
Analysis of Variation E7016 Electrode Heating Time and Humidity on E7016 Electrode Tensile Strength of Joints Welding Material SS400

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Abstract: *This research aims to determine the effect of variations in heating time and humidity of the E7016 electrode on the tensile strength of welded joints in SS400 material. The research was carried out using three humidity levels and two electrode heating durations (2 hours and 3 hours) at a temperature of 300°C. The research results show that electrode humidity and heating time have a significant influence on the tensile strength of the welded joint. The highest tensile strength value was found in the welding variation using welding wire without treatment with heating for 3 hours with an average of 529.62 N/mm², then the lowest tensile strength was found in the outdoor electrode humidity treatment variation with a heating time of 2 hours with an average of 378.12 N/mm². The analysis was carried out using the two ways ANOVA method to analyze the resulting tensile strength data. The analysis results show that electrodes heated for 3 hours produce higher tensile strength compared to electrodes heated for 2 hours*

Keywords: E7016 Electrode, Heating Time, Electrode Humidity, SS400

1. Introduction

Science and technology, including the field of welding, continues to develop. The use of welding technology currently plays an important role in modern industry and its application is spread beyond industries such as shipbuilding, bridge and building construction, vehicle steel frames and so on [1]. One of the materials that has the most important role in the welding process is the electrode. electrode or usually called welding wire. Welding wire or electrodes are the main material in joining two metals. In research conducted by [2] and [3] it was concluded that electrode storage which is often neglected will cause the electrode to become damp which is caused by the absorption of water vapor in the surrounding air which ultimately damages the flux or electrode protective material and storing electrodes in the field after use and then not storing them back in their packaging so that they are not properly

protected from the surrounding air and the protective material becomes damp. If the electrode protective material is wet, it can cause welding defects such as over spatters and porosity. Apart from that, the presence of welding defects in the joint can reduce the strength of the welded joint itself [4]. A similar theory is also supported by research findings [5] which concluded that the higher the level of porosity, the lower the tensile strength of the material.

In his research, it concluded that the higher the electrode drying temperature level, the higher the hardness will be. And apart from that, welding using electrodes without an oven will show porosity in the welding results [6]. A similar conclusion was also found in research conducted [7], it can be concluded that the higher the bow storage temperature, the better the resistance to breaking. Similar things were also found by other

researchers. Welding with electrodes that are not heated in a heating oven will produce porosity defects [8]. SS400 steel is a type of low carbon steel because it has a carbon content of less than 0.3%. In the field of engineering, low carbon steel is one of the main types of materials for shipbuilding such as ship hulls [9]. In the process of building a ship, many processes are passed so it is not free from mistakes. One of them is deformation of the ship's hull. Deformation is a change in the shape of a material caused by tensile forces on the material that is exposed to heat from welding. The Indonesian Shipping Bureau has regulations regarding the use of marine steel that requires high strength. There are two types of steel: steel with a tensile strength of 50kg/mm² to 63kg/mm² and steel with a tensile strength of 48kg/mm² [10].

2. Methods

2.1 Flowchart

This research, several stages will be carried out, which can be seen in the flow diagram below:

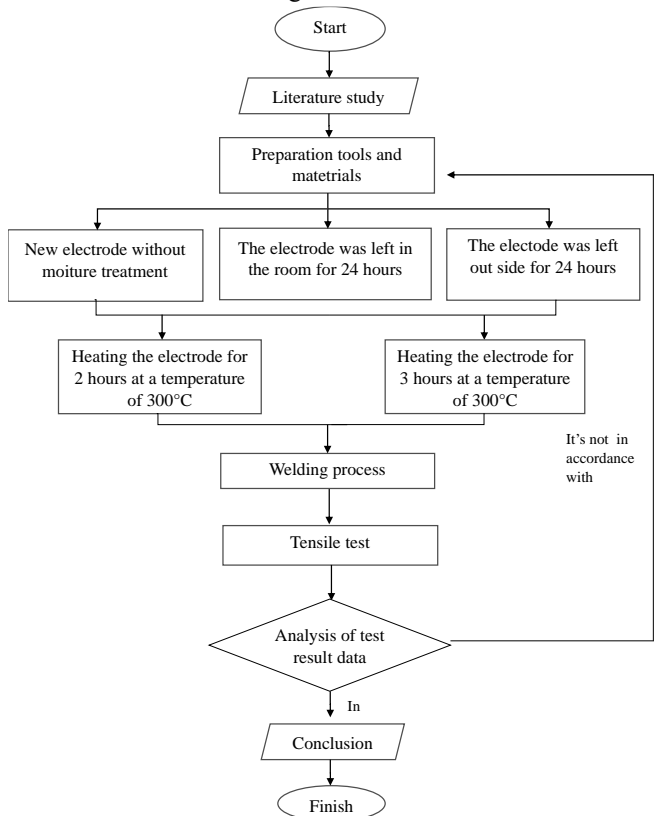


Figure 1. Flowcharts

2.2. Materials

In this research, low carbon steel SS400 metal material was used. SS400 steel is included in the low carbon steel group or usually called mild steel, or also commonly referred to as SS400 JIS 3101, the word "SS" is an abbreviation of structural steel. SS400 steel is a common steel because the price tends to be cheaper and the use of SS400 steel is widespread, such as

in the construction and shipping sectors. This steel is also suitable for the welding process because SS400 steel can undergo heat treatment [11].

Table 1. Chemical composition of SS400 Steel

Chemical composition	Percent (%)
C (carbon)	0.14
Si (silicom)	0.223
Mn (manganese)	0.66
P (phosphorus)	0.008
S (sulfur/sulphur)	0.0110
Nb (niobium)	0.004
Cu (copper)	0.05
Ni (nickel)	0.02
Cr (chromium)	0.02
Mo (molybdenum)	0.002
V (vanadium)	0.001
Al (aluminum)	0.040
Ti (titanium)	0.001
N (nitrogen)	0.0030
Ce (cerium)	0.26

2.3 Tensile Testing

Tensile testing is a type of destructive testing in which a test object is pulled end-to-end to measure its maximum strength. This test measures the elastic strength, plastic strength, yield strength, and maximum strength that the material can accept [12].

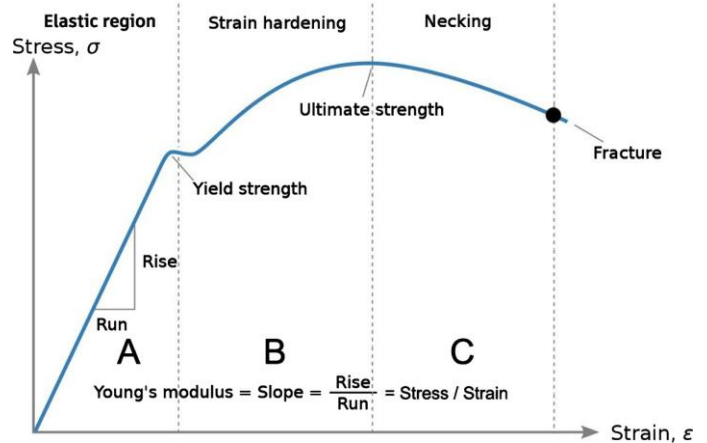


Figure 2. Strength-Strain Curve [13]

Maximum tensile strength

$$\sigma_u = \frac{P_u}{A_o} \tag{1}$$

where:

- σ_u = Maximum tensile strength (N/mm²)
- P_u = Maximum tensile load (N)
- A_o = Initial area of the specimen (mm²)

Yield strength

$$\sigma_y = \frac{P_y}{A_o} \tag{2}$$

where:

- σ_y = Yield tensile strength (N/mm²)
- P_y = Yield load (N)
- A_o = Initial area of the specimen (mm²)

Strain

$$\epsilon = \frac{\Delta L}{L_0} \times 100\% \tag{3}$$

where:

- ϵ = Strain (%)
- ΔL = increase in specimen length (mm²)
- L_0 = Original length (mm²)

2.4 Sample Preparation

This research used 18 tensile test samples with 2 variations of treatment. Tensile test sample dimensions are adjusted to ASTM E8 standards. Length Gauge (G) length is 50, Width (W) dimension is 12.5 mm, Thickness (T) dimension is 6 mm, Radius of fillet (R) dimension is 12.5 mm, Overall length (L) dimension is 200 mm, the dimensions of the Length of reduced section (A) are 57 mm, the dimensions of the Length of grip section (B) are 50 mm, the dimensions of the Width of grip section (C) are 20 mm [15].

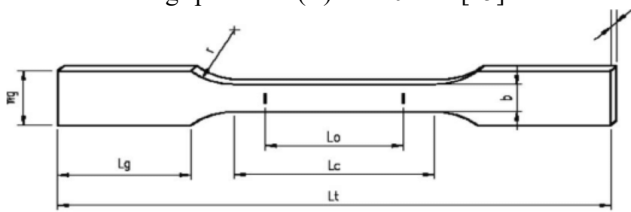


Figure 3. ASTM E8 standard Tensile Test Sample

2.5 Data analysis

Data analysis of tensile test results of welded joints with variations in heating time and humidity was carried out using the systematic ANOVA method and IBM SPSS tools.

3. Results and Discussion

3.1 Electrode moisture

The data in Table 2 is data on the percentage of water content on the electrode with variations in electrode treatment and electrode heating.

Table 2. The percentage of water content on the electrode after moistening and heating

Treatment	Code	Grams (Water content %)			
		Heavy beginning	Weight After moisturized	Warmup for 2 hours	Warmup for 3 hours
New electrode	A1	20.39	-	20.10 (-1.42%)	-
	A2	20.36	-	-	20.09 (-1.32%)
The electrodes were	B1	20.32	20.51	20.12	-

left in the room for 24 hours			(0.93%)	(-1.93%)	
	B2	20.34	20.53 (0.92%)	-	20.17 (-1.78%)
The electrodes were left outside for 24 hours	C1	20.34	20.58 (1.17%)	20.05 (-2.64%)	-
	C2	20.30	20.54 (1.18%)	-	20.04 (-2.44%)

From the table above, the moisture content contained in the electrode is explained by reviewing the provisions of the 1998 ASME Section II Part C (A7.6.1 Low Hydrogen Electrodes) standard, the maximum humidity content allowed for AWS E-7016 low hydrogen electrodes is 0, 6% [15]. If the overall average initial weight is 20.34g then the maximum weight of the damp electrode is 20.46g or 0.6g of the weight of 20.34g. And it can be concluded that the treatment of electrodes B1, B2, C1, C2 exceeds the maximum humidity limit.

Heating the electrode affects the weight of the electrode. If viewed from the maximum humidity limit of the electrode, which is 20.46g or + 0.6% of the initial weight of 20.34g, electrodes A1, A2, B1, B2, C1, C2 meet the humidity standard. And it can be concluded that heating the electrode is good for reducing humidity or water content on the electrode even if the electrode is left outside or indoors for up to 24 hours.

3.2 Tensile Testing

Data on Table 3 is data from the results of tensile testing for each variation of electrode treatment and electrode heating.

Table 3. Tensile Test Results Data

Sample	Specimen	Areas Mm ²	Max Force N	Yield Strength N/mm ²	Tensile Strength N/mm ²	Elongation (%)
1		70,785	25866.1	358.19	365.42	3.4
2	C1/heating 2 hours	69,688	26084.1	341.77	374.3	6.3
3		90,457	35699.5	347.62	394.66	8.16
4	B1/heating 2 hours	79,335	35370	358.47	445.83	9.2
5		72,522	30038.9	411.05	414.19	18.4
6		74,721	30147	409.66	403.47	10.4
7	A1/heating 2 hours	79,98	39390	381.19	492.5	22.1
8		78,996	38790	383.96	491.04	21.34
9		58,506	27627.1	430.26	472.21	6.16
10	C2/heating 3 hours	94,875	40612.2	289.77	428.06	7
11		77,978	36659.9	365.79	470.13	8.7
12		83,779	38582	331.59	460.53	5.12
13	B2/heating 3 hours	46,339	38094.9	518.24	506.3	5.26
14		65,908	30315	385.01	459.96	7.24
15		76.32	31590	331.66	413.92	9.24
16	A2/ heating 3 hours	52,495	28662.3	454.59	546.34	14.88
17		73,929	36480	321.18	493.45	15.6
18		83,478	45836.3	279.7	549.08	26.2

- Note: A = Electrode without moisture treatment
- B = The electrode is humidified indoors
- C = The electrode is humidified outdoors

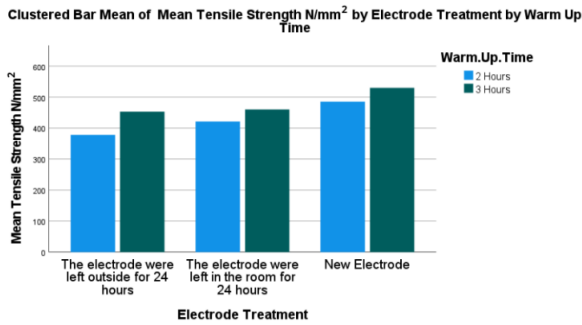


Figure 4. Tensile Test Results Graph

Figure 4 can be concluded that electrodes heated for 3 hours tend to produce higher tensile strengths compared to electrodes heated for 2 hours. In addition, untreated electrodes showed the highest tensile strength compared to electrodes treated indoors or outdoors.

3.3 Data Analysis of Tensile Test Results

3.3.1 Normality test

Table 4. Tensile strength norm test results

Tests of Normality	Kolmogorov-Smirnova			Shapiro-Wilk		
	Statistics	df	Sig.	Statistics	df	Sig.
Standardized Residual for Tensile Strength	,100	8	,200*	,982	18	,971

To find out whether standardized data is normally distributed or not, a Normality Test must be carried out [17]. From the table above it can be seen. sig value. 0.971. Based on decision making guidelines if the sig value. $0.971 \geq 0.05$ then H_0 is accepted, so it can be concluded that the data is normally distributed and the prerequisites for the first ANOVA test have been fulfilled.

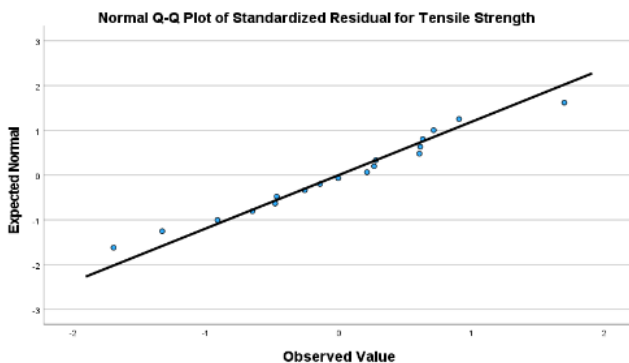


Figure 5. Normalization Test Plot

From Figure 5 above, it can be seen that the plot points follow and approach the diagonal line. As the basis for decision making in technical normality tests, it can be concluded that the residual values are normally distributed.

3.3.2 Test Homogeneity

Table 5. Tensile Strength Homogeneity Test Results

Levene's Test of Equality of Error Variances, b					
		Levene Statistics	df ₁	df ₂	Sig.
Tensile Strength	Based on Mean	1,194	5	12	,368
	Based on Median	,546	5	12	,738
	Based on Median and with adjusted df	,546	5	7,562	,738
	Based on trimmed mean	1,146	5	12	,389

From Table 5, it can be seen whether the data is homogeneous or not. From the results above, the sig value is obtained. based on the mean 0.368. Based on decision making guidelines if the sig value. $0.368 \geq 0.05$ then the data is declared homogeneous, so the homogeneity test in the ANOVA test has been fulfilled

3.3.3 Test hypothesis/ANOVA two-way tensile strength

The following is a table of results from two-way hypothesis testing/ ANOVA using IBM SPSS Statistics 29 for Windows

Table 6. Two Ways Anova Test Results

Tests of Between-Subjects Effects						
Dependent Variable: Tensile_Strength						
Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Eta Squared
Corrected Model	40700.240a	5	8140.048	10,998	<.001	,821
Intercept	3718619.018	1	3718619.018	5024.375	<.001	,998
heating_time	12489.901	1	12489.901	16,876	,001	,584
electrode_treatment	27089.252	2	13544.626	18,301	<.001	,753
heating_time * electrode_treatment	1121.086	2	560,543	,757	,490	,112
Error	8881.389	12	740.116			
Total	3768200.648	18				
Corrected Total	49581.629	17				

From the two-way hypothesis test/ANOVA results table above, the conclusion results are:

1. In the electrode treatment factor, the sig value is obtained. equal to $0.001 < 0.05$, so it can be concluded that there is a difference/influence in the results of the tensile strength test based on variations in heating time. In the heating time factor, the sig. equal to $0.001 < 0.05$, so it can be concluded that there is a difference/influence in the tensile strength test results based on variations in humidity treatment. In the electrode treatment factor * heating time, the sig value is obtained. amounting to $0.490 < 0.05$ so it can be concluded that there is "no interaction" between variations in electrode heating time and variations in humidity treatment. in determining the tensile strength test results

2. The results of the hypothesis test/ two way ANOVA can be seen in the percentage effect of variations in electrode treatment and electrode heating time. The squared eta column (η^2) explains the percentage influence of factors on the dependent variable, the following is the conclusion of the percentage influence based on the results of the hypothesis test above:
3. On The eta squared electrode treatment factor is 0.584 so it can be concluded that the percentage effect of variation in humidity treatment on the tensile strength value has an influence of 58.4%.
4. For the heating time factor, the squared eta value is 0.753, so it can be concluded that the percentage influence of variations in electrode heating time on the tensile strength value has an influence of 75.3%.
5. On the electrode treatment factor * eta squared heating time is 0.112 so it can be concluded that the interaction of variations in electrode heating time with variations in humidity treatment has an influence of 11.2%.
6. Based on the results obtained from the partial squared eta above, the biggest factor that influences the tensile strength value is the electrode heating time factor with a squared eta value of 0.753 or the influence given to the tensile strength of the test object is 75.3%.

4. Conclusion

Based on research that has been carried out on tensile strength test specimen material on SS400 steel connections, the following conclusions are obtained. The highest tensile strength value was found in the welding variation using welding wire without treatment with heating for 3 hours with an average of 529.62 N/mm², then the lowest tensile strength was found in the outdoor electrode humidity treatment variation with a heating time of 2 hours amounting to 3578.12N/mm². Long electrode heating produces differences in tensile strength values. A heating time of 3 hours tends to produce a higher tensile strength value compared to 2 hours heating time. From the ANOVA data it can be explained that the greatest influence in increasing the tensile strength is the length of time the electrode is heated, namely 75.3%. while the smallest influence in increasing the tensile strength is in the electrode treatment factor (*) heating time, namely 11.2%.

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