APPLICATION OF ULTRASONIC TOMOGRAPHY TO DISPLAY TOMOGRAM OF LIQUID/SOLID FLOW REGIME BY USING LINEAR BACK PROJECTION

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***Abstract*— this paper present on software implementation to display tomogram of solid/liquid flow regime by using ultrasonic tomography (UT). Ultrasonic tomography system is designed to find imaging process for flow composition in pipe or vessel especially in chemical industries. The projection of sensor is constructed by using fan beam mode and the linear back projection (LBP) algorithm was implemented in this project for the image reconstruction. Therefore, this project only uses software system which is MATLAB software for data acquisition, measurement analysis and visualization of project. Finally, the results showed in this project are the arrangement of tomogram for flow regime of solid/liquid which was identified and analyzed by differentiating colors of tomogram. Voltage distribution obtained by using LBP algorithm is higher if the transmission coefficient is lower.**

Keywords— Ultrasonic Tomography (UT), Linear back Projection (LBP), Transmission mode, Concentration Test Profile, Tomogram

I. INTRODUCTION

Nowadays, the application of ultrasonic tomography in industries is widely used in order to identifying the fluid compositional. However there is some common problem that occurred in pipeline or vessel which are an interruption in flow process caused by other thing or impurities in pipe for instance and difficulty to observe the flow process inside pipeline. Without shutdown the process to examine the problem, linear back projection (LBP) method, the fastest and simplest algorithm to display the image of tomogram solid/liquid flow regime and the compound will be differentiating according to their colors.

There are many researches about application of ultrasonic tomography in process of flow composition in pipe and vessel. Iskandar in [1] present the development of suitable ultrasonic tomography system that can identify water and solid flow regime. The transmission mode for sensing purpose was implemented by using 4 sensors for transmitters and 4 sensors for receivers where 4x4 projections were produced. The author in [2] present about on monitoring of liquid / gas flow using ultrasonic tomography. 16-pairs of ultrasonic sensor have been used in this project and the author in [3] presents a comparison of frame rate between Visual Basic and C++ programming. Zhang-Xin Chen et.al (1996), reported an ultrasonic tomography technique suitable for gas/liquid and solid particle flow measurement.

This paper will discuss the implemented of Linear Back Projection (LBP) on MATLAB SIMULINK to display tomogram of solid or liquid by using Ultrasonic Tomography. Then the arrangement of tomogram for flow regime of solid/liquid which was identified and analyzed by differentiating colors of tomogram.

II. PROCESS TOMOGRAPHY

Tomography technology involves the acquisition signal from sensors located on the periphery of an object to provide cross sectional profile in a process of vessel or pipeline. The basic tomography system is constructed by the combination of sensor system, data acquisition system image reconstruction and a display unit to display the cross sectional image [4].

The tomography images are derived using a linear back projection (LBP) algorithm. In order to derive this algorithm, forward problem must be solved first which provides solution to the inverse problem [5]. Forward problem determines the theoretical output of each of the sensor when the sensing area is considered to be two-dimensional. The cross-section of the pipe is mapped by using graph paper. There are 16 projection produced by 4 x 4 sensor projection as shown in fig.1.

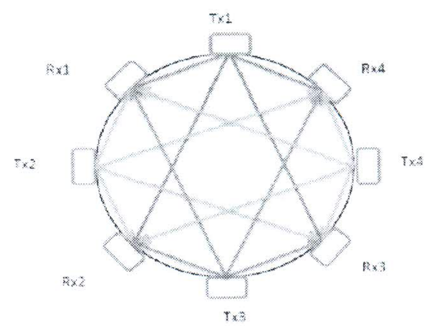


Fig. 1 4 X 4 Transmitter to receiver sensor projection

The forward problem can be solved using the analytical solution of sensitivity map which produces the sensitivity matrices. Each transmitting sensor is virtually excited and the affected pixels are taken into account. The sensitivity distribution can be determined by calculating the ultrasonic energy attenuation at positions of each receiver due to obstruction in the object space. Sensitivity maps were derived for individual sensor to use in LBP algorithm in order to calculate concentration profile. For transmitter one to receiver one, it can be expressed mathematically as shown in equation below where V_{LBP} equal to voltage distribution obtained using LBP algorithm, S_{Tx1RX1} equal to the sensor loss voltage of transmitter (Tx) to receiver (Rx) and $\overline{M}_{Tx1Rx1}$ equal to normalized sensitivity maps.

$$V_{LBP} = \sum_{Tx1}^{4}\sum_{Rx1}^{4} S_{Tx1Rx1} \times \overline{M}_{Tx1Rx1} \qquad (1)$$

$$S_{Tx1Rx1} = V_{refTx1RX1} - V_{Tx1Rx1} \qquad (2)$$

In this project, the forward problem can be solved by using the analytical solution of sensitivity maps which produces the sensitivity matrices. Calculation of the sensitivity maps was done by using graph paper. To create sensitivity maps, a model of measurement section has been developed according to specified diameter of transducer ring. The cross section of the pipe is mapped into 60X60 rectangular array consisting 3364 pixels. Then, this size reduced to 12x12 pixels by grouping the 60x60 pixel into 5x5 pixel each.

Each pixel occupied by projection is counted and summed in graph paper into the corresponding major pixel (12X12 pixels). In order to construct the image to ease coordination of the color level on the tomogram, a normalized sensitivity map is used. The normalized sensitivity have been obtained by each element in the sensitivity map is divided by sum of the same element *N(x, y)* in sensitivity map. In order to get accurate value, this step was done by using MATLAB coding. There are total 16 of sensitivity maps obtained for this project.

There are only 8 projection that have normalized sensitivity map which are transmitter one to receiver two (*Tx1* to *Rx2*), transmitter one to receiver three (*Tx1* to *Rx3*), transmitter two to receiver four (*Tx2* to *Rx4*), transmitter two to receiver three (*Tx2* to *Rx3*), transmitter two to receiver four (*Tx2* to *Rx4*), transmitter three to receiver one (*Tx3* to *Rx1*), transmitter three to receiver four (*Tx3* to *Rx4*), transmitter four to receiver one (*Tx4* to *Rx1*) and transmitter four to receiver two (*Tx4* to *Rx2*). Other value was not considered because of lamb wave and it is not a part of receiver signal.

III. SOFTWARE SYSTEM

The basic structures of ultrasonic tomography system are hardware and software. But, this project is concentrated on software implementation. The software that used for this project is MATLAB Simulink. The normalized value of sensitivity maps for each tomogram for different medium is same.

IV. RESULT AND DISCUSSION

The purpose of this project is to display tomogram of solid/liquid flow regime that was analyzed according to the colors. The implementation of linear back projection algorithm (LBP) is needed to find in order to solve the inverse problem. The concentration profile is a pixel values of test profile or tomogram that has been converted from measured value based on a complex transformation matrix from the system response matric. The concentration profile is also generated by multiplying the projection data (sensor loss voltage) of each transmitter (Tx) and receiver (Rx) with the computed sensitivity maps (normalized sensitivity maps). Therefore, it is very important to know the material used in this project and its transmission coefficient that shown in Table I.

Table I: Material used for this project and transmission coefficient

Medium	Material	Transmission Coefficient (%)
Liquid	Water	62.89
Solid	Ceramic	20.13
Solid	Steel	6.35

In this project there are 3 types of obstacles in PVC pipe which are water, ceramic and steel. However the projection of transmitter to receiver was done for water, water and ceramics, water and steel and lastly, water, ceramic and steel in each pipe. All data from hardware system that used for sensor loss voltage in this research had been taken from previous research which is from [1]. The analysis was done by differentiating the colors of tomogram. The tomogram was developed based on LBP algorithm by using coding in M-file in MATLAB Simulink.

The analysis was done for test profile and tomogram. Test profile was done to prove the analysis done using hardware system is acceptable or not.. In Fig. 2 and Fig. 3, it is shown that there are no differences between both test profile and tomogram of water. This is because the value of sensor loss for test profile and tomogram of water are same. For sensor loss voltage of test profile, it was assume as 1 and 0. The number 1 means there is projection of transmitter in the medium and 0 means the projection of transmitter was not exist. Sensor loss voltage for water was calculated using equation (2). Due to its value, as a reference voltage, the normalize sensor loss voltage of water for each projection become 1. The dark red colour in tomogram is refer to all pixels that the signals were totally have been transmitted in water due to no object is blocking from transmitters to receivers.

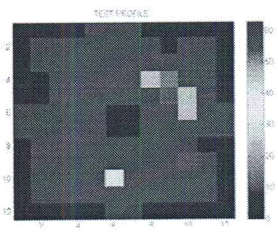


Fig. 2 Test profile for water

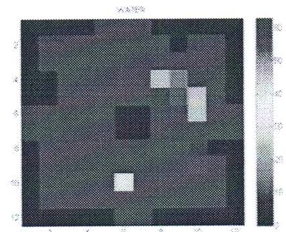
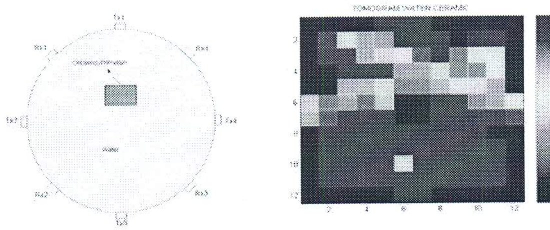


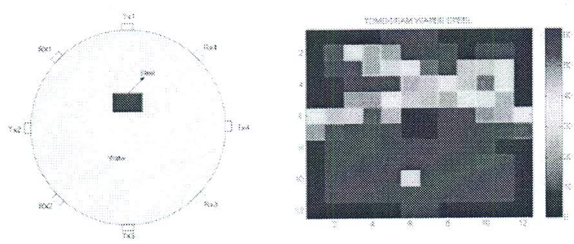
Fig. 3 Tomogram for water

However, the test profile and tomogram show that not all the transmitted positions were red. This might be caused by the less projection or the data from hardware were not too accurate. The difference colors of tomogram with different materials were shown in Fig. 4 until Fig 6. It shows that when there is obstacle or material in water, the tomogram got indicate the differences colors. It means that the projection of transmitter to receiver was blocking.



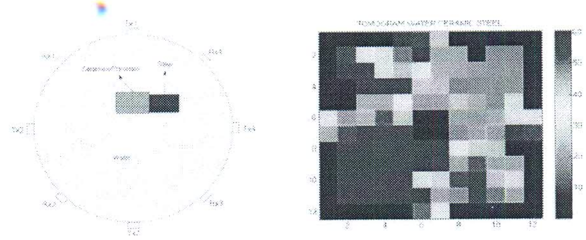
(a) (b)

Fig. 4 Water and Ceramic. (a) Position of ceramic in PVC pipe; (b) Tomogram for water and ceramic



(a) (b)

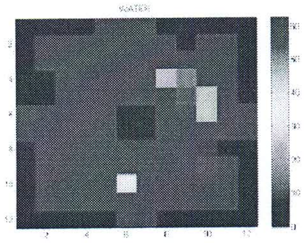
Fig. 5 Water and Steel. (a) Position of steel in PVC pipe; (b) Tomogram for water and steel



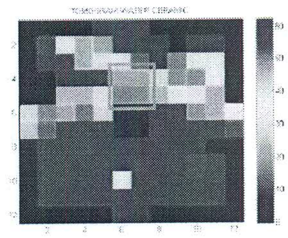
(a) (b)

Fig. 6 Water, Ceramic and Steel. (a) Position of ceramic and steel in PVC pipe; (b) Tomogram for water, ceramic and steel

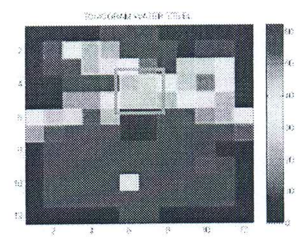
Besides, if the transmission coefficient higher, the sensor loss voltage is lower. This is because the amount of energy reflected will be greater which means the transmitted signal to receiver are smoothly projected without any obstacle block the signal. That is why, it is very important to know the ultrasonic propagation for each material used in this project. Fig. 10 (a) – (d) shows the different colors of tomogram for different material due to each medium have different sensor loss value after propagates.



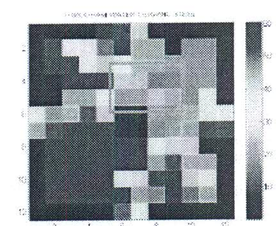
(a) Tomogram water



(c) Tomogram water & ceramic



(b) Tomogram water & steel



(d) Tomogram water, ceramic & steel

Fig. 7 Differences of tomogram between water with different material

Based on Fig. 7, the color of tomogram in purple line is to show the position of material in the PVC pipe. Its shows that the types and sizes of material gave impact to transmitted signal. It was proven by the colors of tomogram referred to voltage distribution obtained using linear back projection algorithm (V_{LBP}) are different due of different voltage of water, ceramic and steel when the transmitted signal to receiver. For Fig. 7 (b) and (c), *Tx2-Rx3* and *Tx4-Rx1* have different colors compared to Fig. 7 (a) because the sensor loss voltage is larger than other projection caused by ceramic and steel are blocking the transmitted signal. For Fig. 7 (d), there have more projections that causing more different colors which that are *Tx1-Rx3*, *Tx2-Rx4*, *Tx3-Rx4* and *Tx4-Rx1* because the size of material larger when ceramic and steel arranged in series in PVC pipe.

Results show that, the values of V_{LBP} when steel blocking the transmitted signal are lowest than ceramic because the transmission coefficient of steel is lower than steel. If the transmission coefficient low, the sensor loss voltage is higher so that the voltage distributions obtained by LBP algorithm become low. Besides, value of V_{LBP} also depending on size of materials.

V. CONCLUSION

Generally, the objective of this research had been achieved. The tomogram of flow regime for solid/liquid in has been display. Results show that the tomogram of flow regime for solid/liquid has been analyzed according to their colors which referred to value of V*LBP*. This paper was discussed more to theoretical output of sensor in order to reconstruct the image by using LBP algorithm. LBP algorithm was developing in M-file MATLAB SIMULINK. From this project, V_{LBP} for liquid is higher than V_{LBP} of solid. Besides, it shows the result from hardware is validated by differentiating the color of tomogram based on the position of material in the pipe.. Thus as conclusions, if the transmission coefficient low, the sensor loss voltage is high so the voltage distributions obtain by LBP algorithm become low.

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