Research Progress in Mechanical and Manufacturing Engineering Vol. 4 No. 1 (2023) 404-412

RPMME

Homepage: http://penerbit.uthm.edu.my/periodicals/index.php/rpmme
e-ISSN : 2773-4765

The Evaluation For Accuracy of Ultrasonic Non-Destructive Testing In Measuring Thickness on Dissimilar Material By Using A1207 Pen-gauge

Babie Jane Roger[1], **Shahruddin Mahzan@Mohd Zin**[1]*

[1]Faculty of Mechanical and Manufacturing Engineering,
Universiti Tun Hussein Onn Malaysia, Batu Pahat, 86400, Johor, MALAYSIA

*Corresponding Author Designation

DOI: https://doi.org/10.30880/rpmme.2023.04.01.046
Received 10 Aug 2022; Accepted 01 Dec 2022; Available online 01 June 2023

Abstract: During pre-service and in-service inspections, ultrasonic thickness measurement (UTM) is critical for ensuring the integrity and dependability of components, structures and plants. In general, all measurements are subject to error, which adds to the result's uncertainty. Errors can be classified as either human or technical. The components perform as expected for the duration of their expected useful lives because they have been put through their paces in terms of UTM. This study looks at how a portable thickness gauge A1207 Pengauge compares to vernier calliper and ruler in terms of performance of precision, accuracy, sensitivity and ability to achieve the desired result when determining material thickness. In this research, recording devices were used to record the before and after calibration thickness. The calculated velocity then was applied on the experimental specimens which are carbon steel and aluminium plate. The results show that UTM method has demonstrated as accurate as callipers when measuring the thickness of any material in any situation. UTM produces the closest response to the actual measurement even without access on either side.

Keywords: Ultrasonic Thickness Measurement, A1207 Pen Gauge, Electromagnetic Acoustic Transducer, Accuracy Assessment

**Corresponding author: sharudin@uthm.edu.my*

1. Introduction

Ultrasonic Testing (UT) integrates an extent of Non-Destructive Testing (NDT) procedures that send ultrasonic waves into a thing or material. These high recurrent sound waves are sent into materials to portray the substance or for issue finding. Most UT appraisal applications utilize brief heartbeat waves with frequencies going from 0.1-15 MHz, while frequencies up to 50 MHz can be utilized. In actual testing, the minimum thickness that can be measured is determined by the highest detection frequency that can be achieved. For example, the resonance method can be used to test steel or aluminum thicknesses as thin as 0.127 mm when using a 25 MHz frequency. [1] One outstanding application for this test method is ultrasonic thickness evaluation, which is utilized to quantify the thickness of a thing. For example, while investigating pipework disintegration.

Ultrasonic inspection uses a piezoelectric transducer coupled to a flaw detector, which in its most basic form is a pulser-receiver and oscilloscope display. The transducer is passed over the object being inspected, which is commonly connected to the test object by gel, oil or water. This couplant is essential to efficiently transport the sound energy from the transducer into the part, although this couplant is not required when doing tests with non-contact techniques such as electromagnetic acoustic transducer (EMAT) or by laser excitation. [2]

Ultrasonic thickness measurement data gives clients the essential data required to spread out accepting the attempted thing has the appropriate metal thickness for which it was planned. Perhaps, an ultrasonic thickness check is to measure the time taken of a sound heartbeat and to create the little test called an ultrasonic transducer. The limit of the ultrasonic transducer is to go through a test piece and reflect back to inside surface or far divider unequivocally. The thickness of the test still up in the air and displayed on an electronic screen considering this assessment. The testing gear's convey capacity thinks about on the spot appraisal and brief results. If the system detects a problem, additional non-destructive testing procedures, such as ultrasonic thickness measurement and disintegration evaluations, can be used to further investigate the disclosures for all industry sectors, such as oil and gas, power plants, critical specialists for recruit, and foundries.[3]

Hence, this research was performed to identify the equipment’s accuracy, precision and sensitivity. The aims focused on the dissimilar material and properties study, include type of material, velocity, and the thickness of the material.

2. Methodology

The flowchart of methodology process of this research has been developed as shown in the Figure 1, in order to achieve the objectives of this research.

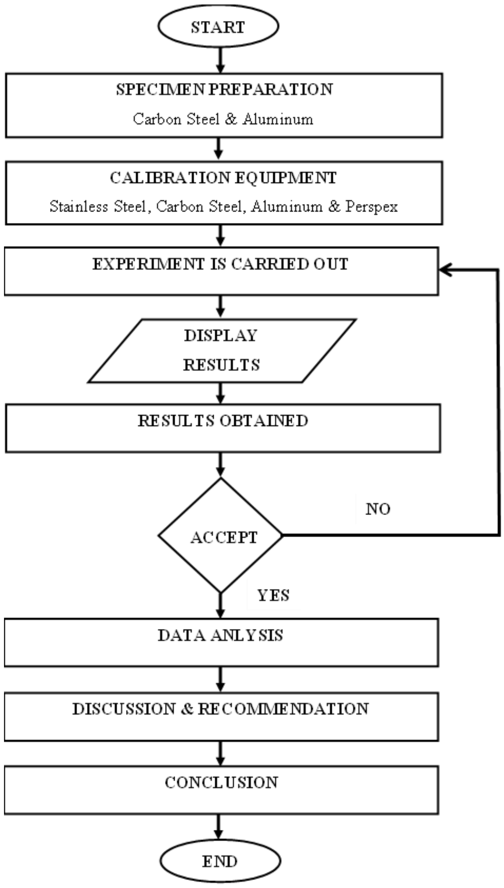

Figure 1: Research Flow Chart

2.1Testing Material

The accuracy in sample preparation is important to ensure the reliability of the finding. Here, the carbon steel and aluminum specimen were prepared for the experimentation. Figure 2 and Figure 3 shows the carbon steel specimen cut into 15.10 cm × 2.5 cm with thickness 26 mm and aluminum 15.00 cm x 2.5 cm with thickness 16 mm respectively.

Figure 2: Carbon steel plate dimension

Figure 3: Aluminum plate dimension

Next, the milling process was introduced to create flat, curved or angled surfaces. In order to estimate the machined surface roughness upon face milling for 20 mm wears of cutter tooth on the back surface. The experimental studies were performed. Grinding is the next step in the process, and it is used to remove impurities from the sample as well as to minimize surface damage from the previous process, which can lead to corrosion. Hand-grounding was done on the specimen at Grade 400 of roughness. The process was continued on until the specimen has very smooth surfaces. Lastly, it was polished. This is important because it prevents the surface from being scratched.

2.2 Methods

To perform the objectives of this study, the thickness of the carbon steel and aluminum is measured by ruler, vernier caliper and A1207 Pengauge. The sample were initially polished by using the sand paper Grade 400. In this experimental inspection on the thickness measurement, A1207 Pengauge is calibrated by using 4 dissimilar calibration blocks as shown in the Figure 4. There are 4 dissimilar blocks used in the study had the following dimension in Figure 4. The thickness of the calibration block is 5mm, 10mm, 15mm and 20mm used.

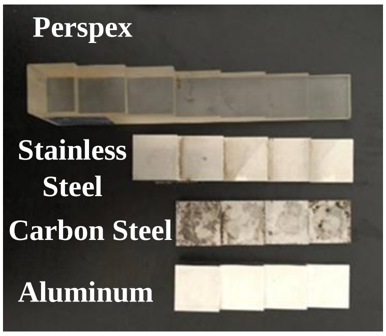

Figure 4: The calibration block

Figure 5: Calibrate on the aluminum

Figure 6: Calibrate on the Perspex

Figure 5 and Figure 6 show the carbon steel denoted as CS and Aluminum as AL. Basically, the carbon steel be the reference specimen in the entire experiment. From the left side of Figure 5 which is before calibration the reading of the aluminum is 18.40 mm after calibration it become 20 mm. As demonstrated in Figure 6 calibration on the Perspex, before calibration the reading was 43.70 mm and after calibration it become 20 mm by using Snell’s Law formula.

2.3 Equations

Snell's law was used to determine the direction of sound rays through pair of media with varying indices of refraction. [4] For the each θ as the angle measured from the normal of the boundary, ν as the velocity of light in the respective medium, m/s and the λ as the refractive index of the respective medium.

$$\frac{\sin\theta\ 1}{\sin\theta\ 2}=\frac{\nu 1}{\nu 2}=\frac{\lambda 1}{\lambda 2} \qquad \text{eq. 1}$$

3. Results and Discussion

This chapter discussed the results and data obtained from the experimental which is comparison of the equipment on the dissimilar material. The X-axis and Y-axis of the average accuracy thickness of the Pengauge that obtained from the android device, ruler and vernier caliper are used to calculate the required data. The data has been calculated by using Snell’s law equation. The collected and calculated data shown in Table 1 and Table 2. From the result obtained, discussion is made on the experimental conducted.

3.1 Data verification

Table 1 demonstrated the average thickness measured on the carbon steel plate. The average thickness and the standard deviation of the carbon steel measured by ruler, vernier caliper and A1207 Pengauge is 24.00 mm, 24.89 mm, 25.01 mm and 0.7071, 0.3037 and 0.4916. In A1207 Pengauge the average of the thickness is the closest to the experiment thickness 25 mm as the first distribution, the standard deviation is higher 0.4916 compared to 0. 3037.

Besides, Figure 7 show the trend of the average thickness of carbon steel measured by the three tools, it can be seen that the accuracy of the vernier caliper and A1207 Pengauge remained close to each other, it’s showing the accuracy, precision and sensitivity of both tools is higher compared to ruler.

Table 1: The average thickness of the carbon steel plate.

Plate : Carbon Steel	Experiment Thickness 25.00 mm		
Area	Ruler	Vernier Caliper	A1207 Pen-Gauge
A	25.00	25.30	25.59
B	24.00	25.05	25.21
C	24.00	24.71	24.99
D	23.00	24.51	24.24
Average of thickness	24.00	24.893	25.008
Standard Deviation	0.7071	0.3037	0.492
% of accuracy thickness difference	0.000	1.4438	2.000

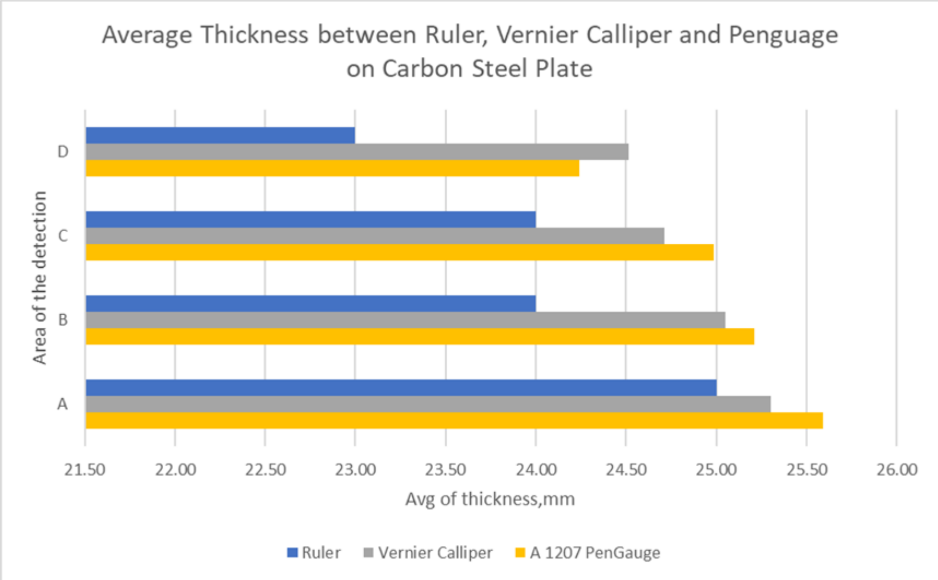

Figure 7: The average thickness between ruler, vernier caliper and Pengauge on carbon steel plate

Table 2: The average thickness of the aluminum plate

Plate : Aluminium	Experiment Thickness 15.00 mm		
Area	Ruler	Vernier Caliper	A1207 Pen-Gauge
A	16.400	16.230	16.100
B	15.600	16.646	15.500
C	15.000	15.154	15.140
D	14.000	14.424	14.462
Average of thickness	15.250	15.614	15.300
Standard Deviation	0.876	0.876	0.593
% of accuracy thickness difference	0.000	0.4575	2.000

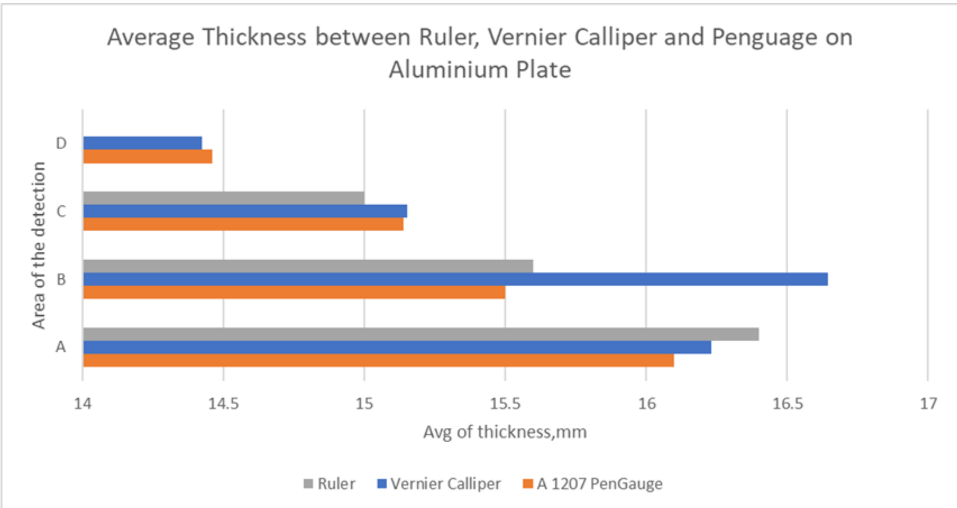

Figure 8: The average thickness between ruler, vernier caliper and Pengauge on Aluminum plate

Table 2 shows the experimental thickness is 15 mm. From the average thickness and the standard deviation for ruler, vernier caliper and A1207 Pengauge is 15.25 mm, 15.61 mm, 15.30 mm and 0.8760, 0.8763 and 0.5932, respectively. In A1207 Pengauge the average of the thickness is closer to the experiment thickness 15mm, the standard deviation is smaller which is 0.5932 compared to ruler and vernier caliper. From both results obtained of the standard deviation the A1207 Pengauge has a thin narrow bell curve with a high probability of accuracy which the value close to the experimental thickness.

Besides, the bar chart in Figure 8 illustrates the average thickness between ruler, vernier caliper and A1207 Pengauge on aluminum plate. It can be seen that the accuracy of the vernier caliper and A1207 Pengauge remained close to each other, it's showing the accuracy, precision and sensitivity of A1207 Pengauge is higher compared to ruler and vernier caliper.

Overall, the result demonstrated that the accuracy of the vernier caliper and A1207 Pengauge give a good accuracy result with the regression result and both can be used in the industrial. According to the Table 1 and Table 2, the accuracy is compared between ruler, vernier caliper and A1207 Pengauge. Vernier caliper was the best instrument for thickness estimation since more likely close to zero percentage as it had performed precisely on each piece of the example contrasted with the ruler and A1207 Pengauge. However, the consistency of the A1207 Pengauge thickness is very consistent. Which mean from the percentage of the accuracy thickness difference for both plate carbon steel and aluminum plate which is 2% error. From the data obtained it shows that the value of its sensitivity and precision of the A1207 Pengauge. As indicated by a past report, the main part of vernier caliper adjustment is guaranteeing that the precision rules are met.

Furthermore, significant thickness readings are sometimes impossible to obtain because the material standardization, range, surface roughness on the instrument control has been changed incorrectly, resulting in erroneous data interpretation. As stated in ASME E797, Standard Practice for Measuring Thickness by Manual Ultrasonic Pulse-Echo. [5] Therefore, three methods have been discussed. A comparison of these method is provided in Table 3, giving a brief overview.

Table 3: The advantages and disadvantages of ruler, digital vernier caliper and A1207 Pengauge

Method	Advantages	Disadvantages
Ruler	Can measure longer/larger objects	The measurements are not very precise nor accurate.
Digital Vernier Calliper	It does not need to record data manually, so it is convenient, fast and labour-saving. Save cost and improve work efficiency.	The electronics of a digital calliper can be affected by very hot or cold conditions. This decreases the reliability of its measurements.
A1207	Small, lightweight, Fast, inspect large area, excellent for corrosion detection	Reference standards are required, surface needs to be smooth

From the observation, result of precision mean how close the measurement on the same equipment. So, the Pengauge has the same percentage difference of the accuracy thickness which is 2%. Moreover, accuracy mean how close a measurement is to the true or accepted value. So, meaning that vernier caliper is accurate because it close to zero percentage. Lastly, the Pengauge is the best because it portable, precise, accurate, sensitive, can be inspect in large area and excellent for corrosion detection to the measurement and the accuracy is same to vernier caliper. It can be demonstrated that the higher the percentage of accuracy thickness, the accurate the tools/method are.

Table 4: The visibility of distance range of the A1207 Pen-gauge

Distance measurement of connection for Bluetooth data transmission.

Distance (m)	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00	6.50	7.00	7.50	8.00
Reading connection on hand-phone	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good

Distance (m)	8.50	9.00	9.50	10.00	10.50	11.00	11.50	12.00	12.50	13.00	13.50	14.00	14.50	15.00	15.50	16.00
Reading connection on hand-phone	Good	Good	Good	Delay	Delay	Delay	Delay	Delay	No Reading	No Reading	No Reading	No Reading	No Reading	No Reading	No Reading	No Reading

Data transmission between A1207 Pengauge and receiver from the android system was the best from 0.50 meter to 9.50 meter but started to have delay of data receiving by the Android device from 10m to 12m. The connection has been severed on 12.5m onwards. To sum up, the distance taken without barrier because the transmission of the data is in open space. If the usage of WIFI and internet to connect all available, operators on the inspection can share data through live streaming using screen sharing or online meeting.

4. Conclusion

In conclusion, upon the completion of the experiment, it performed exactly as intended during the planning stage. The result obtained of vernier calliper and A1207 Pengauge required parameters precisely by interpreting the calculated velocity. The main objective was to determine the percentage error of the thickness based on theoretical and experimental method on the calibration of the A1207 Pen-gauge. The results show that the A1207 Pengauge can still measure the thickness of plate precisely same as vernier calliper. The thickness measurement changed based on the results of different areas of inspection, which could be due to inaccuracies or other factors such as the operator's incompetence when using the A1207 Pengauge method. The A1207 Pengauge method necessitated the use of a high-skilled operator who was adept at interpreting results. As a result, if vernier calliper are unavailable, A1207 Pengauge could provide accurate and dependable results. When compared to a vernier calliper with a lower error, the results show a good percentage.

During the experimental stage, the A1207 Pengauge performed very well as expected. Where the visibility distance range when receiving the data using android device is up to 8 meters. Hence, the Pengauge has been proven to be reliable and the results given can be used and act as a good reference to the operator.

Acknowledgement

The authors would also like to thank the Faculty of Mechanical and Manufacturing Engineering, Universiti Tun Hussein Onn Malaysia for its support.

References

[1] Cong, S., & Gang, T., "Ultrasonic thickness measurement for aluminum alloy irregular surface parts based on spectral analysis," *Transactions of Nonferrous Metals Society of China (English Edition)*, *22* (SUPPL.2), s323-s328, Dec 2012

[2] Xie, Y., Yin, W., Liu, Z., & Peyton, A. (2016). Simulation of ultrasonic and EMAT arrays using FEM and FDTD. *Ultrasonics*, *66*, 154–165.

[3] Lebowitz, C. A., & Brown, L. M. (1993). "*Ultrasonic Measurement of Pipe Thickness," Review of Progress in Quantitative Non-destructive Evaluation, Vol. 12 Edited by D.O. Thompson and D.E. Chimenti, Plenum Press, New York, 1993, pp.1987 – 1994.*

[4] Jankowski, Ł. (2005). *Modelling and simulation of light propagation in non-aged and aged step-index polymer optical fibres*. Wirtschaftsverl. NW Verl. für Neue Wiss

[5] Iskandar, N., & Yusup, E. M. (2021). The Evaluation for Accuracy of Non-destructive Testing (NDT) in Ultrasonic Inspection on Stainless Steel Material by Ultrasonic Testing Thickness Measurement. *Research Progress in Mechanical and Manufacturing Engineering*, *2*(2), 685–692.