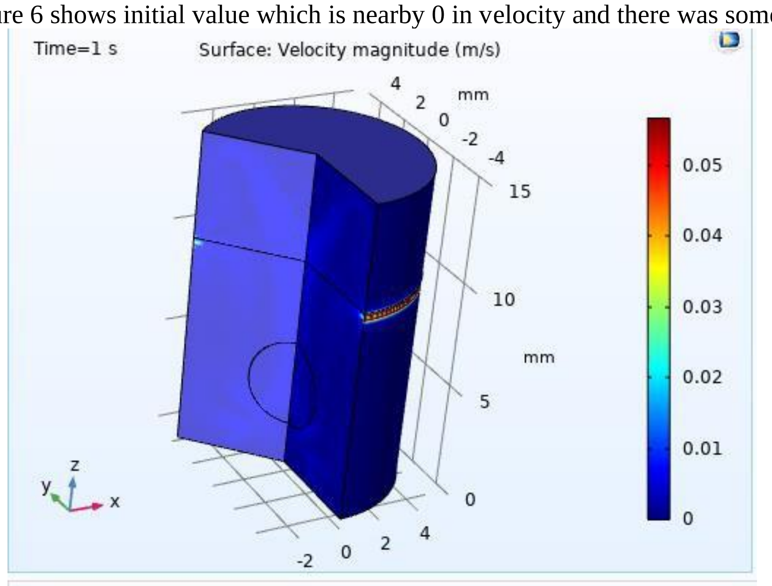

Figure 4: Asymmetric 2D image of velocity

So after the simulation started, the velocity changes when the transformer oil particles flow through the water. Between the height of 5mm to 10mm, higher velocity fluids detected which transformer oil flowed within the viscosity and created a much pressure in the region.

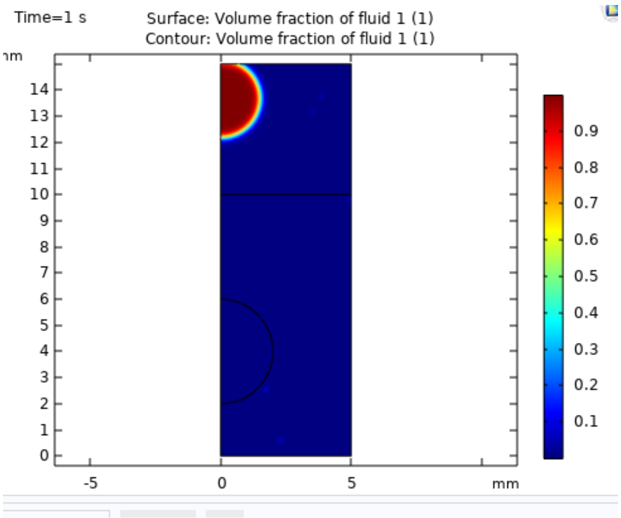

Figure 5: Volume fraction of liquids

So in figure 4, the volume fraction of oil is shown where it flows from 2 mm to 12 mm. The volume fraction consists of velocity and pressure. The velocity was in maximum value as the pressure and the pressure was at maximum before the flow ended.

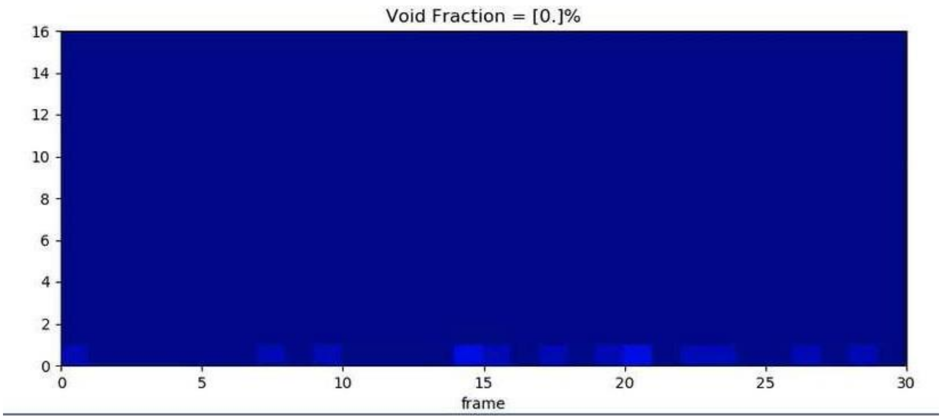

Figure 6: Empty pipe tomogram result

Two analysis which on empty pipe and full pipe conducted to view the tomogram images. The pipe was filled with surrounding air but with the absence of water. All of the sensing points on transmitter planes and receiver planes are not connected. There is slightly fluctuation on conductance measurement between 0 to 1 S/cm² comparing to 0 S/cm² (theoretical value) which is mainly due to the remaining water droplets on the wire mesh sensor. The void fractions for each frame are 0% and the average void fraction for the condition is 0% which is same with the theoretical void fraction, 0%. This shows that system able to generate high accuracy results on gas only process column with a maximum percentage of error of 0%.

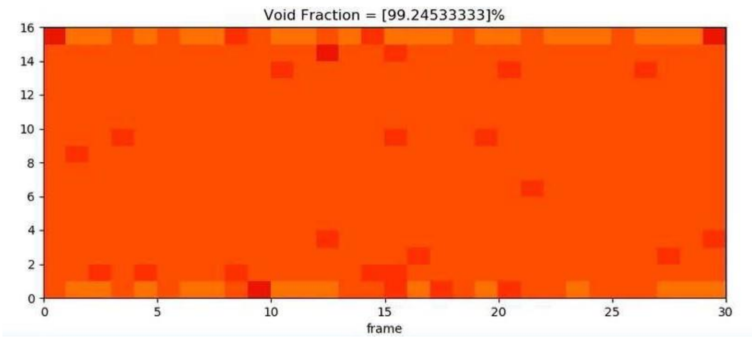

Figure 7: Full pipe tomogram result

Similar with previous results, slightly fluctuation on conductance measurement occurred between 20 to 25 S/cm² comparing to 20 S/cm² (theoretical value). The inconsistent conductance measurements are possibly caused by the minerals within water or the surrounding noise. The void fractions for each frame vary between 98.66% to 99.75% and the average void fraction for the condition is 99.25% where the theoretical void fraction should be 100%. This shows that system able to still able to generate high accuracy results on liquid only process column with a maximum percentage of error of ±1.74%.

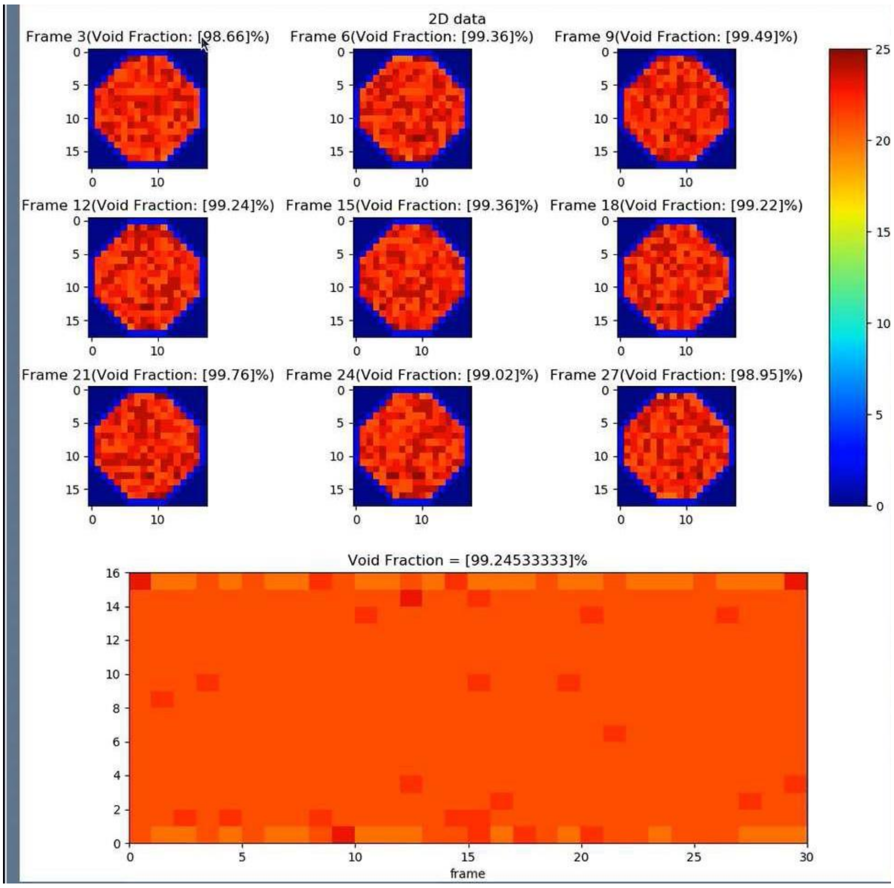

Figure 8: Example of void fraction distribution

4. Conclusion

The results show that wire mesh tomography system able to analyse and recon-struct the phase distribution of a two-phase liquid/gas flow and successfully distin-guish liquid and gas phase. Python used as the programming language to make the image reconstruction algorithm is feasible. Wire-mesh sensor assure efficient tomo-graphic imaging on multiphase flow. Although the paper had discussed the capability within the limitations some improvements being made on current research as well such as improvement on image reconstruction algorithm on Python platform without hindering the objective on not using complex algorithms.

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