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Core laboratory measurements of ultrasonic tomography using the robot RTDs-U100 magnetic

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Abstract. Along with the rapid development in technology, geophysical methods emerge as one of the research alternatives. Some research requires non-destructive test to determine characteristics of an object without causing any damage, such as core rock samples. Ultrasound tomography is non-destructive methods that reconstructing cross-sectional image of the internal structure of an object by analysing the propagation of ultrasound wave. The conventional method to measure core samples that usually use for determining the position of transducer and receiver sensors is by dragging manually. This manual measurement have weaknesses in terms of efficiency and accuracy. In this research, we design prototype of the Robot RTDs-U100 to improve the quality and efficiency measurements of core samples. The magnetic sensor used to control the rotation of transducer and receiver sensors. With this robotic rotation, the position of sensors is more precise and it takes less time. Our findings of core laboratory measurements show that Robot RTDs-U100 improved measurement error from 0,32% with manual measurement to 0,12% after using Robot RTDs-U100.

1. Introduction

In recent years, there have been rapid developments in technology which have emerge geophysical methods as one of the research alternatives. Some research requires non-destructive test to determine characteristics of an object. The field of non-destructive testing as shown by Schmerr and Song [1] involves the identification and characterization of damages on the surface and interior of materials without cutting apart or otherwise altering the material. Cheeke and David [2] shows that numerous technique are used in non-destructive testing, including ultrasound tomography method. Ultrasound tomography is described as the process of reconstructing cross-sectional image of the internal structure of an object by analysing the propagation of ultrasound wave through it. Some applications of ultrasound tomography are to study shale gas¸ shear wave anisotropy and pore pressure. Ultrasonic waves have unique features, it can easily penetrate opaque materials, whereas many other types of radiation such as visible light cannot. Since ultrasonic wave sources are inexpensive, sensitive, and reliable, this provides a highly desirable way to probe and image the interior of opaque objects.

The method utilizes core specimens at laboratory scale from previous drilling. In practice, the core measurement using ultrasound tomography is still using the conventional method which is manually drag the position of transducer and receiver sensors. This manual measurement is impractical and

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requires a lot of time. It also give different results from one researcher to another, due to the lack of uniformity and high subjectivity of the researcher during conventional measurement. Therefore, a tool that can help to optimize the performance of ultrasound tomography measurements is needed. Armed with technology, a combination of simple robotic application and a supporting tool can be a solution to get better data quality and takes less time. Robotic instrument with magnetic sensor can be arranged in accordance with our needs, in order to get fast, precise and uniform ultrasound tomography data [3][4].

2. Design Measurements

Measurements consisted of 16 points. The measurement system uses Transducer V103RM (P-wave), 5072PR pulser receiver, preamplifier 5676, and NI-PCI digital oscilloscope 5911. DC motor HJxxxx, high torque, low speed.

2.1 Transducer

One pair of transducers (source and receiver) P-waves are utilized to observe the propagation of ultrasonic waves. Transducer frequency used was 1MHz frequency with 0,63 inch in diameter as shown in the Table 1.

Table 1. Specification of Transducers V103RM

Unit Name	S-Wave Transducer Panametric V103-RM
Frequency	1 MHz
Diameter	0,63 inch
Type	Single elements
Temperature object range	122^0 F / 50^0 C

Figure 1. P-wave Transducer V103RM

2.2 Pulser

Ultrasonic pulser model 5072PR (Table 2 and Figure 2) used as ultrasonic wave power/receiver. This tools connect with power supply and have a certain control that can produce converted electrical power into ultrasonic wave.

Table 2. Specification of Pulser/Receiver 5072PR

Unit Name	Panametrics Pulser/ Receiver 5072PR
Pulse type	Negative
Pulser rise time	Typically 5 ns, 10ns max
Available pulse voltage	-360 V
Pulser Damping	Select 15, 17, 20, 25, 36, 50, 100 or 500 Ω
Receiver Bandwidth	1 KHz – 35 MHz
Receiver Gain	0-59, 1 –dB steps (RL 50Ω)
Receiver Phase	Inverting or non-inverting
Max input power	400 mW

Figure 2. P-wave Pulser/Receiver 5072PR

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2.3 Preamplifier
Ultrasonic preamp 5676, can be use as an enhancer and filter on output that produced by the first transducer. Panametrics Preamplifier 5676 will amplify transducer signal by 40 dB as listed in Table 3.

Table 3. Specification of Preamplifier 5676

Unit Name	Panametrics Preamplifier 5676
Voltage gain	40 dB (fixed)
Bandwidth	50kHz-20MHz
Input resistance	100K ohm
Input capacitance	Approx. 80 pF
Current consumption	32 mA

Figure 3. Preamplifier 5676

2.4 Oscilloscope
NI-PCI digital oscilloscope 5911 (Table 4 and Figure 4) used to display and analyze the waveform of electronic signals. In effect, the device draws a graph of the signals as a function of time. Through this signal, picking first break is applied for calculating S-wave velocity.

Table 4. Specification of NI-PCI Digital Oscilloscope

Dimension	33.8 cm x 9.9cm
Operating System	Windows 98
Product Family	Digitizers / Oscilloscopes
Number of Channels	1
Maximum Sampling Rate	100 MS/s
Vertical Sensitivity	0,1-10V
Input Impedance	1MΩ ±2%
Dynamic Range Noise	43dB - -124dB
Power Requirement	5VDC, 12VDC

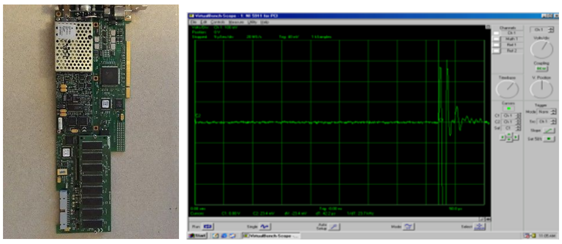

Figure 4. NI-PCI Digital Oscilloscope

2.5 The Robotic Instrument
The robotic instrument is designed to improve the quality and efficiency measurements of core samples. The Magnetic sensor is used to control rotations of transducer (source and receiver sensors). With this robotic rotation, the position of sensors is more precise and it takes less time. Robotic instrument consists of DC motor, High Torque-Load, and Magnetic Sensors. Designed of robotic instrument can be seen in Figure 5.

It assumes that ray path of ultrasonic wave is a straight line. The ultrasonic wave velocity is measured around the core sample. To reconstruct a tomographic image, measurements of travel time are made at various angles from transmitter (T) to receiver (R). Workflow of tomography measurements can be seen in Figure 6.

2.6 Integrated System Measurements

Before conducting measurements, we have to calibrate the tranducers. The sample used to calibrate is iron. The measurement result in the form of P wave travel time with reference ultrasonic wave velocity is 5920 m/s. Pickings are conducted for each first break from every data acquisition. P wave velocity from both conventional and robotic methods are calculated and compared. Distances from the transmitter to the receiver are assumed to be equal for both conventional and robotic methods.

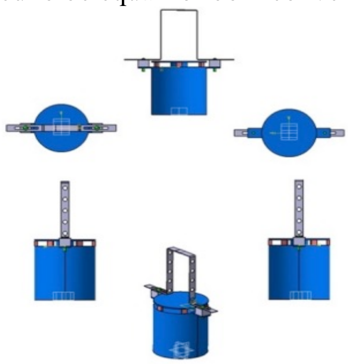

Figure 5. Robot RTDs U100 from many point of view

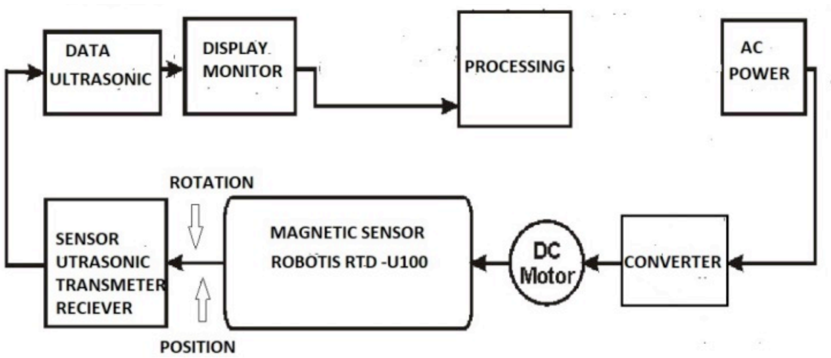

Figure 6. Workflow of tomography measurements

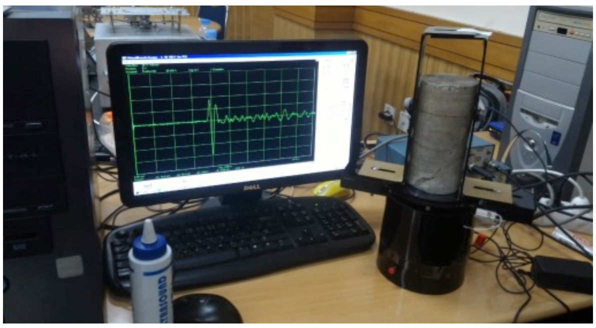

Figure 7. Integrated system measurement with robot magnetic instrument

To see the difference between conventional and robot magnetic measurements, core sample cross measurements are conducted. Cross measurements begin with the transmitter at 16th point and the receiver at 8th. One measurement is, namely measurement 16_8 (format: transmitter_receiver), followed by 1_9, 2_10, and so on. Figures 8 a, b and c show to give illustrations for straight path measurements. To test quality of ultrasonic tomography data, measurement experiments were conducted with two types of observations. The first is fully manual measurements, whilst the second is a combination of manual measurements and the robotic measurements at certain points.

(a) (b) (c)

Figure 8. Straight path measurements using the robotic instrument: (a) cross, (b) ¾ cross, (c) quarter.

3. Results

Data measurements are presented in a comparison of three variables at once, the P wave velocity from conventional measurement (manual), robotic, and references/literature. Table 5 shows measurement results, from literature, manual and robotics.

Table 5. Results of Cross Measurements

Measurement number	Literature	Manual	Robotic	%Error manual	%Error robotic
1	5920,00	5960,78	5953,00	0,69	0,56
2	5920,00	5960,78	5953,00	0,69	0,56
3	5920,00	5922,08	5922,08	0,04	0,04
4	5920,00	5960,78	5953,00	0,69	0,56
5	5920,00	5922,08	5937,50	0,04	0,30
6	5920,00	5922,08	5891,47	0,04	0,48
7	5920,00	5891,47	5922,08	0,48	0,04
8	5920,00	5937,50	6000,00	0,30	1,35
9	5920,00	5937,50	5922,08	0,30	0,04
10	5920,00	5922,08	5876,29	0,04	0,74
11	5920,00	5953,00	5891,47	0,56	0,48
12	5920,00	5937,50	5891,47	0,30	0,48
13	5920,00	5922,08	5953,00	0,04	0,56
14	5920,00	6015,83	5876,29	1,62	0,74
15	5920,00	5922,08	5937,50	0,04	0,30
16	5920,00	5937,50	5953,00	0,30	0,56

Our findings of core laboratory measurements show that the Robot RTDs-U100 instrument improves measurement errors. From Table 5, an average error of calculations is 0,32% with manual measurement and 0,12% after using Robot RTDs-U100. This significant error provides that measurements using the robot magnetic instrument can improve data quality. One reason is the robotic instrument can determine position of source and receiver accurately and consistently. Hence wave velocity calculations close to the reference velocity. This, in turn, can reduce and minimize error due to human error and dependency of users.

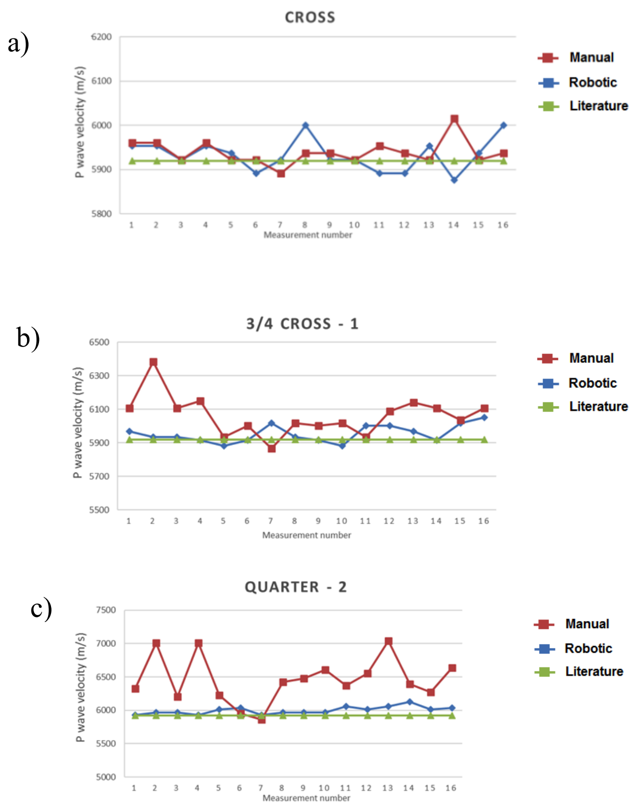

Figure 9. P wave velocity from (a) cross, (b) ¾ cross, and (c) quarter measurements.

Figure 9 shows measurements from 3 different types, with total numbers of 16. The blue curve is robotic measurements, while the red curve is conventional measurements. Then, the reference curve is shown with a green color, with value of 5920 m/s.There are increase in data quality by using the robotic instrument when compared to conventional data. This is indicated by the red curve that represents conventional measurements having a sigSnificant gap with reference data. In contrast, the blue curve that shows the robotic measurements close to the reference.

4. Conclusion

The qualitative analysis of ultrasonic tomography for core samples are achieved through several measurements using conventional method and robotic instrument. Data quality improvement by modifying conventional method of ultrasonic tomography with technology can be achieved through robotic application. Our findings of core laboratory measurements show that Robot RTDs-U100 instrument improve measurement error from 0,32% with manual measurement to 0,12% using Robot RTDs-U100. With this robotic rotation, the position of sensors is more precise, uniform and it takes less time. The ultrasonic tomography using robotics equipment proves to be helpful in obtaining better measurements when compared in terms of conventional measurements.

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