Ultrasonic Measuring Water Quality as a Tool for Non-Destructive Testing (NDT)

N. Hamzah, Z. Sehat

Abstract— **Ultrasonic are one of the most popular technique used by industries to test and evaluate their product called non-destructive testing (NDT). This paper presents the design of a model water quality measurement using sound signal. The model is preliminary action to measure time travel of sound wave in water. Ultrasonic will transmit and receive the sound signal by with 42 KHz frequency operation. Data received by ArduinoMega and at the same time send to the smartphone using HC05 Bluetooth module. Measurement of water located at Klang River where most of factories are located near to it. The time of flight (ToF) from the sensor are recorded, analyzed and presented in result.**

Keywords **–Time of Flight (ToF), Non-Destructive Testing (NDT).**

I. INTRODUCTION

In the future, clean water will be the most valuable and precious to human and environment. Thus, competition will occurred to dominate population and also limited water resources for growth. Hence, a simple and low cost system using NDT technique was developed. Ultrasonic testing method is very popular used for composite material or crack inspection inside metal. Application of ultrasonic transducers range from underwater sonars [1] to medical imaging and biomedical applications [2]. The ultrasonic NDT sensor works at frequency range from 40 kHz up to 400 kHz. The sensor use high frequency to prevent the low frequency due to noise from the other unwanted source. It also prevents interferences from many audible during transmission signal [3]. Ultrasonic transducers (or probes or search unit) are devices to generate and receive ultrasound [4]. The ultrasonic transducers convert mechanical energy into electrical energy and electrical to mechanical energy. The size of the pulse reflected from the defect is influenced by many different factors, such as: type and shape of discontinuity, area of discontinuity, density molecule, distance between ultrasonic head and defect, elastic properties of tested material [5]. The ultrasonic are completely submerged into selected river to measure sound travel inside the water. Comparison was made on same river with 500 m after and before the first location.

In this paper, the ultrasonic measurements of time of flight (ToF) send and receive by transducer. The sensitivity and resolution of ultrasound ToF measurement can be significantly enhanced by combining averaging and accurate interleaved sampling [6]. This technique is preliminary action before the water send to laboratory for analyzed.

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II.OBJECTIVE

In order to develop the access system using ultrasonic, the following objectives have been set to be followed:

- To conduct non-destructive testing NDT on water pollution by using ultrasonic transducer, microcontroller Arduino and personal computer.
- To compare the effect type of water be sampled and the time of flight of ultrasonic wave.
- To investigate the relationship between the speed of sound in water and time of flight (ToF).

III. PROBLEM STATEMENTS

The world is now developing in parallel with technology. There are pros and cons of progress that has been generated. Polluted river will endangering all ecosystem and need to be avoid. Besides that, traditional method takes long time and actions. In traditional method, a water sample must be taken to the laboratory to be analyzed.

IV. SCOPE OF PROJECT

The scope of this project was just to compare the speed of sound that propagates through water. Interface to the smartphone using Bluetooth HC-05 to send data to user. Develop android app using MIT inventor2 to allow using monitor data send by microcontroller. Transducer will send data which time of flight, speed of sound and scale factor. Result and data were analyzed from the experiment.

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V. METHODOLOGY

A. Project Research

This project started with researching the non-destructive testing and some review through previous journals, books, thesis, and internet. The information gathered was focusing on the ultrasonic technique that been used for range finder and metal crack. Besides that, the research also made on effect of harmful or polluted water to the human and ecosystem.

B. Software and Hardware Design.

The development of software begins by applying formula for calculating the speed of sound using time of flight. The distance of detection was fixed to 100 cm in order to get the accurate results. The distance were multiplied by 2 was due to transmit and receive distance from the blockage object. The high acoustic noise tolerance work to reduce or eliminate false detections caused by external noise sources. Acoustic noise tolerance also provides reliable and stable readings.

$$V = \frac{2 * d}{ToF} = cm/\mu s$$

$$Scale\ factor = \frac{1}{Sound\ speed}$$

The block diagram in Figure 1 shows all the components used in this system. The ultrasonic transducer collects data from the sample. Microcontroller accessing the sensor value and process them to transfer through Bluetooth module to smartphone. A simple voltage regulator is made to step-down 9 V battery into 5 V required for supply power to the circuitries.

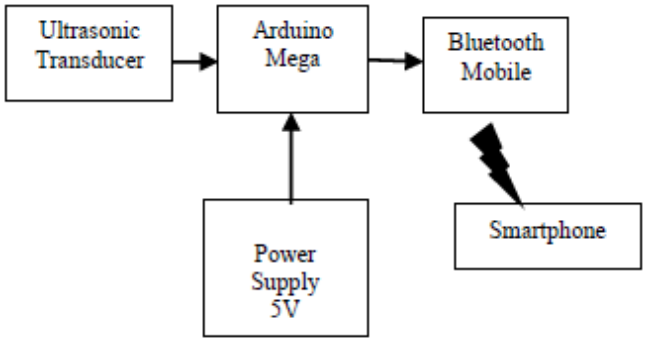

Figure 1: Block diagram of components.

C. Data Collection.

The experiments were done at Sungai Klang, Section 25, Shah Alam in Malaysia. The temperature of the water was recorded before starting the experiment. Connection of microcontroller with smartphone using Bluetooth and data of the water recorded in the log book. The reading was taken 3 times a day in the morning, midday and evening for 1 month to gain accurate and stable reading.

D. Analysis & Comparison

The project was run in free space to record the speed of sound in free space as to set a standard value of speed of sound. Ultrasonic was run through in clean water and the data recorded. The comparison was made between the clean water and sample water taken to observe the differences in term of time of flight and speed of sound.

VI. RESULT AND DISCUSSION

Measurement on speed of sound in free space was recorded to proof that the speed of sound propagate through water faster than free space. Sound wave propagates through vibration of molecule in the medium. Molecules in free space moves freely. Sound requires more energy to transmit vibration from one particle to another. Meanwhile, in liquid medium the particles are closer together thus less energy requires to transmit the sound.

Table 1: Speed of sound in free space.

Temperature (°C)	Time of Flight (µs)	Speed of sound (µs/cm)	Scale Factor (µs)
32	5559	0.036	27.7778
32	5559	0.036	27.7778
32	5586	0.0358	27.9324
32	5566	0.03593	27.8312
32	5576	0.03586	27.8862

Clean water form a pool was taken to be the reference reading in order to compare the quality of the river water taken. If the value for speed of sound is more than the reference value, it can be considered as polluted environment.

Table 2: Speed of sound in clean water.

Temperature (°C)	Time of Flight (µs)	Speed of sound (µs/cm)	Scale Factor (µs)
29	1332	0.1502	6.6578
29	1329	0.1505	6.6445
29	1329	0.1505	6.445
29	1332	0.1502	6.6578
29	1329	0.1505	6.6445

Table 3 : Speed of sound at Location 1

Temperature (°C)	Time of Flight (µs)	Speed of sound (µs/cm)	Scale Factor (µs)
29.5	1694.92	0.18	8.475
29.5	1754.39	0.114	8.772
29.5	1709.4	0.117	8.547
29.5	1709.4	0.117	8.547
29.5	1694.92	0.118	8.475
29.5	1680.67	0.119	8.403

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Table 4 : Speed of sound at Location 2

Temperature (°C)	Time of Flight (μs)	Speed of sound (μs/cm)	Scale Factor (μs)
29.5	1694.92	0.118	8.475
29.5	1428.57	0.14	7.143
29.5	1538.46	0.13	7.693
29.5	1333.33	0.15	6.667
29.5	1709.4	0.117	8.547
29.5	1724.14	0.116	8.621

Table 5 : Speed of sound at Location 3

Temperature (°C)	Time of Flight (μs)	Speed of sound (μs/cm)	Scale Factor (μs)
29.5	1818.18	0.111	9.009
29.5	1768.35	0.1131	8.842
29.5	1869.16	0.107	9.346
29.5	1722.65	0.1142	8.757
29.5	1751.31	0.1161	8.613
29.5	1705.03	0.1173	8.525

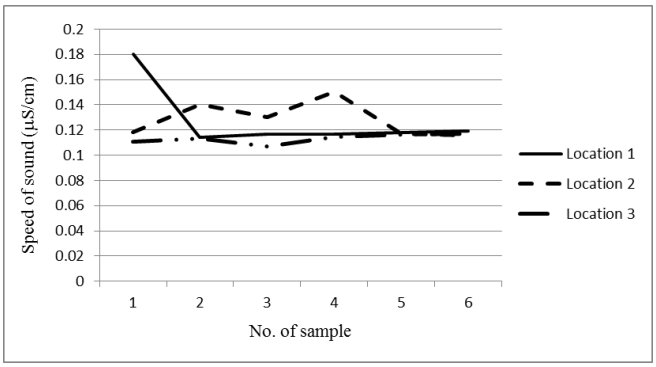

Figure 2: Comparison of sound speed at the 3 locations.

The graph shows the differences of reading for water samples in three different locations. Location 1 was the main area where several factories were located along the river. The reading of the speed of sound taken at this location shows higher values compared to the other two locations. This may show that the amount of chemical and pollution particles is high. But, in order to identify the chemicals and particles the samples should be done in the laboratory.

The next two locations are located 500 meters away from the location 1. The reading from location 2 shows some decrement which may due of effluents into the river. Meanwhile, location 3 does not show too much of a difference from location 1.

VII. CONCLUSION

As conclusion, the objectives to conduct non-destructive testing using ultrasonic were successfully achieved. This project was very handful and affordable method compared to traditional method in term of portability and pricing. Besides that, the fast response of the system allows users to monitor or analyze the result without delay. With the results obtained, a monitoring and pollution preventing system can be built at the area of interest. But, there are limitations of detecting the chemicals and organic compound contained in any liquid.

VIII. RECOMMENDATION

Further improvement can be made to this system to increase the accuracy and reliability. Internet of Thing (IoT) technologies can be used to process and send data to the cloud using Wi-Fi module. Building a data base to store the data taken daily from the selected locations. A detection system can also be developed to detect the chemicals and organic compound contained in any liquid.

REFERENCES

[1] David F. Waechter, S. Eswar Prasad, Richard G. Blacom and Bin Yan, Internally biased PZT materials for high-power sonar transducers, 11th CF/DRDC International Meeting on Naval Applications of Materials Technology.

[2] D.A. Hughes, J.M. Girkin, S. Poland, C.Longbottom, T.W. Button, J.Elgoyhen, H.Hughes, C.Meggs, S.Cochran, Investigation of dental samples using a 35MHz focused ultrasonic piezocomposition transducer. Ultrasonic 49 (February (2))(2009) 212-218, Elsevier Science ISSN 0041-624X.

[3] ISHAK, N. B. (2012). Development of real-time ultrasonic sensoring system to measure distance using labview (Doctoral dissertation, Universiti Malaysia Pahang).

[4] J. Prasad, C.G. Krishnadas Nair. Non-Destructive Test and Evaluation of Materials. New Delhi:Tata McGraw-Hill,2008,ch.1,pp.1.

[5] K.Wierzbicki, J.Stabik, G.Wrobel, M.Szczepanik,"Efficiency of two non-destructive testing methods to detect defects in polymeric materials" Journals of Achievement in Materials and Manufacturing Engineering, Volume 38, issue 2, February 2010, pages 163-170.

[6] A.N.Klashnikov, V.Ichenko, R.E.Challis and B.R.Hayes-Gill, "High-accurancy data acquisition architectures for ultrasonic imaging", IEEE Trans. UFFC, vol.54(8), 2007, pp.1596-1605.

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