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The Evaluation for Accuracy of Non-Destructive Testing (NDT) in Ultrasonic Inspection on Mild Steel Material by Ultrasonic Testing Thickness Measurement (UTTM)

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Abstract: Ultrasonic testing (UT) refers to a group of non-destructive testing techniques that include sending ultrasonic waves through a substance or object. Ultrasonic testing is frequently utilized in industrial applications on metals, polymers, composites, and ceramics. UT is used for thickness measurement when ultrasound wave reflected back to the surface. This study is to analyze the thickness measurement of mild steel plate using three different measuring tools which are ruler, vernier caliper and ultrasonic testing. Also, the Ultrasonic Testing Thickness Measurement (UTTM) method is applied with couplant such as oil, water and grease to evaluate the thickness properties using single probe and twin probe. The ultrasonic waves will pass through the transmitter and receiver of mild steel plate for UTTM method. After constructing the experiment for 30 days exposing to environment, the result obtained from the study shows that UTTM method can be applied to 5 mm mild steel plate. Overall, the percentage difference of UTTM compared to Vernier Calliper is only 1 to 2%, while 10% compared to ruler. Thus, UTTM can be applied for thickness measurement especially for complicated or material that only require one side access.

Keywords: NDT, Ultrasonic Testing, Couplant, UTTM, Mild Steel, Thickness

1. Introduction

Methods for determining structural integrity for surface or internal defects or metallurgical faults are Non-Destructive Testing (NDT). Condition without interfering in any way with the material's destruction or service suitability (Kumar & Mahto, 2013). NDT includes the detection and identification of characterization of damage or defects to the surface and interior of materials without the material being broken apart or otherwise changed. NDT make available or have a cost-effective solution means

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of evaluating a sample for individual investigation and analysis or as for the whole substance to be applied for inspection in a method of manufacturing quality control (Gholizadeh, 2016).

Ultrasonic Testing (UT) uses high-frequency sound waves in the range of 0.5 to 15 MHz for testing purposes. Under inspection, A probe transmits high frequency sound wave into the material tested. There are two output signals, one from the initial sound wave of the probe and the second due to echo from back wall (Sharma & Sinha, 2018). The primary type of defect that occurs within the component is delamination, leading to inhomogeneity within the composite component. Delamination must be observed at a length greater than 1 mm. The identification of defects within the part can be complicated by several variables, such as porosity, incorrect volume fraction, inadequate curing and moisture absorption. (Jolly, et al., 2015). The inspection is actually can be divided into two types which are Ultrasonic Testing Flaw Detector (UTFD) and Ultrasonic Testing Thickness Measurement (UTTM).

The research is connected to prior measurement tools such as a ruler and a Vernier Caliper, which were not reliable in certain situations since they required both inside and outside access to the test piece. If just one side of the test sample can be accessed, it is impossible to determine the thickness without changing the sample, equipment, or system. As a result, the UTTM approach is a viable option for measuring thickness when only one side is accessible. UTTM can be applied to monitor corrosion, erosion and damage of test piece to ensure the continued safety and operation of the inspected test piece.

2. Materials and Methods

The study involved the practice of Non-destructive Testing (NDT) method. UTTM is applied on the surfaces with different couplants; grease, oil and water after 30-days of exposing mild steel plates to the environment with two other measuring tools which are ruler and Vernier Caliper (VC). Also, the inspection involved single crystal probes and twin crystal probes to analyze its zero degrees probe sensitivity.

2.1 Materials

Mild steel plates are chosen as the testing specimen. The velocity of mild steel is 5960 m/s. (Mathies & Klaus, 1998) The sound velocity in a specific test material should always be determined by completing a velocity calibration on a sample of known thickness for the best accuracy in thickness gauging. (Olympus, 2019). Figure 1 illustrates the effect of velocity on the corrosion rate of mild steel.

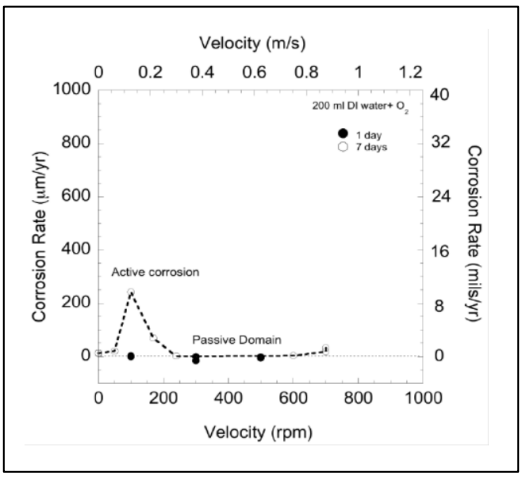

Figure 1: The effect of velocity on the corrosion rate of mild steel (Fredj et al., 2014)

UTTM is carried out with two different probes which are the single probe and also the twin probe. Figure 2 and Figure 3 show the single probe and twin probe respectively while Table 1 shows the specifications of the probe used for the inspection.

Table 1: Specifications of Probe

Type of probe	Single Probe	Twin Probe
Model	MB 4S (57749)	MSEB 4 (57642)
Frequency	4MHz	4MHz
Diameter	3.5x10	10
Brand	USM GO	USM GO
Standards	EN ISO16946:2017	

Figure 2: Single Probe

Figure 3: Twin Probe

2.2 Methods

The flow chart on methodology for this study is illustrated as in Figure 4 and Figure 5.

In this study, the scope and limitations are as follow:

i. The thickness measurement of Mild Steel plate is measured by using ruler, vernier calipers and UTTM method.
ii. The couplant for scanning during UTTM method is based on three different types of couplant which are water, oil and grease.
iii. The sample of Mild Steel plate is sand blasting which is to analyze the rigidity of the material.
iv. The sample of Mild Steel plate is exposed to environment in certain period of time before measured its thickness for ageing effect testing.
v. UTTM method is implemented with different 0º probe; Single Crystal Probe and Twin Crystal Probe to measure the thickness of Mild Steel plate.

2.3 Standards

i. Standards for the Calibration Block – ISO 16946: 2017. Non-destructive testing – Ultrasonic testing – Specification for step wedge calibration block
ii. Standards for the CRT Screen - BS EN 14127:2011. Non-destructive testing – Ultrasonic thickness measurement

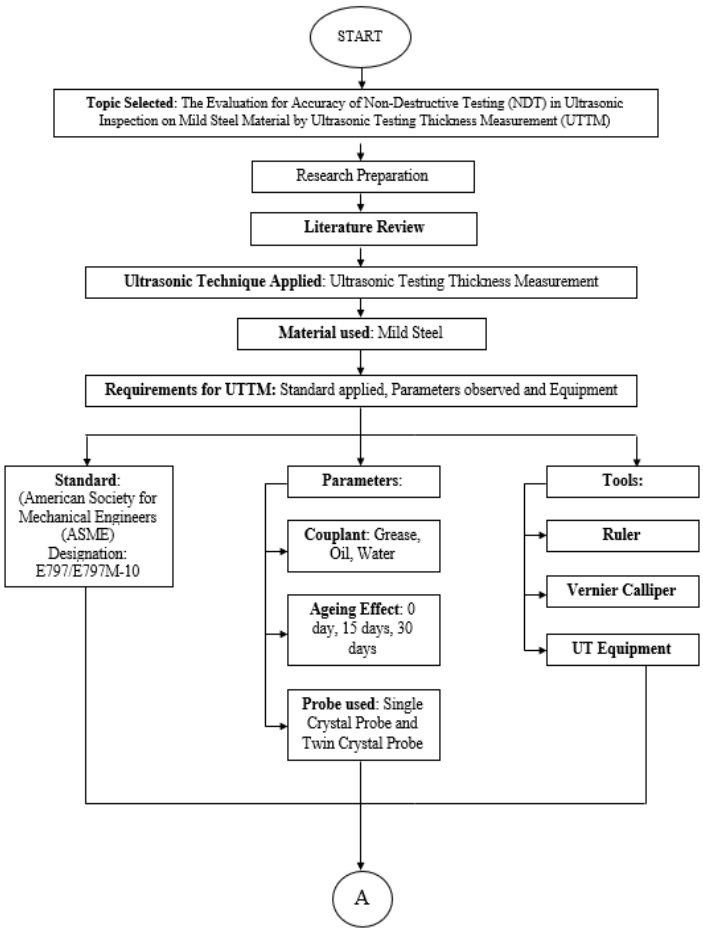

Figure 4: Flowchart on methodology

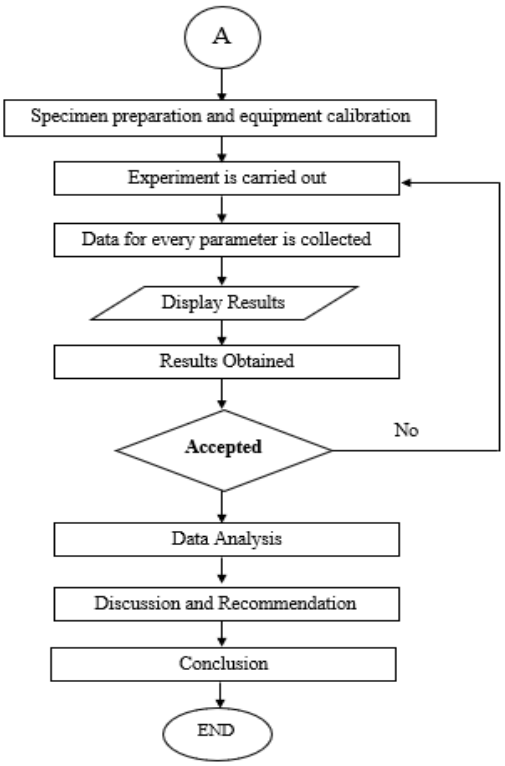

Figure 5: Flowchart on Methodology (continued)

2.4 Equations

Formulae applied for this section is the best line percentage to find the accurateness (%) of couplants respectively to the probes being used is as the following:

$$Best\ line = \frac{AverageValue(mm)}{ExactValue(mm)} \times 100 \qquad \text{Eq. 1}$$

3. Results and Discussion

In this section, results obtained for UTTM application to the mild steel plates are highlighted. It covers:

i. Non-blasting Mild Steel
ii. Blasting Mild Steel

Table 2: Results Summary for Mild Steel Plate

	Day	Probe	Gain Value (dB)	Couplant
Non-blasting mild steel plate	0	Single	36.3	Water
		Twin	36.1	Water
	15	Single	36.0	Grease
		Twin	36.6	Oil
	30	Single	36.8	Oil
		Twin	38.0	Oil
Blasting mild steel plate	0	Single	34.8	Grease
		Twin	36.1	Grease
	15	Single	35.7	Grease
		Twin	37.5	Grease
	30	Single	35.1	Grease
		Twin	36.0	Grease

3.1 Non-blasting Mild Steel

The results are categorized into three which are Day-0, Day-15 and Day-30 results. For non-blasting mild steel, the mild steel plates do not undergo sandblasting process where the surface only be cleaned using sand paper before inspection. Based on Table 2, the highest gain value for non-blasting mild steel is on day-30 inspection recorded by the twin probe with oil as couplant with 38.0 dB. Thus, twin probe is more precise in UT inspection for the non-blasting mild steel on Day 30 since the transmission coefficient is higher because the gain value is higher than the single probe. (Netshidavhini & Mabuza, 2012) Oil is suitable to medium rough samples' surface. (Chandrasekaran, 2021) The surfaces of sample are observed to be quite rough after 30 days of exposing samples to the environment due to rusting process. Comparing the accurateness (%) of twin probe with oil to ruler and Vernier Calliper, UTTM and ruler has 15.8% gap difference while for Vernier caliper the accurateness is the same.

3.2 Blasting Mild Steel

Referring to Table 2.3, the highest gain value obtained from the inspection is on day-15. The value is 37.5 dB held by the inspection using twin probe with grease as couplant. When the amplitude is higher, the transmission coefficient also gets higher which explains that grease reflected maximum back-wall echo for samples inspected compared to oil and water. (Netshidavhini & Mabuza, 2012) Grease is preferably for rough surface, (Chandrasekaran, 2021) On the other hand, when compared the twin probe with grease with ruler and Vernier Caliper, the percentage difference is in the range of 1 to 2% only which explained high UTTM method accuracy. According to Cygnus Instrument (2016), twin probe is more capable to thin plates with standard twin crystal probe frequency.

4. Conclusion

As a conclusion, the experimental was successfully conducted. UTTM is proved to give the equivalent results of measurement for thickness of mild steel plate when compared the readings with ruler and VC. There are a lot of factors affecting the accuracy reading of UTTM where one of them is the requirement of high skills in handling the equipment and also in interpreting the signal arise. UTTM can best be applied to condition that having difficulty in accessing through two access in order to measure the thickness for example in measuring the thickness of pipeline. It is not possible to measure the thickness of pipeline under operation by using both ruler and VC, because the pipe need to be cut to allow the measurement since they need two access to implement it. Overall, the percentage difference of UTTM compared to VC is only 1 to 2%, while 10% compared to ruler. Thus, UTTM can be applied for thickness measurement especially for complicated or material that only requires one side access.

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