

# Non Destructive Test Dye Penetrant and Ultrasonic on Welding SMAW Butt Joint with Acceptance Criteria ASME Standard

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**Abstract.** The purpose of this research is to know the type of discontinuity of SMAW welding result and to determine acceptance criteria based on American Society of Mechanical Engineer (ASME) standard. Material used is mild steel 98,71% Fe and 0,212% C with hardness 230 VHN with specimen diameter 20 cm and thickness 1.2 cm which is welded use SMAW butt joint with electrode for rooting LB 52U diameter 2.6 mm, current 70 Ampere and voltage 380 volt, filler used LB 5218 electrode diameter 3.2 mm with current 80 Ampere and 380 volt. The method used to analyze the welded with non destructive test dye penetrant (PT) method to see indication on the surface of the object and Ultrasonic (UT) to see indication on the sub and inner the surface of the object, the result is discontinuity recorded and analyzed and then the discontinuity is determine acceptance criteria based on the American Society of Mechanical Engineer (ASME) standards. The result show the discontinuity of porosity on the surface of the welded and inclusion on sub material used ultrasonic test, all indication on dye penetrant or ultrasonic test if there were rejected of result of welded that there must be gouging on part which rejected and then re-welding.

## 1. Introduction

The rapid industrial market in various fields in the country is characterized by the increasing infrastructure development in various region. In the infrastructure development is not spared from the role of the metal welding process. The welding process in this metal is of many kind include Shielded Metal Arc welding (SMAW), Gas Metal Arc Welding (GMAW), Gas Tungsten Arc Welding (GTAW), Flux-cored Arc Welding (FCAW), and Submerged Arc Welding (SAW).

Welding technology at this time is experience a very advanced development with a variety of new methods that have been found both using conventional and automatic. Behind the benefits of the welding process so much, but in the process of metal welding the results are not always good, this happen is influenced by many factor both intentionally and unintentionally. To handle it, it is necessary to inspect the welding results to be in accordance with the wishes and safe to use. Methods to inspect the welded results are one with non-destructive test (NDT) method of dye penetrant and ultrasonic.

The method of Liquid Penetrant Test (dye penetrant) is the simplest method of NDT but the advantage of speed and accuracy in detecting defects on the surface. This method is used to find defects in the open surface of solid components, both metal and non-metal, such as ceramics and fiber plastic. Through this method, defects in the material will be seen more clearly by looking at the indication on



the surface of the test object after sprayed developers who then in skeet to be used as reporting work that will be translated to acceptance criteria.

This test can also be used in the aircraft industry for routine maintenance in checking of aircraft components, in which the test procedure, the surface preparation of the components, the component protection during the test and all pertaining to the penetrant test [1].

Ultrasonic Testing (UT) is one of the non-destructive test on the material. Ultrasonic test is that uses the sound frequency to detect defects in solid objects. This is based on the fact that solid objects represent good sound waves. This Testing Principle is performed by reflecting ultrasonic sound waves an object then the reflection of the wave from the object is captured by the probe. The difference in surface depth is an indication of a defect in an object [2].

Ultrasonic waves can be generated by changes in electrical energy to the mechanical energy of a transducer called a probe, via a piezoelectric effect. The piezoelectric effect is a reversible effect means that if there is a change of electrical energy to mechanics, the mechanical energy changes to electrical energy occurs. To check the thickness of the material and the presence of defects in a material with ultrasonic waves can be done in three ways, namely resonance techniques, transmission techniques, and echo techniques. Of the three techniques, echo techniques are most commonly used primarily on field checks [2].

The basic principles of the three techniques are:

### *1.1. Resonance technique*

The thickness of the material can be measured by measuring the ultrasonic frequency or wavelength that can cause maximum resonance on the material. The presence of defects can be detected by the occurrence of resonance change as the distance of the resonating material changes.

### *1.2. Transmission technique*

The existence of defects in the material can be known from the decrease of wave intensity. Ultrasonic received by the receiver probe while the thickness of the material can not be measured by the transmission technique.

### *1.3. Echo technique*

The thickness of the material, location and magnitude of the defect can be determined from the time of propagation and wave amplitude received by the probe.

The velocity ( $v$ ) of ultrasonic wave in a material depends on the type of material through which the wave modes pass as defined in the following equation [2].

Longitudinal Mode:

$$V_L = \sqrt{\frac{E(1-\sigma)}{\rho(1+\sigma)(1-2\sigma)}} \quad (1)$$

Transversal Mode:

$$V_T = \sqrt{\frac{E(1-\sigma)}{2\rho(1+\sigma)}} \quad (2)$$

Couplan serves to facilitate the propagation of wave from the probe into the specimen. Because if between the probe and the test object is air then almost 100% of the wave will be reflected back into the probe and the reflected wave will spread more than focus on the defects in the material. In order for the thick coupling between the probe and the fixed assay, the pressure applied to the probe must be constant so as not to affect the amplitude of the indication on the screen [2].

Ultrasonic aircraft have in common with oscilloscopes where measurements are made based on time and voltage measurements. Time measurements are presented on a horizontal scale as ultrasonic wave distance measurements. Voltage measurements are presented on a vertical scale as an amplitude

measurement to determine the attenuation coefficient of the wave through the medium. This horizontal and vertical scale must be linear in order and produce an accurate output value [2].

There are 3 types of probes:

- Single Normal Probe
- Single Angle Probe (450, 600, 700)
- Normal Probe and Twin Corner

The purpose of this research is to determine the specimen can be accepted based on acceptance criteria of ASME standard. The expected result of this research is to provide input to take holder the welding test about non destructive test ultrasonic methods and provide standard description for acceptance criteria of defect indication on weld result based on ASME standard.

## 2. Literature Review

The metal welding process has been known for a long time, various techniques have been developed till now, and one of the most applied welding techniques in the field is Shield Metal Arc Welding (SMAW). The SMAW welding process is included in the arc welding process group, which includes Tungsten Arc Welding Gas and Metal Arc Welding Gas. In some previous studies stated that the welding arc welding technique can be examined the results weld using ultrasonic testing [3]. The assessment process was developed using an ultrasonic method of a transducer conducted on the welded joint area by direct contact technique.

The methodology for qualifying and demonstrating ultrasonic test technique to determine the results of welded joints on pressure vessels. The pressure vessel is made of welded steel plate welded joint with customized shape and size. The inspection process is carried out from only one part i.e. the outer part of the welded joint [4].

Ultrasonic tests by comparing SMAW and GTAW welding results in AISI 316L steel. The austenitic character is divided into grain orientation distribution and anisotropy shows that on GTAW specimen is more isotropic than SMAW for grain orientation. B-scan results show SMAW inspection easier than GTAW process [5].

Ultrasonic applications for conventional processes include casting and welding. They reported ultrasonic wave on austenitic stainless steel (AISI 316) with an investigation system of 20 kHz ultrasonic wavelength effect on the material microstructure during the welding process [6]. The complex vibration system in which ultrasonic welding is effectively applied to different types of specimens include the same metal specimen as well as to specimen with different metals.

The inspection of the thickness of the welded joint using an ultrasonic laser SAFT. Detecting from the defects on the butt connections on the welding is required to reduce the cost and rework time. The specimen were used from steel with thickness 25 mm and 50 mm [7].

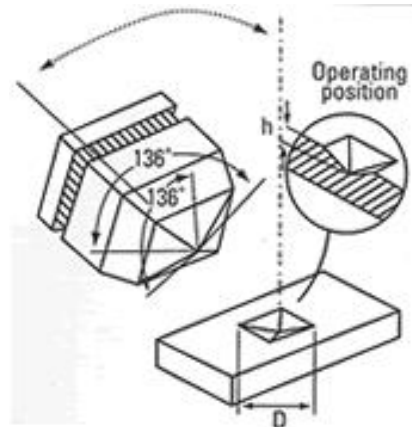
### 2.1. ASME standards

Standard American Society of Mechanical Engineers (ASME) Section IX is the most commonly used standard for welder qualification. Committees and subcommittees of volunteer workers are interested in advancing the quality and efficiency of the welding industry by developing this code. ASME is specialized for welder qualification and welding procedures. A "construction standard" such as ASME part VIII Division I must be used in conjunction with Part IX for fabrication [8].

## 3. Methods

In this study using material from mild steel which then made SMAW welding process of 3G butt joint position on plate material with size 30 cm x 20 cm x 1.2 cm which bevel 300 on each specimen. The welding process uses a maxstar 200 miller with LB 52U diameter electrode diameter of 2.6 mm using 70 Ampere current and 380 volt voltage, while for filler using LB 5218 diameter 3.2 mm electrodes with 80 Ampere current and 380 volt voltage [9].

Hardness testing process using innovates engine type verus 700AS vickers method with the use of 20 Kgf load and indentation time 10 seconds. The hardness test method according to ASTM E-384 (see figure 1), sets the diamond indenter to the angle between opposing surfaces is 136° [10].



**Figure 1.** Hardness vickers.

After the force is removed then it is measured diagonally, so the hardness of vickers can be formulated by the equation [10]:

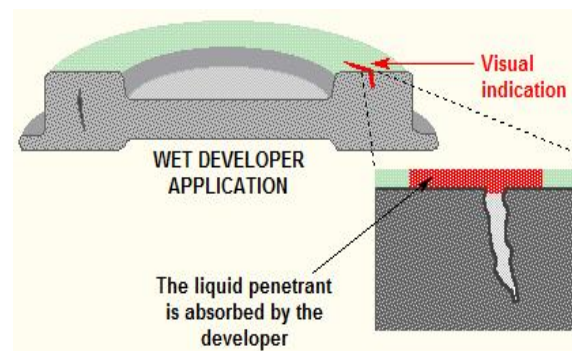
$$H = \frac{1.8544 P}{d^2} \quad (3)$$

NDT of dye penetrant test spotcheck method using the visible Magnaflux type visual marker with SKC-S No. code cleaner. 170404, Penetrant SKL-SP2 No. 160408 and developer SKD-S2. 170401. Tools used include wire brushes, coats, and duster.

### 3.1. Dye penetrant test

Non Destructive Test Dye Penetrant process is done with the following stages:

- Check the light intensity of at least 1000 lux
- Check penetrant sensitivity using standard blocks
- Clean the surface using a wire brush to remove the dirt that covers the defect
- Clean the surface by using solvent to remove dirt in the form of dust, oil and others
- Spray the penetrant to surface evenly
- Allow the penetrant (dwell time) for 10 minutes
- Remove excess penetrant using solvent on fabric in one direction
- Dry the surface after use of solvent
- Spray the developer to surface evenly
- Wait for the developer to react (dwell time) about 30 minutes
- Evaluation of discontinuity indication (see figure 2)
- Record indication of discontinuity (indication of length, diameter, discontinuity of reference point)
- Post cleaning using solvent until clean.



**Figure 2.** Indication of discontinuity [11].

### 3.2. Ultrasonic test

This Ultrasonic NDT Test uses the Karl Deutch 1090 series flaw ultrasonic detector with 700 probes, 4 Mhz frequency and coupl grease. The Tools needed such as pencils and long gauges (Ruler).

The method used in the Determination of Disabled Dimensions is done by the 6 dB drop method is when the probe position on the edge of the defect can be determined if 50% of the wave is continued while the other 50% is reflected back to the probe. Therefore, the probe can be said to be in a defective edge position. By shifting the probe across the surface of the specimen, the edge of the defect will be determined to obtain its dimensions. In this method also performed the addition of 6 dB from the previous calibration gain. 6dB increment occur because to detect defects should look for pulses that are in the position of 50% full height screen. When the initial pulse position 100%FSH changes to 50%FSH there is a dB reduction of 6dB. Therefore, the maximum amplitudes are obtained to determine the edge defect. To detect the end limit of the long edge of the defect then the probe must be moved back to find the pulse in the same position that is 50%.

Test steps are as follows:

- 1) Measure base material and configuration drawing
- 2) Check the visual root
- 3) Normal probe calibration
- 4) Inspection of laminate defects in base material
- 5) Inspection on weld result
  - Check the angle index point of the probe
  - Determine calibration using blocks V1 and V2
  - Perform mileage calibration
  - Place the DAC curve at 700 angles
  - Setting gain sensitivity
  - Analyze defects on the ultrasonic screen detector tool
  - After you see any defect indication, find the maximum pulse then measure from the point of probe indices to the middle of the weld (X0) and read M1 patch on the tool screen (S0)
  - Find the defect length by shifting the probe up down to down to 20% DAC and marked on the center of the probe face.
  - Plotting determines the position and location of defects in scan B
  - Measure the long bar of defects (L)
  - Measure position (Y) from the nearest zero point
  - Specify acceptance criteria see ASME sec. VIII app.

## 4. Results and Discussion

### 4.1. Composition test

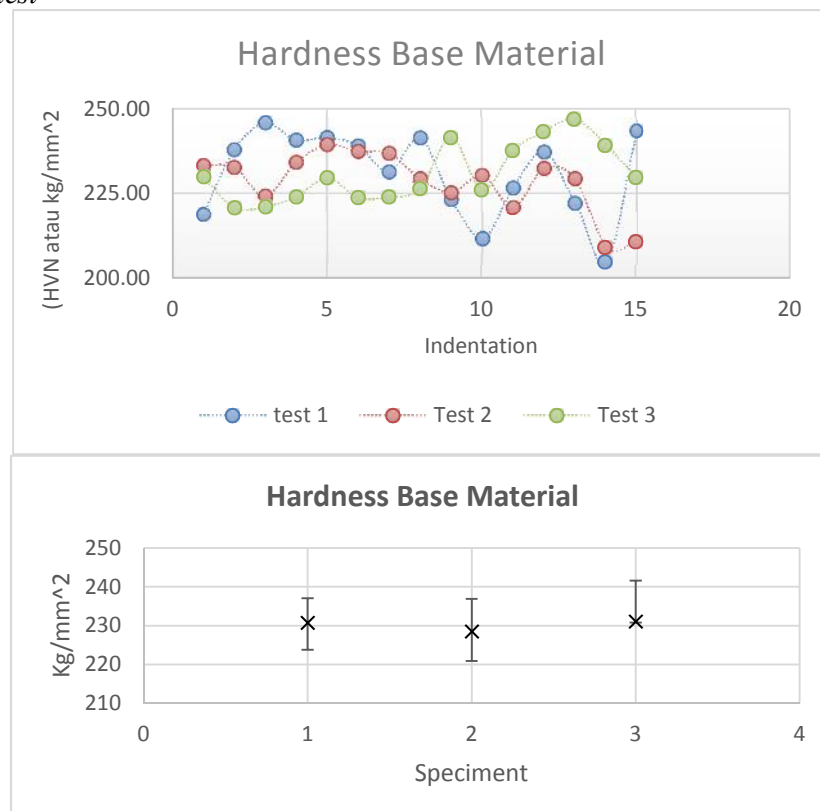
This material composition test uses optical emission spectrometer with brand ARL 3460 with the following results (see table 1):

**Table 1.** Composition base material.

No	Element	Value (%)
1	Carbon	0,212
2	Silicon	0,189
3	Sulfur	0,014
4	Phosporus	0,021
5	Manganese	0,716
6	Nickel	0,02
7	Chromium	0,06
8	Molybdenum	0,005
9	Ferro/iron	98,713

The composition test results can be seen on the table 1 that the main elements contained in the material is Iron (Fe) that is equal to 98.713 percent and with carbon content of 0.212 percent. With this steel having carbon content of less than 0.25 percent it is classified into low carbon steel [12, 13].

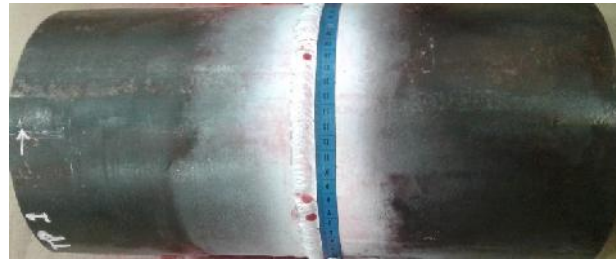
### 4.2. Hardness test



**Figure 3.** Hardness of base materials.

Based on figure 3, the material hardness that contains three materials tested the lowest hardness value is 209.05 VHN and the highest hardness value is 247.00 VHN. As for the average value of the three specimens is 230.16 VHN.

#### 4.3. Dye penetrant test



**Figure 4.** Specimen 1.

**Table 2.** Indication discontinuity specimen 1.

No	Size of discontinuity (mm)	Distance (mm)	Indication	Remark
1	8	57	porosity	Rejected
2	6	73	porosity	Rejected
3	4	77	porosity	Accepted
4	6	171	porosity	Rejected
5	3	182	porosity	Accepted
6	2	185	porosity	Accepted
7	3	188	porosity	Accepted
8	4	233	porosity	Accepted
9	1	246	porosity	Accepted
10	5	250	porosity	Accepted

Based on figure 4 and table 2 above, according to the standard ASME Section VIII Division 4 mandatory appendix 8 on the liquid penetrant testing method states that the standard criteria for discontinuity contained in the welding results shall be independent of linear indication, rounded indication greater than 5 mm and there are 4 or more Rounded indication with a distance of 1.5 mm. So based on the existing data then on this specimen 1 indication that there are some that still fall within the limits of the existing standard so that is stated Accepted. But there are some that are rejected on indications 1, 2, and 4 so it must be repaired welding results by way of gouging then re-welded.

**Table 3.** Indication discontinuity specimen 1.

No	Size of discontinuity (mm)	Distance (mm)	Indication	Remark
1	2	23	porosity	Accepted
2	7	102	porosity	Rejected
3	2	111	porosity	Accepted
4	3	195	porosity	Accepted
5	1	201	porosity	Accepted
6	3	234	porosity	Accepted



Based on table 3, according to the standard ASME Section VIII Division 4 mandatory appendix 8, then based on the available data then in specimen 3 this indication is still within the permitted tolerance limits so that the specimen 3 is declared accepted.

#### 4.4. Ultrasonic test

**Table 4.** Specimen 1 ultrasonik test.

Indication nomer	Probe/Angle	From Surface/side	Reference Level (dB)	% DAC of Discontinuity	Position, Location and size (mm)								Discontinuity			
					Sweep Reading S0		SOD stand of Distance	L Length (mm)	Y Position (mm)	d Dept(mm)	Pos (x)(mm)	M1 pd(mm)	Type	Accepted	Reject	Remark
Sk1	S <sub>0</sub> (mm)	X <sub>0</sub> (mm)														
1	70	I	46,5	32	2,6	26,9	21	10	52	9,2	5,9	25,1	inc		V	gouging
2	70	I	46,5	34	2,8	27,8	22	6	93	9,5	5,8	25,2	inc	V		
3	70	I	46,5	34	2,8	26,7	24	5	102	9,1	2,7	25,1	inc	V		
4	70	I	46,5	43	2,8	28,2	24	11	123	9,6	4,2	25,1	inc		V	gouging
5	70	I	46,5	40	2,8	26,9	23	14	150	9,2	3,9	25,3	inc		V	gouging
6	70	I	46,5	38	2,6	25,4	20	10	205	8,7	5,4	23,3	inc		V	gouging

The test on specimen 1 table 4, six discontinuities were found, where the defect location was spread along the weld. In general, the location of the defect is located on the root of the weld is around the depth of 8.7 mm to 9.6 mm. The shortest defect length is 5 mm and the longest defect length is 14 mm. Referring to the Mandatory Appendix 12 Ultrasonic Examination Of Weld (UT) then the accepted defect (two) is located at a distance, 93 mm, 102 mm. While the rejected there are 4 that is located at a distance of 52 mm, 123 mm, 150 mm and 205 mm.

**Table 5.** Specimen 2 ultrasonik test.

Indication nomer	Probe/Angle	From Surface/side	% DAC of Discontinuity	Position, Location and size (mm)								Discontinuity				
				Sweep Reading S0		SOD stand of Distance	L Length (mm)	Y Position (mm)	d Dept (mm)	Pos (x)(mm)	M1 pd(mm)	Type	Accepted	Reject	Remark	
																Sk1
1	70	2	40	2.8	26.1	26	14	288	9.1	0.1	25	Inclusi		✓		gouging
2	70	2	40	3.3	27.9	21	6	260	9.5	6.9	27	Inclusi	✓			
3	70	2	25	3	28.5	23	4	240	9.7	5.5	26.8	Inclusi	✓			
4	70	2	30	3.4	31.9	30	4	170	9.1	1.9	30	Inclusi	✓			
5	70	2	35	3.2	32.5	29	5	69	8.9	3.5	30.5	Inclusi	✓			
6	70	2	35	3.2	29.8	26	5	40	9.8	3.8	28	Inclusi	✓			



In the test on the specimens 2 table 5, six discontinuities were found, where the defects were scattered throughout the weld. In general, the location of the defect lies in the root of the weld is ranging from a depth of between 8.9 mm to 9.8 mm. The shortest defect length is 5 mm and the longest defect length is 14 mm. Referring to the Mandatory Appendix 12 Ultrasonic Examination Of Weld (UT) then the defects received (accepted) there are 4 pieces located at a distance of 40 mm, 69 mm, 170 mm and 240 mm. While the rejected there is 1 that is located at a distance of 288 mm.

## 5. Conclusions

Based on the results of the above discussion, it can be drawn some conclusions include: Base material contains composition Iron (Fe) 98.713 percent and carbon 0.212 percent. The base material has hardness was 230.16 VHN. All indication on dye penetrant or ultrasonic test if there were rejected of result of welded that there must be gouging on part which rejected and then re-welding.

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