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ULTRASOUND TOMOGRAPHY: PRELIMINARY RESULT

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Abstract. This paper presents the initial result of an investigation into the application of ultrasonic sensors for a tomographic imaging system. Transmitters and receivers are mounted permanently on the inner part of the vertical flow pipe. To overcome the problems of objects blocking each other, four pairs of sensors are used, mounted around the area of interest, and views from different angles are obtained. The results obtained show that the system is capable of detecting particle flow.

Key words: Ultrasound tomography

1.0 INTRODUCTION

Tomography comes from the Greek words tomo (slice) and graph (picture)[1]. From an engineering perspective, tomographic technology involves the acquisition of measurement signals from sensors located on the periphery of an object, such as a process vessel or a pipeline. This reveals information on the nature and distribution of components within the sensing zone. Most tomographic techniques are concerned with abstracting information to form a cross sectional image.

In addition, the process of tomography system is concerned with the derivation of information relating to two or three dimensions. Such derivations require information, or projections, from a number of viewpoints, preferably symmetrical surrounding the object of interest. Most process tomography systems depend upon blocking and reflective interactions, since these are easiest to detect and interpret [2]. A lower limit on the band of frequencies which is likely to be useful will generally be simple to determine.

The basic tomographic system consists of an array of sensors around the pipe or vessel to be imaged. The sensors output signals dependent on the position of the component boundaries within their sensing zones. The sensors signals are transferred to a computer which is used to reconstruct a tomographic image of the cross section being observed by the sensors.

In the process industry, information describing material distribution and validating internal modes of the process are necessary for the optimum design and operation of process equipment. Hence, there is a need for the process engineer to visualize the

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inside of the mixing vessel or reactor, thus relevant measurement techniques are necessary. However, complex experimental approaches are not economically viable for many process design and operation needs. For these latter cases, the process tomography approach using simple non-invasive sensors has much to offer. One of the advantages of ultrasonic sensor is it can be mounted outside the pipe.

2.0 AN ARRAY OF ULTRASONIC TRANSDUCERS

Ultrasonic transducer transform acoustical energy to mechanical energy or vice versa. The transducer is constructed in a manner which incorporates the fundamental structure of piezoelectric ceramic element of monomorph type with a conical metal resonator. This special combination provides high sensitivity, wider bandwidth, excellent temperature and humidity durability, stable electrical and mechanical characteristic, and small size [3].

There are two types of ultrasonic transducers used in this project. When used in air, the open type is used, while enclosed type is used in water. The size of open type is 10 mm in diameter, height is 6.6 mm, and the spacing lead is 4.4 mm. For the enclosed type, the diameter is 168 mm, height 12 mm, and the spacing lead is 10 mm. All the sensors are mounted around the outer part of the pipe.

These sensors can be used in application such as remote control, proximity sensors, intruder detector and data transmission. The enclosed-type can be used for outdoor installation or in dusty atmosphere. It is not recommended to be used under water.

Table 1 The characteristics of ultrasonic transducer

Type of Transducer	**Open**	**Enclosed**
Sensitivity transmitter	110 dB	118 dB
Sensitivity receiver	–70 dB	–68 dB
Resonant frequency	40+/– 1 kHz	40+/– 1 kHz
Typical operating distance	5 m	5 m
Direction angle	30°	30°
Input voltage(maximum) transmitter	10 Vrms	20 Vrms
Capacitance	2000 pF	3000 pF
Operating temperature	–20°C to 60°C	–20°C to 60°C

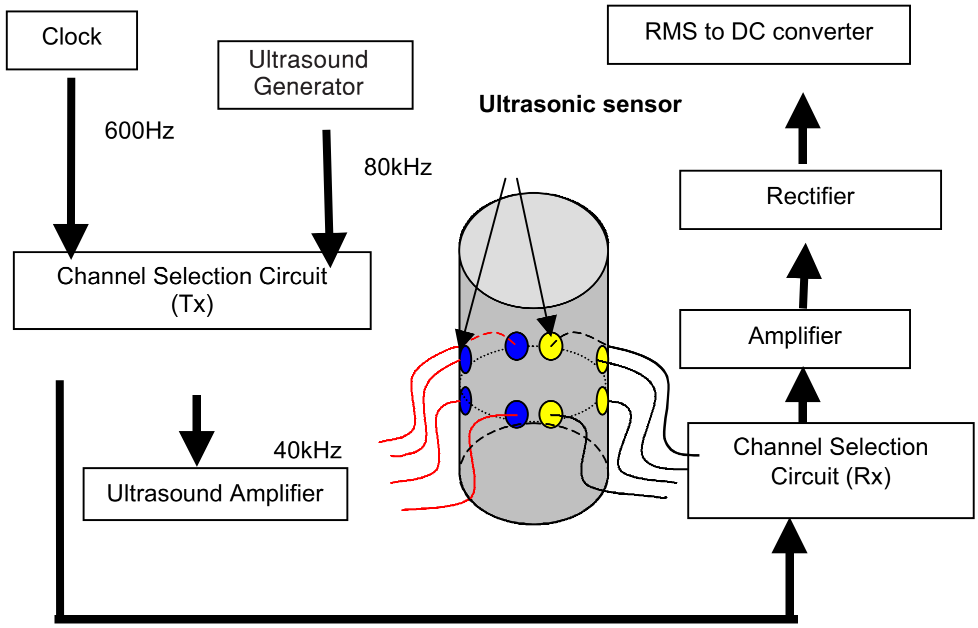

Figure 1 A Block Diagram of an ultrasonic tomography system

Consider the system shown in Figure 1. The interior of the circle defines the cross-sectional region to be image bounded by an array of ultrasonic transmitters and receivers. To overcome the problem of the objects blocking each other and to collect the data as much as possible, four pairs of ultrasonic sensors are mounted around the area of interest, and views from different angles are obtained. Therefore, during the acquisition process, the group of receivers in different angles of the element selected for excitation are capable of producing data by means of ultrasonic transmission mode operation. Data acquisition for a single image frame is performed by sequential excitation of N transmitters. The result produced using multiple sensors in this way improves as the number of elements is increased, however the constraint of producing an image in real-time limit the maximum number of transducers that can be used.

A timer is used to supply the clock with frequency 600 Hz to the channel selection circuit of transmitter. The channel selection circuit is a combination digital logic gates and flip-flops. With the input from ultrasonic generator by frequency 80 kHz, the discontinuous pulses are created. An ultrasonic amplifier is applied to amplify the signal to 15 volt.

For the receiver circuit, a Op-amp with gain 100 times will be used to convert the current signal to voltage. Then, the signals are passed through the full-wave rectifier and RMS to DC converter. An amplifier with a gain of 25 is used to amplify the signals before obtaining the output voltage which is displayed on the osilloscope.

For the transmission mode operation, the assumption of straight-line propagation is used. The element beam patterns are assumed to be fan-shaped, which is transmitted

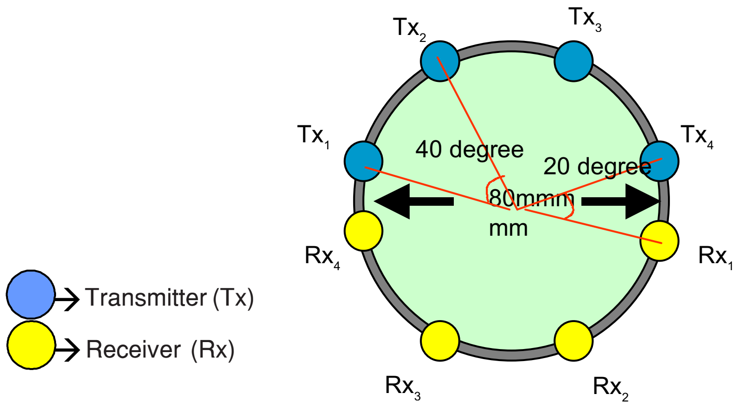

Figure 2 Arrangement of ultrasonic sensors

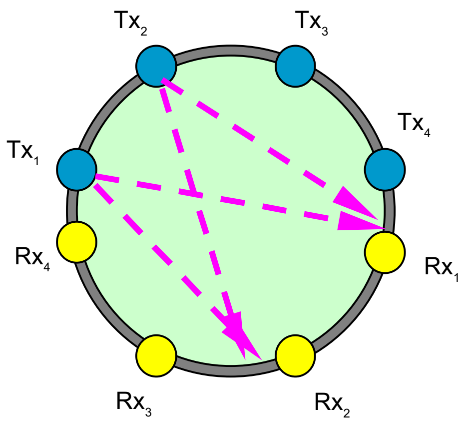

Figure 3 Tx_1 and Tx_2 ON

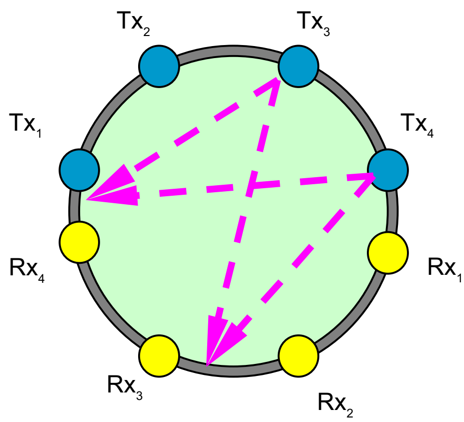

Figure 4 Tx_3 and Tx_4 ON

at a divergent angle. The sensors of the system are divided into two groups. Tx_1, Tx_2, Rx_1 and Rx_2 are grouped into a group while Tx_3, Tx_4, Rx_3 and Rx_4 are in another group (Figure 2). In the approach, the receivers of a group will not respond to the transmitted signal from another group. In this manner, all the transmitters transfer signals by turn.

Figure 3 illustrates that when the transmitters, Tx_1 and Tx_2 are ON, the receivers (Rx_1, Rx_2) will also ON. The data acquired is only concerned with the amplitude. At the same time, receivers (Rx_3, Rx_4) will be OFF. Conversely, when the transmitters Tx_3 and Tx_4 are ON Rx_3 and Rx_4 will be ON (Figure 4) resulting in the data being collected.

3.0 RESULTS

The aim of the initial experiment is to measure the output voltages when a particle was dropped through the sensing area of the pi pe as shown in Figure 5. The particle of the same size was dropped in different sensing zones.

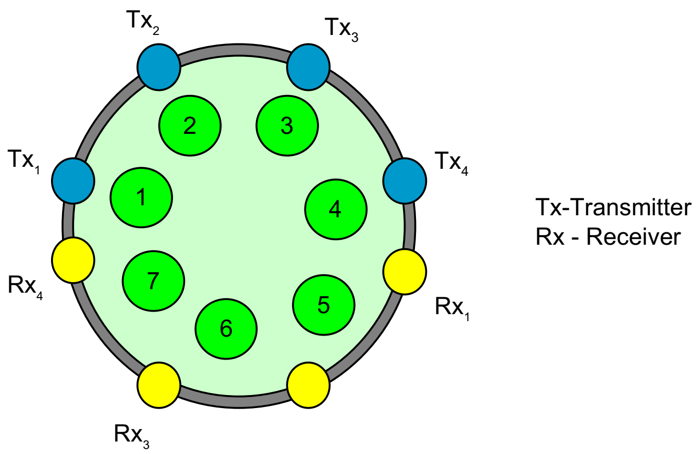

Figure 5 Plane preview of pi pe with different sensing zones

Table 2 shows the results.

Table 2

Sensing Zone	**Receiver Zone**			
	Rx_1	Rx_2	Rx_3	Rx_4
1	12.8V	13.2V	14.0V	13.8V
2	13.8V	13.4V	14.0V	13.6V
3	13.3V	13.6V	12.6V	12.8V
4	13.0V	14.0V	13.2V	12.8V
5	13.2V	13.0V	13.4V	13.8V
6	14.0V	13.2V	12.8V	14.0V
7	14.0V	14.0V	13.6V	13.6V

4.0 DISCUSSION AND CONCLUSION

When a particle with a diameter of 3 cm was dropped through the sensing zone 1, the nearest area to Tx_1, the output voltage of Rx_1 is 12.8 V as shown in Table 2 while the output voltage of Rx_2 is 13.2V. The reduction of voltages are caused by the interruption of object with a diameter of 3cm when it passed through sensing zone 1. It blocked the transferring signal from Tx_1 to Rx_1 and Rx_2. Since Tx_3, Tx_4, Rx_3 and Rx_4 are in one group, they would not respond to the signals from Tx_1 and Tx_2. As a result, output of Rx_3 and Rx_4 are constantly high.

When a particle with a diameter of 3cm dropped through the sensing zone 2, the nearest zone to Tx_2, the output voltage of Rx_1 is 13.8 V as shown in Table 2 while the output voltage of Rx_2 is 13.4V. The reduction of voltages is caused by the interruption of object with diameter 3cm when it passed through sensing zone 2.

In the case when an object was dropped through the sensing zone 3, the signals that are transmitted from Tx_3 and Tx_4 had to be blocked. As a result, output voltages of Rx_3 and Rx_4 will be reduced more obviously compared to Rx_1 and Rx_2.

For the particle dropped through the sensing zone 4, signals that are transmited from Tx_4 and Tx_1 will be blocked by the particle. Hence, the output voltages of Rx_4 and Rx_1 will change as they are in the same group.

When a particle was dropped through the sensing zone 5, Rx_1 and Rx_2 had to been obstructed from the signals that were transferred from Tx_1 and Tx_2. As a result, their output voltages will decrease more sharply compared to the output voltages of Rx_3 and Rx_4.

When a particle was dropped at sensing zone 6, between the Tx_2 and Tx_3, output voltages of Rx_2 and Rx_3 will be reduced compared to Rx_1 and Rx_4. This is because the signals that are transferred from Tx_1 and Tx_2 to Rx_2 had been blocked, while signals that are transmitted from Tx_3 and Tx_4 also have the same results.

When the object was dropped through sensing zone 7, output voltages of Rx_3 and Rx_4 will be reduced. Output voltage of Rx_1 will also drop as the object also blocked some of the signals that are transmitted from Tx_1 and Tx_2.

All the preliminary results show that the system is capable of detecting particle flow. Further work has to be carried out in order to obtain tomographic images of the flow.

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