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INITIAL STUDY ON ULTRASONIC TOMOGRAPHY FOR MULTIPHASE FLOW APPLICATION

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Abstract. This paper presents the initial study on ultrasonic tomography for multiphase flow application to investigate ability of ultrasonic tomography for used in monitoring the three phase flow (solid/liquid/gas) at once since there are no research on this conducted yet. In this project, eight units of 40 kHz ultrasonic sensors were mounted non-invasively around the pipe wall where four of it acts as a transmitter and the other four as a receiver. Each transmitter will transmit two cycles of pulses of 40 kHz at an excitation voltage of 24Vp-p. By using transmission-mode and fan-shaped beam projection approach, the peak to peak voltage of the received ultrasonic wave are measured. The investigation was based on the transmission and reception of sensors that were mounted circularly on the surface of experiment vessel. The results obtained throughout this research project had shown that different flow condition and composition will gives different value of output voltage. And the information and analysis of the results can be used for further investigation on the three phase system.

Keywords: Ultrasonic tomography; multiphase flow; ultrasonic

Abstrak. Kertas kerja ini membentangkan kajian awal terhadap kaedah tomografi ultrasonik ke atas aplikasi pengaliran yang mempunyai lebih daripada satu fasa. Ianya bertujuan untuk mengkaji kemampuan tomografi ultrasonik untuk memantau aliran tiga fasa (pepejal/cecair/udara) berikutan kajian ini belum dilaksanakan oleh mana-mana penyelidik. Di dalam projek ini, lapan unit penderia ultrasonik berfrekuensi 40 kHz di pasang di sekeliling paip di mana empat daripadanya berfungsi sebagai pemancar dan empat lagi sebagai penerima. Setiap pemancar akan memancarkan dua kitar denyut berfrekuensi 40 kHz pada ujaan voltan 24Vp-p. Eksperimen ini adalah berdasarkan kaedah pancaran dan penerimaan gelombang ultrasonik di mana voltan puncak ke puncak gelombang ultrasonik di ambil dan di analisis. Maklumat yang diperoleh

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daripada projek ini menunjukkan bahawa kondisi dan komposisi aliran yang berbeza akan memberikan bacaan voltan keluaran yang berbeza. Ini disebabkan oleh galangan dan halaju setiap bahan adalah berbeza. Hasil dan analisis kajian boleh digunakan untuk kajian dan penyelidikan yang lebih mendalam ke atas sistem tiga fasa.

Kata kunci: Tomografi ultrasonic; aliran pelbagai fasa; ultrasonik

1.0 INTRODUCTION

The word "tomography" is originally comes from the Greek Word which "tomos" means to slice and "graph" means image. In other words, tomography can be defined as a process of making a cross sectional image of an object. A cross section of the object monitored is called a tomogram, while the equipment that generates the image is called a Tomography [1].

Tomography was first applied in medical field before it was applied in the industrial field. In industrial application, it is necessary for the tomography equipments be relatively low cost and able to make measurements rapidly. Research that conducted in the mid of 1980s has led to current implementation of process tomography systems. Many researches on tomography for industrial and medical applications were carried out at universities worldwide until today. There were also many international symposiums, seminars and world congress on tomography held every year in which involvement of many researches around the world.

Process tomography is a technique still in its infancy, but it has the potential for enabling great improvements in efficiency and safety in process industries, while minimizing waste and pollution in a range of applications [2]. It can be used to gain both qualitative and quantitative data needed in modeling a multiphase flow system. Tomography will also provide an increase in the quantity and quality of information when compared to many earlier measurement techniques [3].

Multiphase flow technology which comprise of solid, liquid and gas plays an important role in the chemical and process industry. Managing systems involving two or more phases is commonplace in areas from the processing of fuels and chemicals to the production of feed, food, pharmaceuticals, and specialty materials. However, researches conducted previously only focused either on solid/liquid phase detection, liquid/liquid, solid/gas and liquid/gas flow detection. Up till now, no research has being developed in detecting all the three phase (solid/liquid/gas) at once. A monitoring system that can be applied non-invasively is vital in multiphase flow system. The monitoring system should be able to provide the information about the composition of the multiphase system. Tomography is the most beneficial technology that can be applied to solve the

problem. Therefore, an initial study of ultrasonic tomography for multiphase flow regime identification is proposed in this paper.
Multiphase flow occurs when two or more phases are flowing along a closed or open pipe. The phases may be gas, liquid or solid and two or three phase flow. The multiphase material flowing down the pipe may be fully mixed, fully separated and anything in between depending on the nature and densities of the phases, the degree of turbulence induces in the mixture and the physical geometry of the pipe.

By knowing the process flow conditions, it can be used to manage downstream processes. It would be highly beneficial to measure the flow of each phase in the pipe, ideally mass and volume, and the degree of mixing within the pipe. This is impossible from within the pipes as the very act of measurement disturbs the flow; hence it has to be from outside the pipe. Here the ultrasonic tomography system plays a very important role in knowing the process flow conditions.

2.0 ULTRASONIC SENSING MODES

There are three sensing modes available in ultrasonic tomography, which are the transmission-mode, reflection-mode and diffraction-mode. A practical system may combine the modes based on the data acquired in a system.

2.1 Transmission Mode

Basic assertion of transmission-mode approach is that the transmitted wave travels in a straight line to the receiver. As a consequence, the sensed wave at each point on the receiver can be related to some characteristic of the medium along this straight line.

Even though reasonably good results have been obtained using this method, the straight line approximation is clearly an approximation. If significant transmission passes through strongly inhomogeneous parts of the object field, then large errors may results. In this mode, particles are treated as being ultrasonically opaque because of the significant of acoustic impedance mismatch between the gaseous and solid components of the flow. Hence, transmission technique through component which has large differences in acoustic impedance, the straight line assumption would be false.

2.2 Reflection-Mode

Reflection-mode tomography can be considered as an extension of transmission-mode tomography. In reflection-mode, wave sensed at the receiver can be related to the characteristics of the interface which produces a reflection along the straight line outward and return path.

First theoretical analysis of reflection sensing mode that was made by Norton and Linzer [4] was based upon a single pulse-echo transducer used as a transmitting and receiving element. The transducer is moved around the object on a circular path in the cross-sectional plane viewing the object field radially. The results of it demonstrate that; the back-scattered echoes from a transmitting transducer to a coincident receiver arise from a circular arc at the radius of each object interaction and also for a transmitter and receiver that separated by a constant angle, the same perceived echo lies upon an elliptic arc.

2.3 Diffraction-Mode

It is inappropriate to treat propagation along lines or rays when the object inhomogeneties become comparable in size to the wavelength of the ultrasound. In this sensing mode, energy transmission must be discussed in terms of wave fronts and scattering arising from the inhomogeneties. Interaction of an incident ultrasound with the object to be image can be modeled by wave equations. By solving an inverse scattering problem (referred to as diffraction-mode), the image reconstruction is then accomplished.

Small perturbation approximations are usually employed to solve for the wave equation for weakly inhomogeneous objects, where the scattered field within the scattered can be neglected.

3.0 LIMITATION OF ULTRASOUND IN FLOW IMAGING

Even though ultrasonic sensing technique has been widely used in flow imaging, there are still several limitations that need to be overcome before it can be successfully applied practically in industries [5]. Different types of materials have different set of properties especially the speed of ultrasound and the density. When the waves travel from one medium to another different medium, the waves have to pass the interface of the medium. At this point several interactions may occur in which they are the limitations to take into consideration.

(i) Attenuation of ultrasound is high in most material. The differences of attenuation (acoustic impedance) in multiphase flow such as solid, liquid and gas are so large that it is difficult to model the behavior at state interfaces. The image resolution is thus limited.

(ii) The speed of ultrasound is too slow for the techniques to provide high-resolution images of fast moving flows in large pipes.

(iii) Propagation of ultrasound is based on its frequency in which at different frequencies, its behavior changes in a given medium. The undesired effect such as the scattering of ultrasound wave, reflection and mode changing can occur depending on the wavelength of the ultrasound and the sizes of the particles or bubbles inside the flow. Thus it will become more difficult to ally the flow imaging technique in multiphase flow as the bubble sizes and position of material in the flow may unpredictable and the flow has rapidly changing patterns.

4.0 STUDIES ON ULTRASONIC TOMOGRAPHY IN FLOW APPLICATION

Since its introduction and development in the last two decades, more detailed and advance research on ultrasonic tomography in flow application have been explored and developed by many researchers worldwide.

Gai *et al.* [3] has presented a paper on flow imaging using ultrasonic time-resolved transmission mode tomography. The paper considers some problems encountered in flow imaging and describe an algorithm using transmission mode ultrasound on a solid/liquid and liquid/gas flow. The algorithm takes the pulse's arrival at a specific time as its mage reconstruction data and is viewed as a modified backprojection method.

Browny *et al.* [6] from Glasgow Caledonian University (UK) has developed the ultrasonic tomography technique for imaging gas-solid flow distributions in pneumatic conveying pipelines. Its utilizes ultrasonic transmission-mode measurements and the image reconstruction is performed by an efficient backprojection method with standard graphics algorithms.

Chen *et al.* [7] from Cranfield University (UK) has presented a paper on ultrasonic tomographic technique for gas/liquid and solid particle flow measurement. An ultrasonic tomographic system and image reconstruction algorithm based on measurements of scattered waves is described.

Xu and Xu [8] from Tianjin University (China) have developed an ultrasonic facility for tomographic imaging of gas/liquid two-phase flow based on the binary logic operation and a method of "time-of-propagation along straight path". They established the principle and construction of the facility and their primary emphasize was on the evaluation of its performance in flow regime identification and cross-sectional void fraction measurement.

Warsito *et al.* [9] from Shizuoka University (Japan) has carried out a research on the cross-sectional distributions of gas and solid holdups in slurry bubble column using ultrasonic computed tomography. They utilize the transmission mode method in the experiment. The energy attenuation and the velocity changes were sense by the system in the experimental vessel due to gas and solid hold-ups and the image were reconstruct using Filtered Back Projection algorithm.

Peter Hauptman *et al.* [10] from University Magdeburg (German) have work out a paper work on the ultrasonic sensors application in the process industry in which the advantages, disadvantages, commercial example, possibilities and limitations of ultrasonic process sensors are discussed.

Johan Carlson [11] from Lule˚a University of Technology (Sweden) has carried out a research in the area of multiphase flow measurement, flow imaging and material characterization using ultrasonic technique. The first part was on the development of ultrasonic method that can measure the mass fraction of particles in a solid/liquid multiphase flow. Second part focused on the imaging of opaque flows using ultrasonic speckle correlation velocimetry (SDV) and last but not least is in the field of non-destructive evaluation (NDE) of materials.

Tenoudji *et al.* [12] from Paris University (France) has applied the ultrasonic tomography technique to the visualization of air flow. In order to be practical, tomography needs well suited acoustic sources and receivers with low cost, wide aperture angles and large frequency bands. Therefore, a sonic spark emitter has been developed for this purpose and posses the requirements needed.

Meanwhile, in 2004, Ng Wei Yap *et al.* [1] from Universiti Teknologi Malaysia has developed a research on the ultrasonic tomography for composition of water and oil (liquid/liquid) flow. The composition of the flow is determined based on the propagation time of the ultrasonic waves.

In 2005, Mohd Hafiz [2] had carried a research on the development of ultrasonic tomography in imaging the liquid/gas two phase flows. Transmission-mode approach had been implemented for sensing the flow. Till today, they have come out with many paper works on it.

Cowell *et al.* [13] from University of Leeds (UK) has review a paper on the ultrasonic signal characteristics in the presence of highly reflecting solid/liquid interfaces. The paper was split into three sections which first it review on the basic physical effects that occur when ultrasound waves pass from one material to another. Those principles were then applied and illustrated using a metal wall and surrounded by water in the second section. Last section was on the simulations to illustrate the response.

Supardan *et al.* [14] has presented a paper on the investigation of gas holdup distribution in a two phase bubble column using ultrasonic computed tomography. In the study, time averaged of gas holdup distributions were investigated in a 16cm diameter bubble column for two phase dispersed system of air-water and air-glycerol solution by implementing the transmission mode method.

5.0 HARDWARE IMPLEMENTATION

In this project, the multiphase flow will be indicated by the mixture of wood, water, and air as the representation of solid, liquid, and gas respectively. However, in this paper, only the hardware development will be focused and the results will be displayed using an oscilloscope.

5.1 Front-End System

Front-end system consists of the transducer or transducer array and associated electronic hardware to acquire data needed to produce a meaningful image. This is the fundamental to the success or failure of an acoustic imaging system [15]. In this project, the front-end system that will be implemented has been identified:

(i) Piezoelectric ultrasonic transducer with resonance frequency of 40 kHz.
(ii) Signal Generator Circuit
(iii) Signal Conditioning Circuit
(iv) Microchip PIC18F452 microcontroller

5.2 Ultrasonic Sensing Method

When transmitting ultrasound through a multiphase medium containing solid particles, the sound waves are scattered and attenuated [9]. In this project, the scattering effect will be neglected. Transmission mode method has been chosen as the method that will be implemented in the project. In this method, the peak to peak voltage of the ultrasonic wave received from the transmitter to the receiver through the medium will be measured. Different condition of flow will gives different average peak to peak voltage for every received signal of ultrasonic wave. Ultrasonic tomography for the flow monitoring purpose in this project will be implemented by analyzing the measured data of several flow conditions.

For ultrasonic tomography system, [3] and [16] recommended that the electronic system required for controlling the ultrasonic transducers should has four main functions that are:

(i) Supplying pulses to activate the transmitting sensors should ideally be software controlled so that the timing of the pulses can be easily varies and the synchronization is ensured.
(ii) Amplifying the analogue signals from the receiving sensors.
(iii) Reshaping the received analogue signals into digital pulses which preserved the time of arrival information.
(iv) Interfacing to the digital computer for control of pulses generations and image reconstruction from received data.

Hence, the block diagram of the ultrasonic tomography system has been designed based on the above criteria. But note that the interfacing to the computer will not be included since the image reconstruction part is excluded from the scope of this project. Therefore, the system is shown as in Figure 1 below.

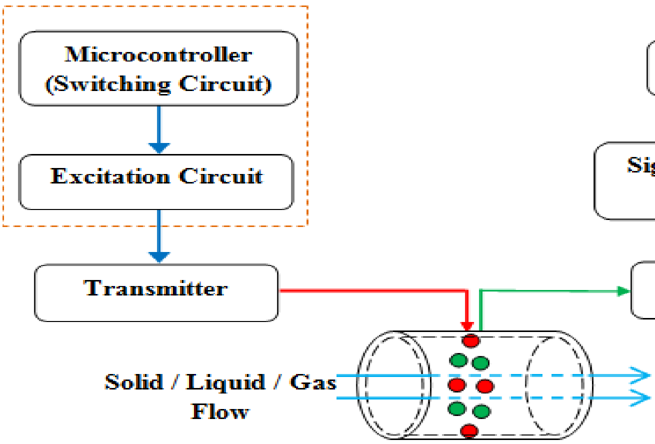


Figure 1 Layout design of ultrasonic tomography system

Eight ultrasonic sensors were mounted alternately and equally spaced around the pipe where four of them work as a transmitter and the other four acts as a receiver. The flow inside the pipe that will be monitored are: gas, full liquid flow, solid/gas, liquid/gas, solid/liquid, and solid/liquid gas. First of all, the microcontroller will act as a switching circuit to control which transmitter transmits first. Pulses generated by the microcontroller unit will then fed into comparator to excite the transmitter so as to transmit the ultrasonic waves that can penetrate through the pipe and the medium, which are then received by the receivers. The received signal will then be amplified at the signal conditioning circuit. The output will be then displayed in term of ultrasonic waves on the oscilloscope and the peak to peak voltage of the ultrasonic waves will be measured.

For this project, acrylic pipe has been chosen as the experiment vessel since we can monitor the flow inside the pipe. It has a diameter of 60mm with a thickness of 3mm. Before the experiment pipe is fabricated, we had to decide either we want it to be vertically or horizontally. Since the flow to be monitored will comprise of solid, liquid and gas, it seems to be more convenient to fabricate the pipe horizontally. Figure 2 and 3 below shows the design of the pipe's fabrication and the real fabrication of it.

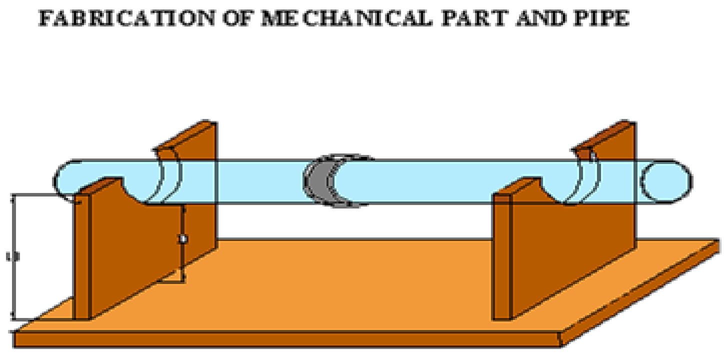


Figure 2 Layout design of the experiment vessel fabrication

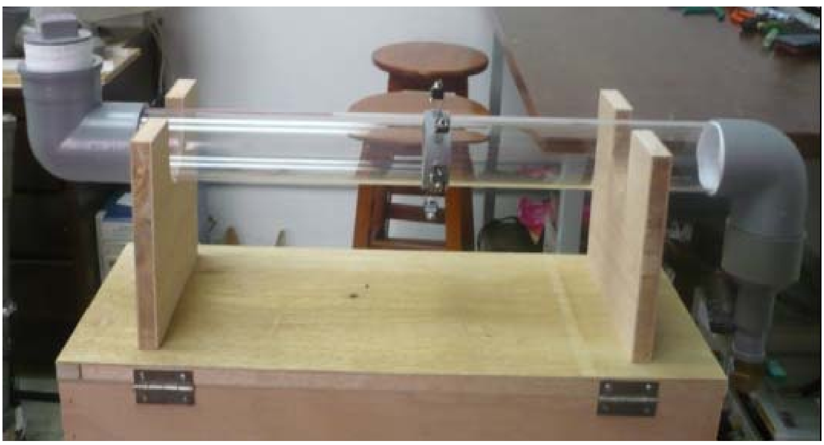


Figure 3 Real fabrication of the experiment vessel

5.3 Mounting of Ultrasonic Transducer

In this project, eight units of ultrasonic sensor which four of them act as a transmitter and the other four as a receiver were mounted alternately and equally spaced around the pipe, as shown in figure 4 and figure 5). These sensors were mounted non-invasively on the pipe by a hollow shape with eight holes or also called a sensor jig which made of PVC. Silicon glue is used as the coupling material between the sensors surface and the pipe surface. Coupling is needed because of the large acoustic impedance mismatch between the air and solid (air surrounding and the pipe wall in this case). Ultrasonic waves suffer a great lose of transmission power in the air. Couplant displaces air and this make the ultrasonic wave can penetrate more efficiently throughout the experiment vessel.

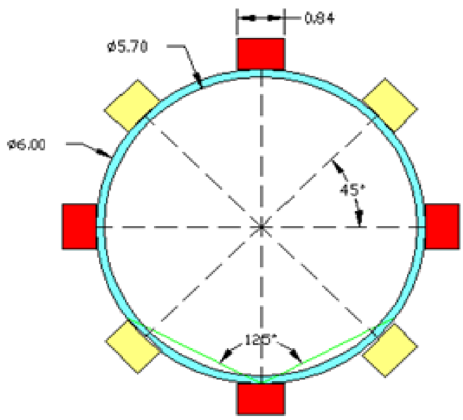


Figure 4 Mounting of ultrasonic transducer

Figure 5 Real mounting of ultrasonic transducer

Ultrasonic transducer is an electronic component that is converts the electrical pulses to mechanical vibrations and then converts the returned mechanical vibrations back into electrical energy. The active element of the transducer is the heart where the electrical energy converts into acoustic energy and vice versa and the active element of the ultrasonic sensor in this project is the ceramic piezoelectric.

For this project, eight ultrasonic transceivers with a 40 kHz frequency is used as it has the dual functionality in which it can act either as a transmitter or receiver depending on where we connect it. If it is connected to the transmitter circuit, it will automatically act as a transmitter and if it is connected to the receiver circuit, it will automatically act as a receiver. Since the arrangements of the transducers were set to act as four transmitters and four receivers, switching circuit can be discarded in this system. The figure of the transducer is shown as in Figure 6.

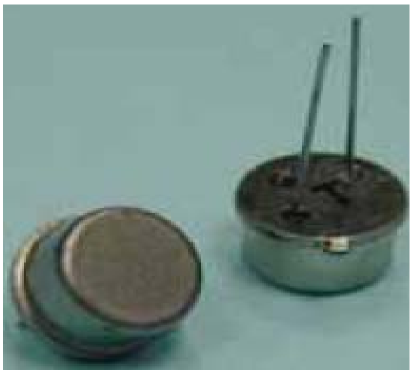


Figure 6 Closed-face piezoelectric ultrasonic transceiver

This transducer is chosen due to its closed faced construction which it will ease the mounting and coupling work. In addition to that, it provides a wide beam angle of 125° in which a wider beam angle will provide a wider visualization area. Beam angle is an important consideration in ultrasonic sensors selection in which it defines how wide the beam can spread and cover an area [3].

5.4 Transmitter Circuit/ Signal Generator Circuit

The transmitter circuit can be divided into two parts which are the switching circuit that is a microcontroller based and the excitation circuit. The function of the transmitter circuit is to generate a two cycles of 40 kHz pulses with 50% duty cycle at a 100 Hz reverberation delay to excite the transmitter (see figure 7). The reverberation effects delay is needed in avoiding the echoes overlapping at the receiver due to two separate ultrasound excitation.

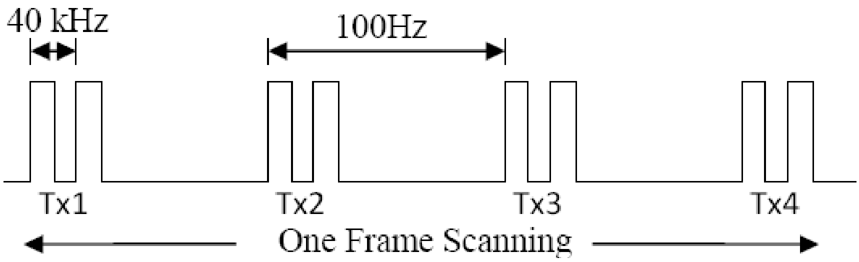


Figure 7 Generated signal by the transmitter circuit

5.4.1 PIC Microcontroller Unit

The microcontroller chosen is the 40 pin PIC 18F452, a product form Microchip company. This microcontroller is chosen since the program is straight forward, its features and number of I/O pins meets the requirement of this project. PIC 18F452 is programmed such that it will control the sequence of the transmitter to transmit the ultrasonic wave, the repetition frequency, the width of the generated pulse the reverberation time. In providing the required reverberation time, the transmitter channel is disabled to make sure that the ultrasonic waves pass through the flow dies down before a new pulse is transmitted. The microcontroller will generate a 5Vp-p pulse in this system. Figure 8 and 9 below shows the basic microcontroller unit in producing a +5Vdc to the microcontroller and the output produced from the microcontroller that is displayed on the oscilloscope.

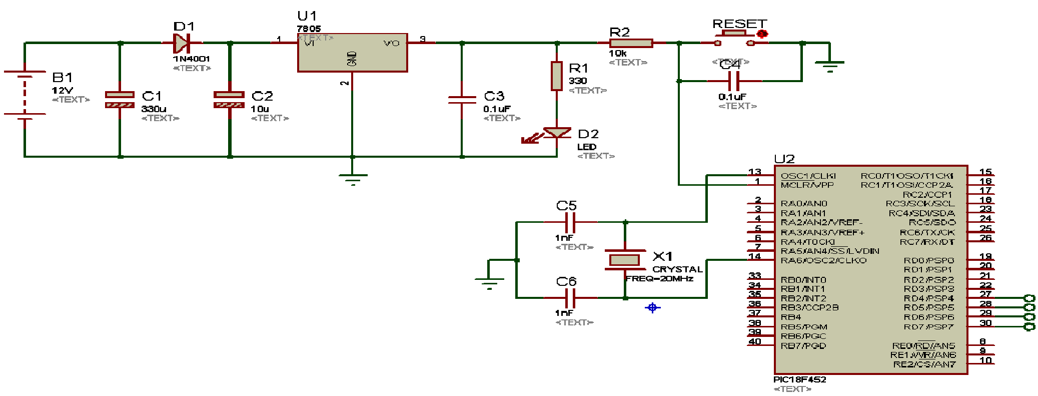


Figure 8 Basic circuit of microcontroller unit

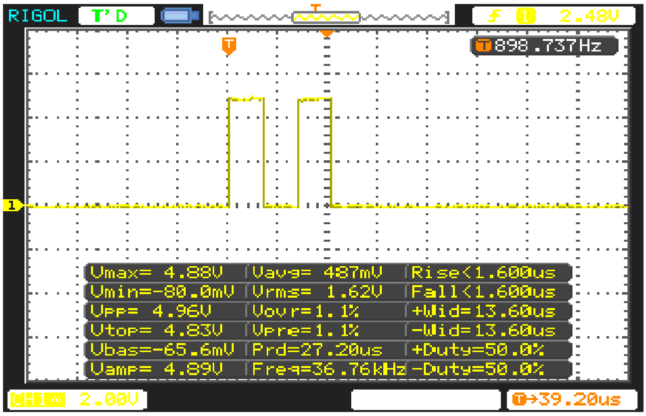


Figure 9 Output signals from microcontroller

5.4.2 Excitation Circuit

Pulses generated from the microcontroller will then fed into the low noise high speed op-amp, TLE2141 that act as a comparator in the excitation circuit. This device is a high performance and internally compensated op-amp built using Texas Instrument complementary bipolar excalibur process. The excitation circuit is as in Figure 10.

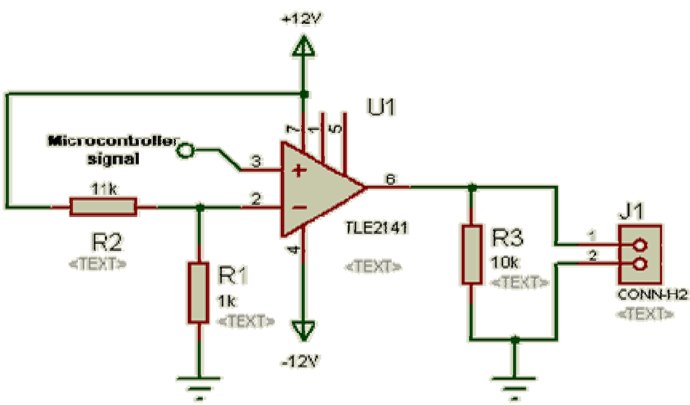


Figure 10 The excitation circuit

The comparator was designed in such that:

$$\text{If } V > V_{(ref)}, \text{then } V_{out} = +V_{cc}$$

$$\text{If } V^{-} < V_{(ref)}, \text{ then } V_{out} = -V_{cc} \tag{1}$$

Where;

$$V^{-}_{(ref)} = \frac{1k}{1k + 11k} \times 12V = 1V \tag{2}$$

Thus, the comparator will generate 24Vp-p tone burst of 40 kHz with reverberation delay of 100 Hz according to the microcontroller to excite the transmitters. The excitation of the tone burst was designed such that it is long enough for transient effects but short enough for it to be received without multiple reflections. The output from the signal generator is as shown in Figure 11 whereas Figure 12 shows the output of the signal generator after it is connected to the transmitter.

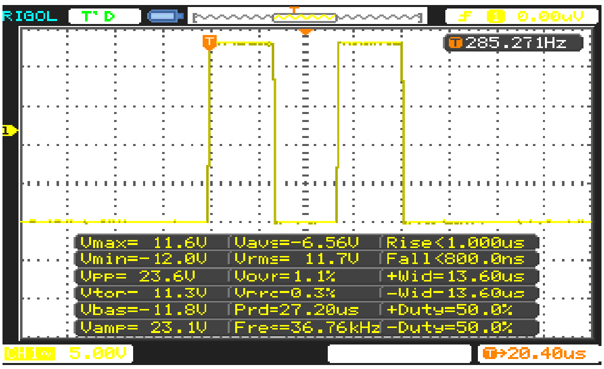


Figure 11 Output from the signal generator

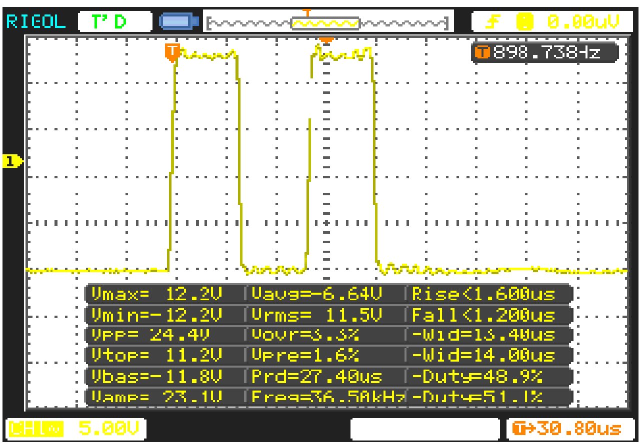


Figure 12 Output from the signal generator after connected to a transmitter

As shown, the output from the signal generator has a little bit change after it is connected to the transmitter. The change of shape as in Figure 12 is due to the ringing effect which caused by the diaphragm of the ultrasonic sensor that is still vibrating although the pulse signal has stopped. However, these will not affect the transmitter because the vibration of sensor's diaphragm has stopped before it starts to vibrate again due to another pulse signal.

5.4.3 Receiver Circuit/ Signal Conditioning Circuit

A low noise dual operation amplifier, LM833N had been chosen to act as the amplifier in the receiver circuit. Besides offering a low voltage noise, LM833 also has a very low distortion (0.002%) and excellent phase/gain margins. The schematic circuit of the receiver circuit is shown in Figure 13 below.

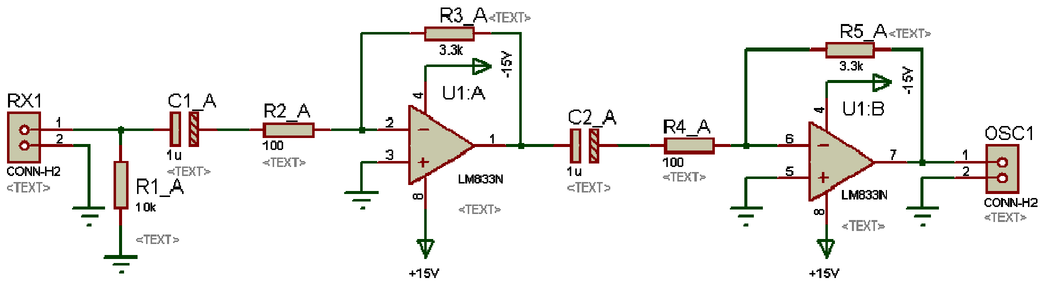


Figure 13 The receiver circuit

The receiver circuit is designed in two stages with an inverting amplifier connection with the gain for each stage is -33. Therefore the total gain for the receiver circuit is equal to 1089. Amplifying the received ultrasonic signals is considered important since the received signal before it is amplified is too small. The value of the amplified gain must be within the range because if it exceeded the range, the output signals will saturate in which the signal will be clipped at the positive and negative peak. The ultrasonic receivers are connected directly to these amplifier circuits and the invasive output signal is as shown in Figure 14 below.

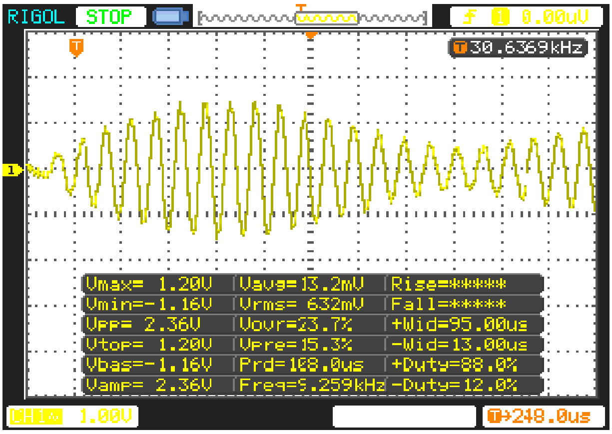
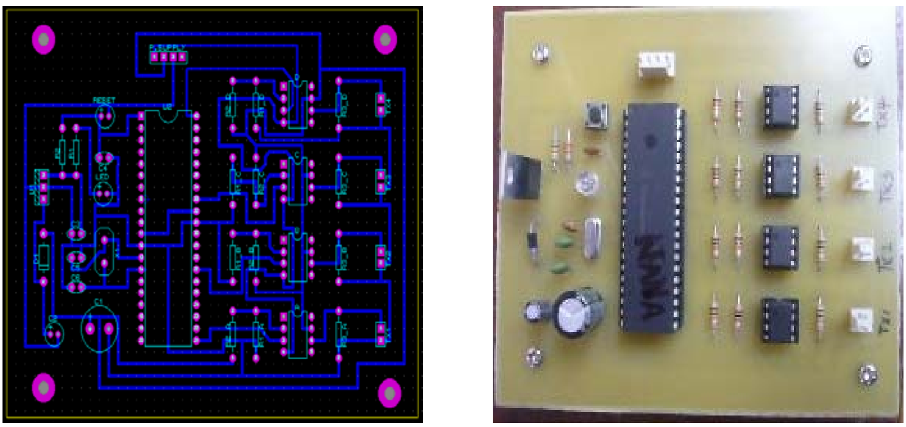


Figure 14 Invasive output signal from receiver circuit

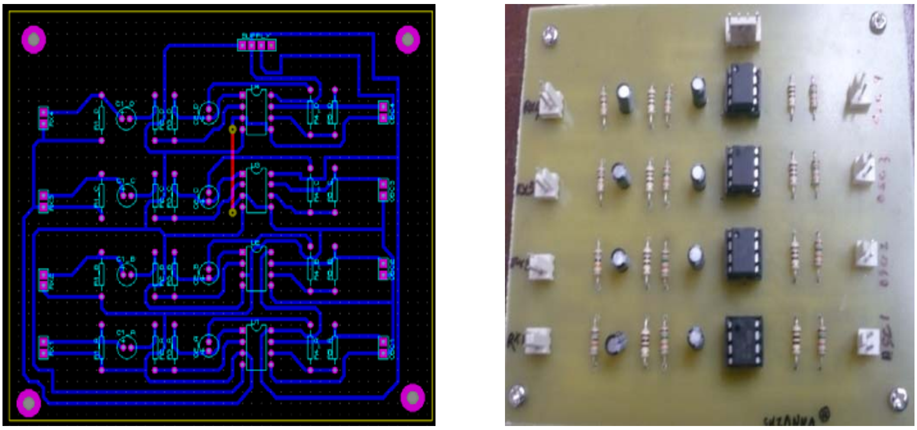
5.4.4 Printed Circuit Board (PCB) Design

The PCB designs of the transmitter and receiver circuit were designed using PROTEUS 7 software since the software has thousand parts of library and it is easy to use. The components are placed on the PCB to reduce the noise. Figure 15 and 16 shows the design of the circuits and the real fabrication of it.



(a) (b)

Figure 15 (a) PCB's design of the transmitter circuit; (b) real fabrication of transmitter circuit

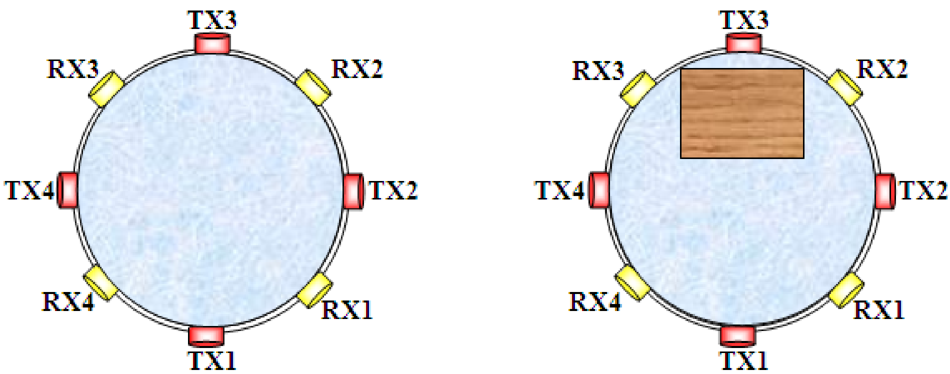


(a) (b)

Figure 16 (a) PCB's design of the receiver circuit; (b) Real fabrication of receiver circuit

6.0 RESULTS & DISCUSSIONS

A line graph has been constructed to analyze the data for solid condition in a liquid flow at several liquid's level. The illustration for each condition is shown in Figure 17 and the graph for it is shown in Figure 18.



(a) (b)

Figure 17 (a) Full liquid flow; (b) Solid in full liquid flow

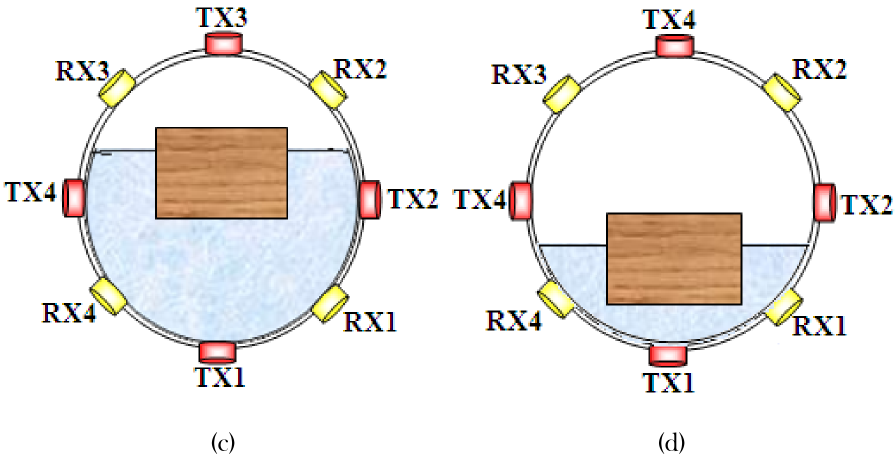


Figure 17 (c) Solid in 60% liquid level; (d) Solid in 40% liquid level

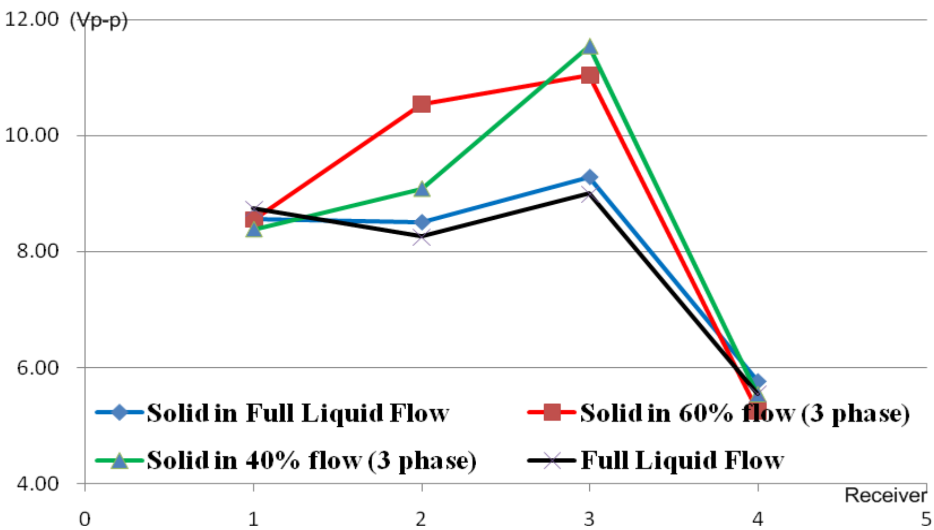


Figure 18 Graph of average Vp-p versus receiver for every flow condition

From Figure 18 above, different flow condition will gives different normalized value for every receiver. Average peak to peak voltage (Vp-p) for every receiver for full liquid flow is lower than when there is existence of solid in the liquid flow. This is due to the higher speed of ultrasound that penetrates through the wood. Thus, it creates a tradeoff between the refracted sound wave and the higher speed of sound. However, there are some values that have discrepancies. It comes from the unstable position of solid floating throughout the flow, from the coupling way where maybe there are some parts that still has air trapped and the discrepancies also comes from the instrument error and also the error while taking the measurement which comes from the existence of noise and parallax error.

In order to investigate whether ultrasonic tomography can be used for three phase application (sensed solid/liquid/gas) at once, comparison between two and three phase with same level of flow has been carried out and analyzed. The illustration of the measurements and the graph obtained is shown in Figure 19 and 20 below.

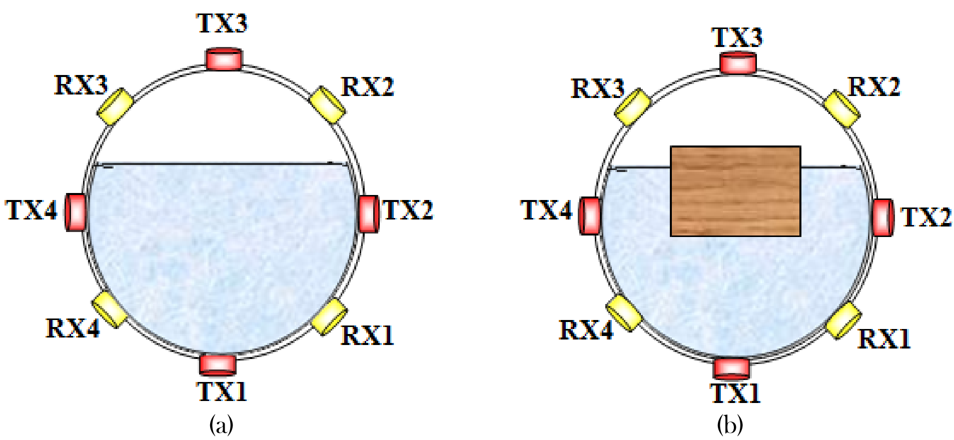


Figure 19 (a) Illustration for 60% liquid flow; and (b) Solid in 60% liquid flow

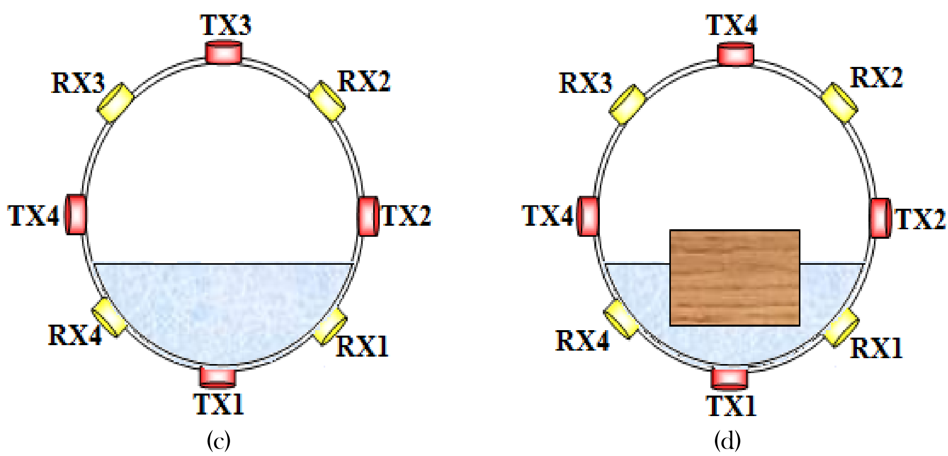


Figure 19 (c) Illustration for 40% liquid flow; and (d) Solid in 40% liquid flow

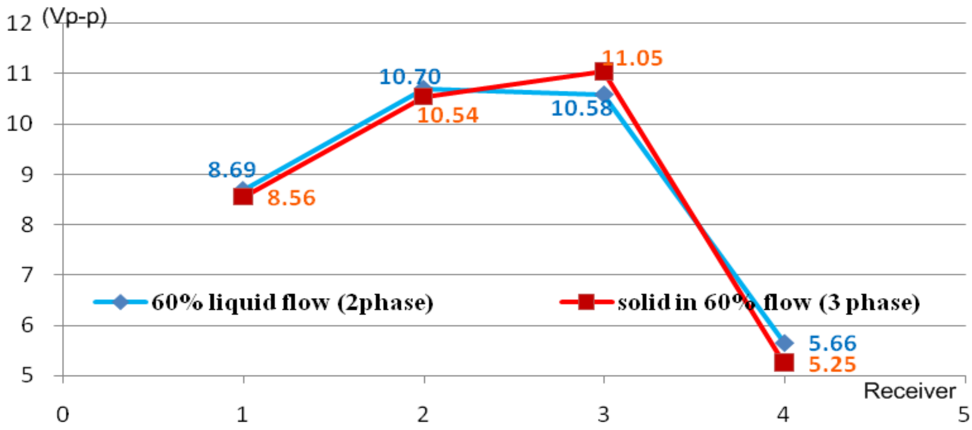


Figure 20 (a) Graph of Vp-p versus receiver for 60% liquid flow versus solid in 60% liquid flow

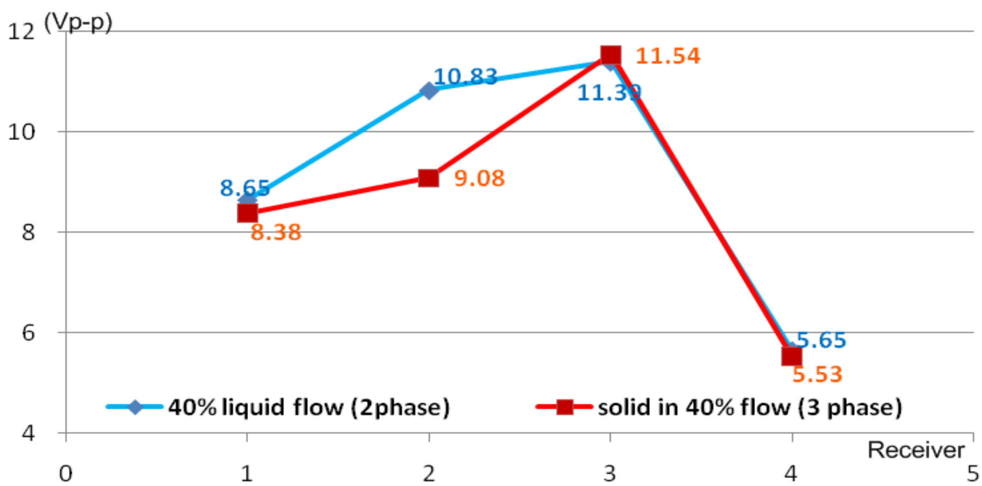


Figure 20 (b) Graph of Vp-p versus receiver for 40% liquid flow versus solid in 40% liquid flow

From Figure 20 above, the results shows that there exists a difference in the output value for every receiver when the two phase data is compared with the three phase flow. This indicates that the system can be used to sense the three phase flow. And as we can observe, the different for the compared data is small. This is because the acoustic impedance for wood and water is not differing too much where the acoustic impedance for wood and water are 0.964MRayl and 1.5MRayl respectively. Here, also we can see that both graphs have discrepancies of output value for RX3. This may be due to the improper coupling of the ultrasonic transducer and the pipe wall. Besides that, the unstable position of wood floating inside the liquid flow, existence of noise in the output waveform, parallax error and instrument error also lead to the error while taking the measurements.

7.0 CONCLUSIONS

In general, the overall objectives of this project have been achieved. A non-invasive ultrasonic tomography for multiphase flow experiment has been developed and investigated using the transmission-mode and the fan-shaped beam approach. The hardware development and the signal conditioning circuit have been successfully implemented. And the initial results show that the system can be used for solid/liquid/gas detection at once. However, further analysis with variation of material's type need to be done and carried out in order for this technique to be practically applied in future. Data that is obtained throughout the project has been analyzed and a number of graphs had been constructed based on the data in order to obtain the initial results for the multiphase flow experiment. It is proved that different flow conditions will provide different value of output measurements.

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