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Quantifying Scheme for Detection Heterogeneous Phase in a Pipe Vessel

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Abstract – This paper describes the different ultrasonic tomography for multiphase flow such as liquid/gas flow which commonly found in chemical columns and industrial pipelines. The information obtained through this research has proven to be useful for further development of ultrasonic tomography. This includes acquiring and processing ultrasonic signals from the transducers to obtain the information of the spatial distributions of liquid and gas in an experimental column. A k-NN analysis on the transducers' signals has been carried out to distinguish between the observation time and the Lamb waves. The information obtained from the observation time is finally used to classify the heterogeneous phase between liquid and gas. It is found that the detection rate reaches 96.67%.

Keywords – Quantifying scheme, Heterogeneous phase, Pipeline, k-NN classifier, Ultrasonic tomography, Liquid and gas flow

1. Introduction

In the 1990s, industry had problem to utilize resources more efficiently, to satisfy demand for product quality, and to reduce environmental emissions. Since then, there is a need for a monitoring instrument that could monitor the industrial processes and provide information to improve yields, quality, efficiency and overall control of the processes. No ultrasonic tomography system for imaging of two liquids or more such as gas, water and oil has been studied in depth so far. Invasive technique is not favored mostly by the industries. The measurement of two-component flow such as liquid or oil flow through a pipe is increasingly important in a wide range of applications, for example pipeline control in oil exploitation and chemical process monitoring. Knowledge of the flow component distribution is required for the determination of flow parameters such as the void fraction and the flow regime. Real-time reconstruction of the flow signal is needed in order to estimate the flow regime when it continuously evolving. It is proven that the operation efficiency of such process is closely related to accurate measurement and control of hydrodynamic parameters such as flow regime and flow rate [1]. Besides, monitoring in the process industry has been limited to either visual inspection or single point product sampling where product uniformity is assumed. This approach for the determination of fluid flow parameters of two-component flow is called flow imaging.

2. Ultrasonic wave at Boundaries

The core of process tomography is in the identification of Interfaces between different materials. Process tomography using ultrasonic sensing will rely upon detectable interactions both in a homogeneous transmission medium and from interfaces, for example gas hold-ups (gas bubbles) in a liquid flow. Several interactions that are possible are [2]

- Attenuation of the amplitude of the incident acoustic waves due to the absorption and scattering effects caused by the object or field of interest.
- Variation of the speed of sound in an inhomogeneous medium.
- Variation of both the amplitude and phase of the scattered field caused by a physical inhomogeneous field.

A useful descriptor of the interaction of ultrasound with a material is its acoustic impedance (the complex ratio of sound pressure to particle velocity), which is analogous to electrical impedance [3]. The acoustic impedance (Z) is described as

$$Z = p.c \tag{1}$$

where Z is the acoustic impedance (kg/m2 s), p the density of the medium (kg/m3) and *c* is the sound velocity in the medium (m/s). The difference of acoustic impedance at the interface will control the amount of energy reflected. Conversely, if the impedances are similar, most of the energy will be transmitted. Fig. 1 shows how the ultrasonic transducer mounted on the experimental liquid/gas column (acrylic). The couplant was used to match the acoustic impedance of the transducer with the experimental column as shown in Figure 1.

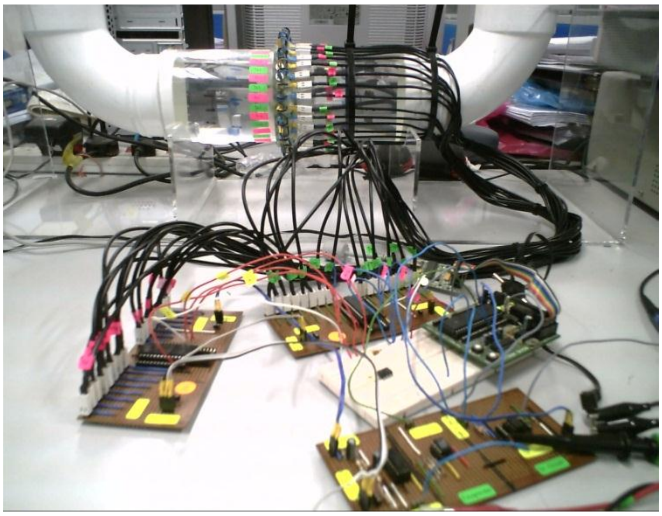

Figure 1. Illustration of ultrasonic sensors mounting

3. System Overview

The block diagram representation of the proposed system is as shown in Figure 2. Fifty trials are tested using proposed system. The different types of flow are determined using k-NN classifier. All the codes are written in MATLAB software.

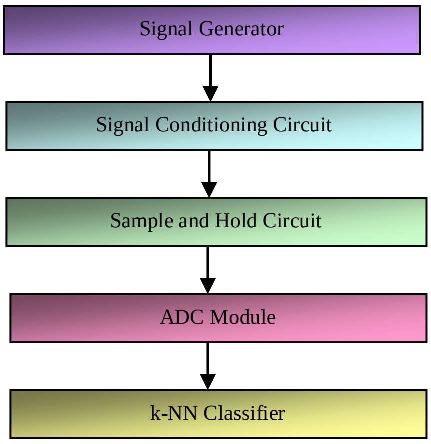

Figure 2 Multiphase Signal Detection Systems

Ultrasonic sensors will be evaluated by circularly arrayed 16-pairs non-invasively on the surface of the process vessel. The signal from transmitter circuit (signal generator) will be send through the transmitter sensor and then, the ultrasonic waves will be received by receiver sensor in the opposite way. To see the internal process of the column, 16-pairs of 40 kHz ultrasonic sensor are used by using the transmission mode method and the fan-beam projection technique. The sensor's fixture configuration is shown as below in Figure 3.

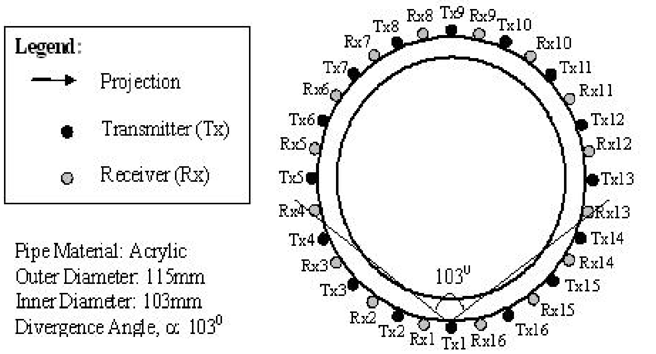

Figure 3. The sensor's fixture configuration

Signal conditioning circuit will convert the signals received by ultrasonic sensors into voltage readings and then amplifies them. The signal will be amplify twice to get the sufficient level. Microcontroller is used to perform the switching signal, analogue-to-digital conversion and also to provide serial communication interface to a personal computer (PC). An example of transmitter and receiver signal is shown in Figure 4 below:

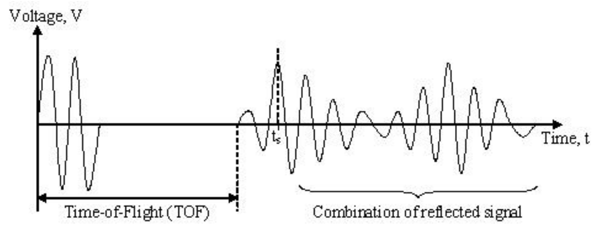

Figure 4. Transmitter and receiver signal waveform

3.1. *k-NN Classifier*

K-nearest neighbor (k-NN) is a simple classification model that exploits lazy learning [4]. It is a supervised learning algorithm by classifying the new instances query based on majority of k-nearest neighbor category. Minimum distance between query instance and the training samples is calculated to determine the k-NN category. The k-NN prediction of the query instance is determined based on majority voting of the nearest neighbor category. Since query instance (test signal) will compare against all training signal, k-NN encounters high response time [4].

In this works, for each test signal (to be predicted), minimum distance from the test signal to the training set is calculated to locate the k-NN category of the training data set. A Euclidean Distance measure is used to calculate how close each member of the training set is to the test class that is being examined. Euclidean Distance measuring:

$$d_E(x,y) = \sum_{i=1}^{N} \sqrt{x_i^2 - y_i^2} \quad (2)$$

From this k-NN category, class label of the test signal is determined by applying majority voting.

4. Results and Analysis

The investigations were based on the transmission and the reception of ultrasonic sensors that were mounted circularly on the surface of horizontal column and the output waveform that produced by using signal conditioning circuit. An experiment had carried out to get the wanted output result for liquid (water) and gas as shown in Figure 5 and Figure 6 below.

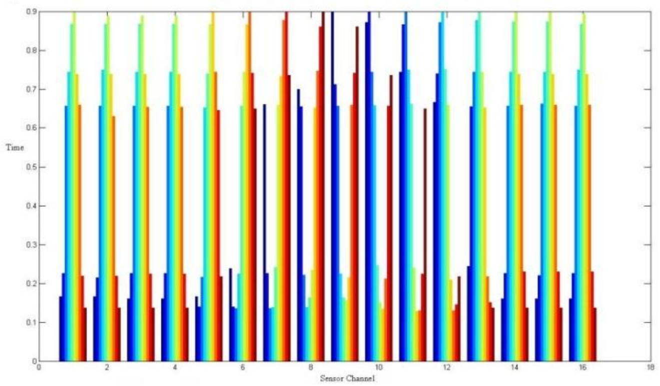

Figure 5. Sensor Channel vs Time Signal for Liquid (water).

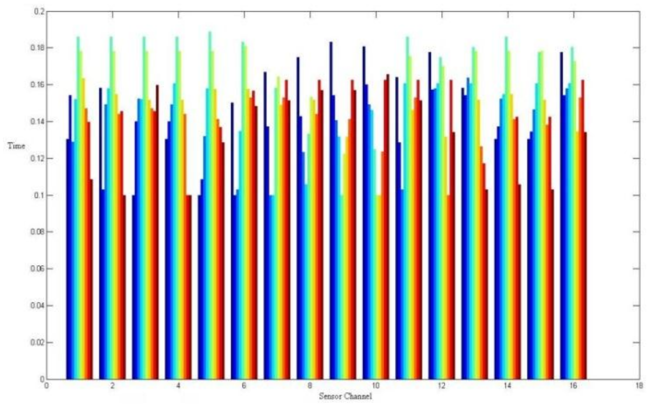

Figure 5. Sensor Channel vs Time Signal for Gas.

Each media which is water, gas can be differentiating from their viscosity, acoustic impedance and density measurement. So, the output waveforms produced from the experiment will also created different value for Time of Flag (TOF) for different media. By using another independent Microcontroller, the time delay for each type of media will be calculated. The time will be taken from the starting trigged pulse for transmitter until the starting trigged pulse for receiver. Finally, the k-NN classifier is implement to determine between homogeneus and non-homogeneus media from the TOF data. The accuracy achieve until 96.67%

5. Conclusion

The paper explains that implementing the measuring system for detection heterogeneous phase in pipeline. This k-NN method obviously differentiates multiphase components of high-acoustic impedance mixtures. Different acoustic impedances between the phases will produce different output waveforms which also help to distinguish and differentiate the composition of the water and gas during the flow until 96.67%.

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