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Experimental Study of Electrode Variation Effect on Connection Strength for Underwater Welding

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ABSTRACT

SMAW welding has various electrodes that can be used in underwater welding. This study will analyze the influence of electrode type on mechanical properties and the influence of welding position on the mechanical properties of joints for underwater welding. This experiment results show that the E7016 electrode pull test has a superior value than the E6013 and E7018 electrodes; when compared between E6013 and E7016, it is reasonable if the E7016 is stronger than E6013 and the frequency level is higher than E6013 even if it already uses a different amper. However, if the E7016 electrode compared to the E7018 is still superior to the E7016 electrode using the same voltage and amper. In addition, the results of macro test observations show that welding using the E7018 electrode has lower porosity levels than E7016 electrodes, while with the same experiment results, the tensile strength of the E7016 is superior to the E7018. So that the power value of E7016 electrodes can be superior to E7018 in this experiment is not only based on porosity that occurs but also slag and imperfect penetration also determines the strength of welding results by using E7016 electrodes.

Keywords: *underwater welding, electrodes, welding positions, tensile tests, macrostructure tests.*

1. INTRODUCTION

This welding technology is increasingly developing because the construction of buildings made with this splicing technique becomes light, and the manufacturing process is also simpler, so the costs incurred are also more economical. Although designed for approximately 20 years, it is unlikely that a structure will not be damaged if the damage is not too much of a problem, but if the damage occurs below the surface of the water, then it takes an underwater technology that will be handled with special requirements as well. [1] Several things can be produced from underwater welding work, one of which is the martensite.

Martensite is a hard form of steel crystal structure, but it can also refer to any crystalline structure formed by diffusion transformation. The martensite phase in the welding results in the marine environment is more than the result of freshwater welding and on land welding, but in macro structures in underwater welding, there is a lot of visible hydrogen embrittlement due to the water dissociation during the welding process. [2] Underwater welding also influences the material's tensile strength, but the material's tensile strength on land is still higher than the tensile strength underwater due to the results of the fault underwater tensile test occurring in the weld metal. Then the hardness of underwater welding material is higher than the material welded on land because the cooling speed on the material welded at a higher temperature, from micro-observations seen in underwater welding is still in the form of ferrite and perlite with the form of lamel from the perlite is very small and tight between the lamel one with the other lamel [3].

There are two different things in seawater: the temperature of water and salt content (salinity) water. Both of these things are very influential in underwater welding activities, but the relationship between temperature and salinity does not affect each other, which means that if the salt content of seawater is high, it does not affect the temperature of seawater and vice versa. Also, precipitation affects the value of salinity. [4] Underwater welding can be done with SMAW and GMAW. SMAW is a welding method usually for repair, but welding in water can cause more brittleness of welding metals and H.A.Z. that obtained reduce the ductility and impact strength of welding metals and increase their porosity and hardness [5].

The ductility of welding done underwater is lower than that of welding done on land, and this is due to the presence of fewer ferrite phases than the perlite phase, which is also characterized by the lowest material elongation. It can also be concluded that the lowest hardness value is found in SMAW and GMAW welding on land welding, due to the salinity that causes the low temperature and finally the cooling speed becomes high, which consequently makes the material become hard and brittle so that it reduces the ductility of the material [6].

After discussing underwater welding above, SMAW welding has various electrodes that can be used in underwater welding. However, there is no discussion of the advantages and disadvantages of these various electrodes that can be used underwater. The experiments' results showed that the advantages and disadvantages of each electrode used for underwater welding could be known.

2. MATERIAL AND METHOD

2.1 Preparation of Material Test and Welding Equipment

The material used is an A36 series steel plate in rectangular shape with length x width x thickness of 300 mm x 150 mm x 10 mm. In conducting this research, the equipment and materials that must be used include:

- SMAW welding machine
- Electrodes E6013, E7016, E7018
- Black duct tape
- Seawater
- Pump
- Hoses
- Water drum 200 liters
- Diving equipment
- Artificial pool with length x width x height (2 m x 1 m x 1.5 mm)
- Lamp

2.2 SMAW Process

The welding process in Figure 3.1 is based on the WPS design that has been created and approved. The welding process is carried out at P.T. Indosal Inti, Kebantenan road II/2, Neighborhood 10, Hamlet 05, Semper Timur Village, Cilincing District, North Jakarta 14130. The type of connection used is the butt joint. In this study, the specimen material used was an A36 steel plate with the SMAW method. Parameters and variations used at the time of welding are:

• Current: 180 – 200 A
• Volt: 78 V
• Electrodes: E6013, E7016 and E7018
• Welding Position: 1G and 2G

Figure 1. SMAW Process

2.3 Specimen Testing

a. Tensile Test

Testing on specimens of welding results will be withdrawn using a test machine until it breaks so that the test results will be obtained in the form of a tensile profile that shows the relationship between the voltage and the strain of the test material.

b. Bending Test

This test will determine the quality of the material visually. As well as bending test used to measure material strength due to loading and bitterness of welding joints in both weld metal and H.A.Z.

c. Macroeconomic Structure Metallography

It examines materials by using our eyes directly or using a magnifying glass with low magnification. Carried out on seven assessments of welding results to examine the surfaces containing crevices, holes in metal structures that are fragile, faulty forms of mechanical testing objects that are subsequently compared with some metals according to their shape and structure, among others according to their needs. Observed are crack, incomplete fusion, incomplete penetration, porosity, and slag.

3. RESULTS AND DISCUSSION

3.1 Welding Procedure Specification (WPS)

In this final task research, the process of welding specimens is carried out at P.T. Indosal Inti, Kebantenan road II/2, Neighborhood 10, Hamlet 05, Semper Timur Village, Cilincing District, North Jakarta. Welding Procedure Specification (WPS) used as a reference for this welding is as shown in Table 4.1 below.

Table 1. Welding Procedure Specification (WPS)

Welding Process	SMAW
Joint Design	*Butt Joint*
Groove	*Single V- groove*
Base Metal	A36 Steel
Filler Metal	E6013, E7016 dan E7018
Posisition	1G dan 2G
Volt Range	78 V
Ampere	180 – 200A

3.2 Result of Tensile Test

Tensile testing on specimens of welding results was carried out at the Welding Laboratory of Politeknik Perkapalan Negeri Surabaya (PPNS). The purpose of this test is to obtain the value of the specimen strength and durability data resulting from welding against the given force load. The results obtained from this test in the form of Fyield and Fultimate data are then processed into yield strength and ultimate strength, then the data can be used as a reference in the design of specimens using A36 steel using the SMAW welding method underwater. Figure 4.1 is the design of the A36 steel material tensile test specimen according to A.W.S. D1.1: 2020

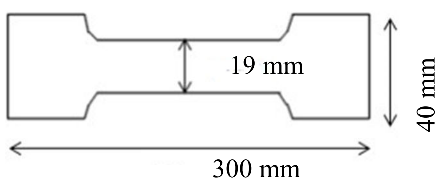


Figure 2. A36 steel plate which has welded

Table 2. show the data from yhe test of speciment are obtained as follows:

Table 2. Fyield, Fultimate data, yield strength, and ultimate strength specimen tensile test

Specimen	Test	Area (mm2)	Fyield (kN)	Fultimate (kN)	Yield Strength	Ultimate Strength	Aver-age Fyield	Average Fultimate	Average Yield Strength	Average Ultimate Strength
E6013 (on land)	1	171	61,95	81,84	362,28	478,62	60,72	81,52	355,1	476,71
	2	171	59,49	81,19	347,92	474,8				
E6013 (1G)	1	171	-	46,69	-	273,03	-	33,15	-	193,85
	2	171	-	19.61	-	114,67				
E6013 (2G)	1	171	24,41	142,74	34,27	200,4	23,31	136,28	33,86	198,005
	2	171	22,2	129,82	33,45	195,61				
E7016 (1G)	1	171	57,01	333,4	61,08	357,2	55,87	326,7	62,225	363,89
	2	171	54,72	320	63,37	370,58				
E7016 (2G)	1	171	54,27	65,25	317,36	381,58	56,58	64,11	330,885	374,9
	2	171	58,89	62,97	344,41	368,22				
E7018 (1G)	1	171	49,12	287,25	53,6	313,45	42,9	245	50,41	294,73
	2	171	34,67	202,75	47,22	276,01				
E7018 (2G)	1	171	58,95	62,83	344,71	367,43	58,73	61,32	343,395	358,585
	2	171	58,5	59,81	342,08	349,74				

So from Table 2, it can be modeled with a graph, it will be shown in Figure 2 and Figure 3 as follows:

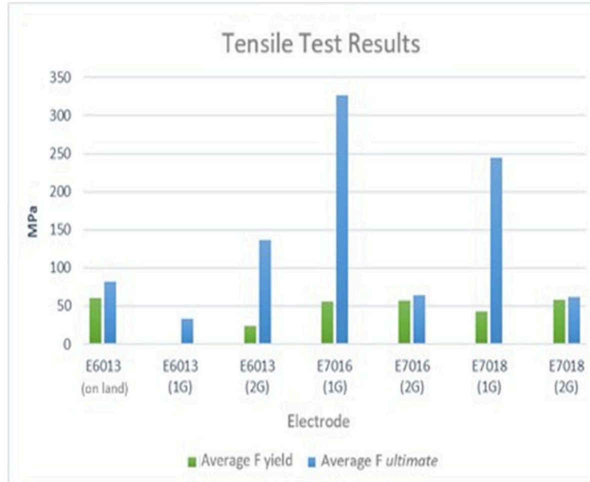


Figure 2. Comparison graph of Fyield and Fultimate tensile test results with electrode variation and welding position

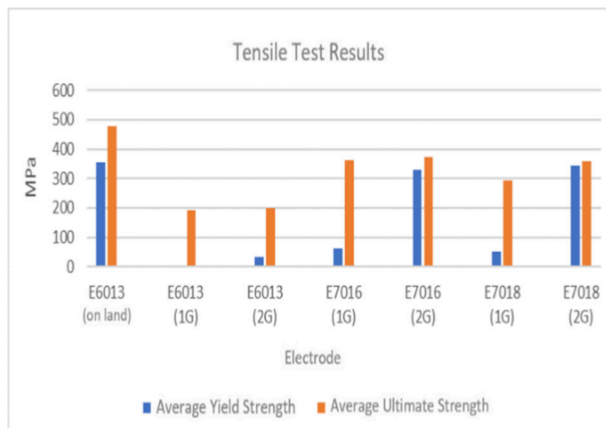


Figure 3. Comparison of yield strength and ultimate strength test values with electrode variation and welding position

From Table 2 and Figure 2, it can be seen that for tensile test results with the most strong yield force value (Fyield) is welding with electrode variation E6013 with conditions on land and 1G position, which is 60.72 kN. However, welding with underwater conditions with electrode variation E7018 with 2G position has the largest Fyield, 58.73 kN. In the ultimate force (Fultimate), the most strong test results showed in welding with electrode variation E7016 with underwater conditions and 1G position, around 326.7 kN. Furthermore, in Table 4.2 and Figure 4.3, it can be seen that the results of tensile tests with yield strength and ultimate strength are the most strong welding with electrode variation E6013 with 1G position and conditions on land, namely by 355.1 kN for Yield strength and 476.71 kN for Ultimate strength. However, for welding results in water, The most strong yield strength is welding results with electrode variation E7018 with 2G position has a value of 343.395 kN and for Ultimate strength welding results with electrode variation E7016 with 2G position has a value of 374.9 kN.

3.3 Result of Bending Test

A bending test on specimens of welding results was carried out at the Welding Laboratory of Politeknik Perkapalan Negeri Surabaya (PPNS). This test was conducted to check the quality of welding results on materials using the reference standard used in this test is A.W.S. D1.1: 2020 with specimen size of 300 mm x 40 mm x 9 mm. This test uses the transverse face bend method and uses mandrel with a diameter of 40 mm and angle of bend of 180^o and open defect measurement using digital funnel term. In the results of bending test on the specimen welding results found an open defect in welding results carried out underwater, but in welding on water found the presence of an open defect on two times faces bend testing, in test 1 was not found open defect but in specimen 2 found an open defect of 40 mm. The result of the bending test that has been carried out is shown in Table 3 below.

Table 3. Bending test result data on test specimens

Electrode	Specimens	Width (mm)	Thickness (mm)	Test Result	
				Open Defect (mm)	Accepted/ Rejected
E6013 (on land)	1	40	9	-	Accepted
	2	40	9	40	Rejected
E6013 (1G)	1	40	9	40	Rejected
	2	40	9	40	Rejected
E6013 (2G)	1	40	9	40	Rejected
	2	40	9	40	Rejected
E7016 (1G)	1	40	9	40	Rejected
	2	40	9	40	Rejected
E7016 (2G)	1	40	9	40	Rejected
	2	40	9	40	Rejected
E7018 (1G)	1	40	9	40	Rejected
	2	40	9	40	Rejected
E7018 (2G)	1	40	9	40	Rejected
	2	40	9	40	Rejected

3.4 Results of Metallographic Macro Structure

A bending test on specimens of welding results was carried out at the Welding Laboratory of Politeknik Perkapalan Negeri Surabaya (PPNS). Macro testing is carried out to determine the welding defects in the specimen welding results, namely crack, incomplete fusion, incomplete penetration, porosity, and slag. Macro testing is done by shooting using DSLR cameras with 7x magnification, but before shooting specimens, welding results must be polished using rubbing paper with grit 80, 120, 240, 400, 600, and 800. Furthermore, etching is carried out using a nital solution and alcohol mixture to see the specimen test results when shooting. In Table 4, the welding defects seen in the welding specimens can be shown.

Table 4. Data of macrostructure metallographic test results on test specimens

Electrode	Test	Crack		Incomplete Fusion		Incomplete Penetration		Porosity		Slag Inclusion	
		Left (mm)	Right (mm)	Left (mm)	Right (mm)	Left (mm)	Right (mm)	Left (mm)	Right (mm)	Left (mm)	Right (mm)
E6013 (on land)	1	-	-	-	-	-	4	-	-	-	-
	2	-	-	-	-	-	3,5	-	-	-	-
E6013 (1G)	1	6	-	-	-	3	-	-	1,5	5,6	-
	2	-	-	-	-	3	-	-	1,2	2,5	-
E6013 (2G)	1	-	-	-	-	v	v	4	-	6	-
	2	-	-	-	-	3	-	-	1,2	-	5
E7016 (1G)	1	-	-	-	-	-	3	2	1	-	-
	2	-	-	-	-	2,5	v	-	1	0,5	-
E7016 (2G)	1	-	-	-	-	-	3	-	0,5	-	1,2
	2	-	-	-	-	3,2	-	0,5	-	-	-
E7018 (1G)	1	-	-	-	-	-	-	-	-	2,8	4,5
	2	-	-	-	-	-	2,5	1	-	-	3
E7018 (2G)	1	-	-	-	-	4,5	-	-	0,5	2	-
	2	-	-	-	2,5	3,2	-	-	0,5	-	-

The process of macrostructure metallographic can be shown in Figure 4 until Figure 10 below.

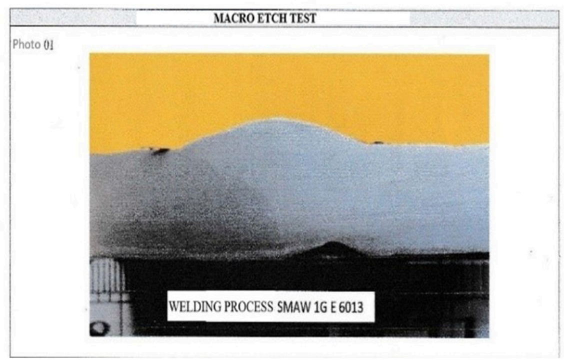


Figure 4. Specimen with E6013 (land) electrode during the macro test

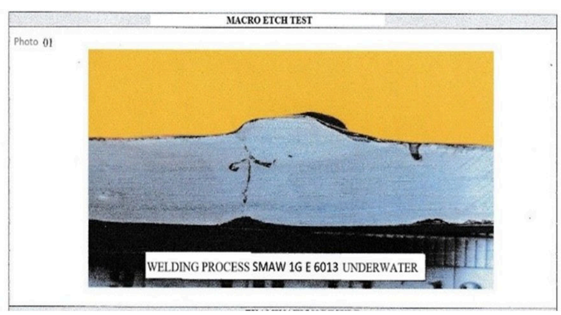


Figure 5. Specimen with E6013 electrode using 1G (underwater) position during the macro test

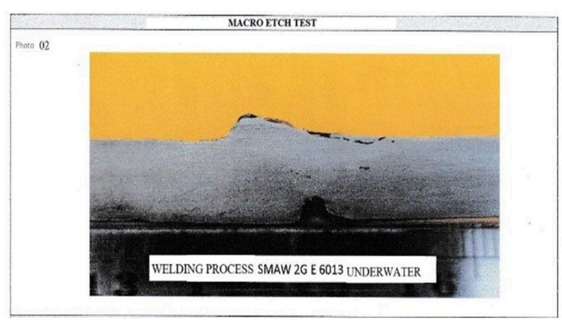


Figure 6. Specimen with E6013 electrode using 2G (underwater) position during the macro test

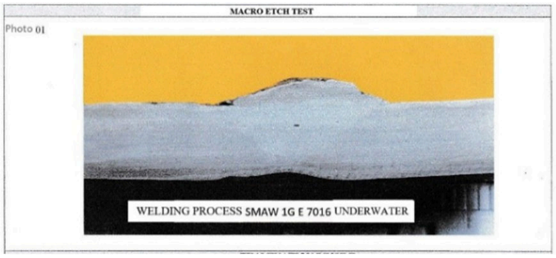


Figure 7. Specimen with E7016 electrode using 1G (underwater) position during the macro test

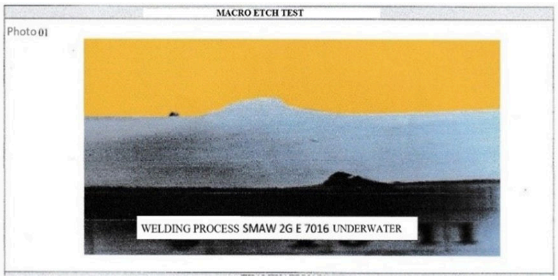


Figure 8. Specimen with E7016 electrode using 2G (underwater) position during the macro test

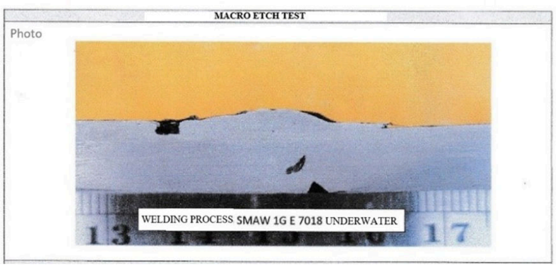
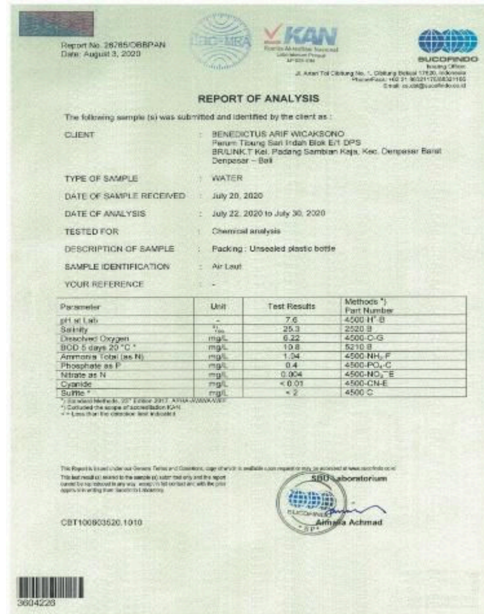


Figure 9. Specimen with E7018 electrode using 1G (underwater) position during the macro test

Figure 10. Specimen with E7018 electrode using 2G (underwater) position during the macro test

3.5 Seawater Testing

The seawater used in this underwater welding activity was taken in the Kali Baru area, North Jakarta. Seawater is very influential for welding results, so it must be tested on the seawater to find out the content contained in the seawater. The test was conducted in Sucofindo Bekasi, located at Cibitung Toll Arterial Road 1, Sukadanau, Cibitung, Gandasari, Cikarang Barat District, Bekasi, West Java 17530. Seawater test results can be seen in Figure 4.11 below.



Report No. 28785/OBBPAN
Date: August 3, 2020

SUCOFINDO

REPORT OF ANALYSIS

The following sample (s) was submitted and identified by the client as :

CLIENT : BENEDICTUS ARIF WICAKSONO
Perum Tibung Sari Indah Blok E/1 DPS
BR/LINK.T Kel. Padang Sambian Kaja, Kec. Denpasar Barat
Denpasar – Bali

TYPE OF SAMPLE : WATER

DATE OF SAMPLE RECEIVED : July 20, 2020

DATE OF ANALYSIS : July 22, 2020 to July 30, 2020

TESTED FOR : Chemical analysis

DESCRIPTION OF SAMPLE : Packing : Unsealed plastic bottle

SAMPLE IDENTIFICATION : Air Laut

YOUR REFERENCE : -

Parameter	Unit	Test Results	Methods *) Part Number
pH at Lab	-	7.6	4500 H⁺ B
Salinity	‰	25.3	2520 B
Dissolved Oxygen	mg/L	6.22	4500-O-G
BOD 5 days 20 °C *	mg/L	10.8	5210 B
Ammonia Total (as N)	mg/L	1.04	4500-NH₃-F
Phosphate as P	mg/L	0.4	4500-PO₄-C
Nitrate as N	mg/L	0.004	4500-NO₃⁻E
Cyanide	mg/L	< 0.01	4500-CN-E
Sulfite *	mg/L	< 2	4500 C

SBU Laboratorium

Alfinda Achmad

CBT100803520.1010

3604228

Figure 11. Seawater Testing Result

4. CONCLUSION

Based on tests and results described in this studythe following conclusions can be achieved:

1. Underwater SMAW welding is most often done using E6013 electrodes because the level of hardness and stiffness during the welding process is not too high. In this experimental activity, the E7016 electrode tensile test results have a greater value than the E6013 and E7018 electrodes. When compared between E6013 and E7016, it is very common if the E7016 is stronger and has a higher level of rigidity than the E6013 even though it has used a different amperage. However, if the E7016 electrode is compared to the E7018, it is still superior to the E7016 electrode using the same voltage and amperage. Also, from the observation of the macro test, welding using the E7018 electrode has less porosity than the E7016 electrode, while with the same experimental results, the tensile strength of the E7016 electrode is superior to that of the E7018. So that the strength value of the E7016 electrode can be superior to the E7018 in this experiment based on not only the porosity that occurs but also slag and imperfect penetration also determines the strength of the welding results using the E7016 electrode. From the macro test observations, welding using the E7018 electrode has less porosity than E7016 electrodes, while with the same experiment results, the tensile strength of E7016 is superior to E7018. So that the power value of E7016 electrodes can be superior to E7018 in this experiment is not only based on porosity that occurs but also slag and imperfect penetration also determines the strength of welding results by using E7016 electrodes.
2. The tensile test results were carried out from the graph comparing the Fyield, Fultimate, yield strength, and

ultimate strength with variations of the electrode and welding position. hThe bar chart showing the highest tensile test results is in the 1G position on the Fyield and Fultimate charts, but on the yield strength and ultimate strength graph, the positions 1G and 2G can be said to be balanced in strength. So that from the two graphs in the tensile test in this experiment, it can be concluded that the 1G position produces better welding results than the 2G position.

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