

# Cooling Media Treatments of the Welding Result of Aluminium 5083 using Gas Tungsten Arc Welding (GTAW) on Material Strengths

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**Abstract**—Cooling treatment will occur in every welding process. In welding construction of Aluminium raw materials using the Gas Tungsten Arc Welding (GTAW), sometimes carried out in different locations and conditions. The study aims to determine and analyses the treatment effect of variations cooling media using air, fresh water, and sea water on the material strength (tensile strength, bending strength and hardness) welding results of aluminium 5083. This research method is experimental by testing specimens of welding results. Data analysis with independent variables of air, fresh water, and sea water cooling media. The dependent variables are tensile strength, bending strength, intervening variable of hardness and as a control variable, Aluminium 5083 the same size of 300x150x6mm. The test results with air media cooling treatment obtained data, the direct cooling treatment the tensile test value was 193Mpa, the bending test was 61Kgf/mm<sup>2</sup>, the hardness test 63HRB, the media cooling treatment was flowed at a speed of 2,8m/s, the tensile test value was 178Mpa, the bending test was 49Kgf/mm<sup>2</sup>, the hardness test 55HRB and the media cooling treatment was flowed at a speed of 4,2m/s, the tensile test value was 157Mpa, the bending test was 55Kgf/mm<sup>2</sup>, the hardness test 59HRB.

**Keywords**—GTAW Welding, Aluminium, Cooling Treatments, Material Strength.

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## I. INTRODUCTION

Currently, one of the efforts made by the private sector and the government, in this case the Indonesian Navy, to participate in encouraging the growth of the national economy and maintaining the security of the Republic of Indonesia, has provided and built many ships using aluminium materials. For example, Speedboats, Crew boats, Fast Ferry Passenger Ships, Fast Missile Boats (KCR), Landing Craft Units (LCU), Fast Patrol Boats (FPB) 57. These ships are all or partially constructed from aluminium alloy grade 5052 or 5083 series [1]. This is often used because the Al-Mg aluminium alloy has properties that are more resistant to corrosion from seawater compared to other aluminium alloys [2,3]. Aluminium alloys, particularly the 5xxx series, are increasingly used in maritime applications due to the favorable strength-to-weight ratio and good corrosion resistance in salt water [4,5,23].

During the welding practice, a welder must be able to adjust the material to the welding process. The welding processes that can be used for welding aluminium

materials in general are the Gas Metal Arc Welding (GMAW) and the Gas Tungsten Arc Welding (GTAW) processes. The GMAW welding process consists of the Metal Active Gas (MAG) process, usually using CO<sub>2</sub> shielding gas, and the Metal Inert Gas (MIG) usually shielded by Argon, Helium, or a mixture of both. And in aluminium welding with the GMAW process, the Metal Inert Gas (MIG) process is used [6,7,8,22,24,25, 28,38,50]. In the implementation of aluminium ship construction work, this process is the most widely used, for example for welding on the hull, frame construction, reinforcement plates (brackets), superstructures. Meanwhile, GTAW welding uses Alternating Current High Frequency (AC-HF) polarity specifically for welding aluminium and its alloys in certain parts [22,23,25,27,36,37]. In the implementation of aluminium ship construction work, this process is only used to weld tanks made of aluminium plate [9]. However, it does not rule out the possibility that the GTAW welding process will also be used to weld non-ferrous pipes in certain installations on ships.

Welding work on certain constructions or special ship products produced, made from Aluminium Alloy base materials. Where in the implementation of the work in some parts using the Gas Tungsten Arc Welding (GTAW) welding process. The welding process implementation of the Aluminium construction, sometimes carried out in several conditions such as in a hangar or workshop, outside the workshop or near the beach or sea. Therefore, the welding results will undergo a cooling process under various conditions that can be affected by air, fresh water, or sea water.

Several studies on the effect of cooling on aluminium welding results have been conducted by

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previous researchers [29,30]. I N Budiarsa [3], in this study on "The effect of large welding current and gas flow volume velocity in the GMAW welding process on the toughness of aluminium 5083" shows that the large welding current and the speed of gas flow use affect the toughness of HAZ. Akbar Triansyah et al [9], in a study on "The effect of cooling temperature with water media on welding results on tensile strength, impact and micrography of aluminium 5083 TIG (Tungsten Inert Gas) welding" shows that the results of tensile testing, impact testing and micrography testing of aluminium 5083. Firdaus Irba R et al [10], in a study on "The Effect of Cooling Media on the Mechanical Strength of GTAW Process Aluminium Welding Results" concluded that the results of tensile testing of 5083 aluminium material from GTAW welding with variations in cooling media produced different tensile strength values from each cooling media. Reza Risqullah Putra et al [11], in a study on "The Effect of Cooling Media on the Impact Strength and Microstructure of 5083 Aluminium Welding Results with TIG Welding" concluded that the TIG welding process with variations in cooling media affects the impact strength and microstructure of Aluminium. Congwei Cai, et al [12], in the journal "Effects of Water-Cooling on the Mechanical Properties and Microstructure of 5083 Aluminium Alloy during Flame Straightening", concluded that there are differences in mechanical properties and microstructure between natural cooling and water-cooling during heat treatment. Janusz Torzewski, et al [13], in the journal "Microstructure and Low Cycle Fatigue Properties of AA5083 H111 Friction Stir Welded Joint". concluded that welding parameters affect the microstructure, microhardness, and tensile properties investigated. P. Shahsavari and H.R. Rezaei Ashtiani [14], in the journal "Effects of Preheating and Cooling Rate on the Microstructure and Mechanical Properties of Tungsten Inert Gas Welded Joints of AA5083-H321 Aluminium Alloy" concluded Microstructural analysis describes varying grain sizes during welding at different preheating and cooling rates. The results showed that the cooling rate has a remarkable effect on the mechanical properties of the welded specimens. M. Srivatsava, et al [15], in the journal "Experimental Study of Mechanical Properties of 5083 Aluminium Alloy Using Gas Tungsten Arc Welding" concluded that increasing the arc welding current on the 5083 aluminium alloy will increase the welding heat input using 5356 filler wire [16].

Previous studies have shown that the cooling process for welded materials was performed directly, followed by an analysis of the mechanical properties of the welding result of material [30,31,32,33,34,35]. The current study differs in that the cooling process is performed directly, with air blowing at varying speeds and water (fresh water and seawater) flowing at varying speeds. The results of this test are expected to approximate the actual conditions of cooling process the aluminum 5083 welding result.

## II. METHOD

### A. Research Method Plan

This research was conducted by experimenting with cooling media treatment (Air, Fresh Water, Sea Water) on the results of welding practice of Aluminum 5083 material with dimensions of 300mm x 150mm x 6mm using the Gas Tungsten Arc Welding (GTAW) process. The cooling treatment was carried out by direct cooling, cooling treatment by blowing air at a certain speed, and cooling treatment by flowing water at a certain speed on the results of welding aluminum 5083.

### B. Flow Framework Diagram

A diagram depicting the flow of thought, the systematic steps to be taken in the research, starting from the problem to the conclusion. A flowchart is shown figure 1 below.

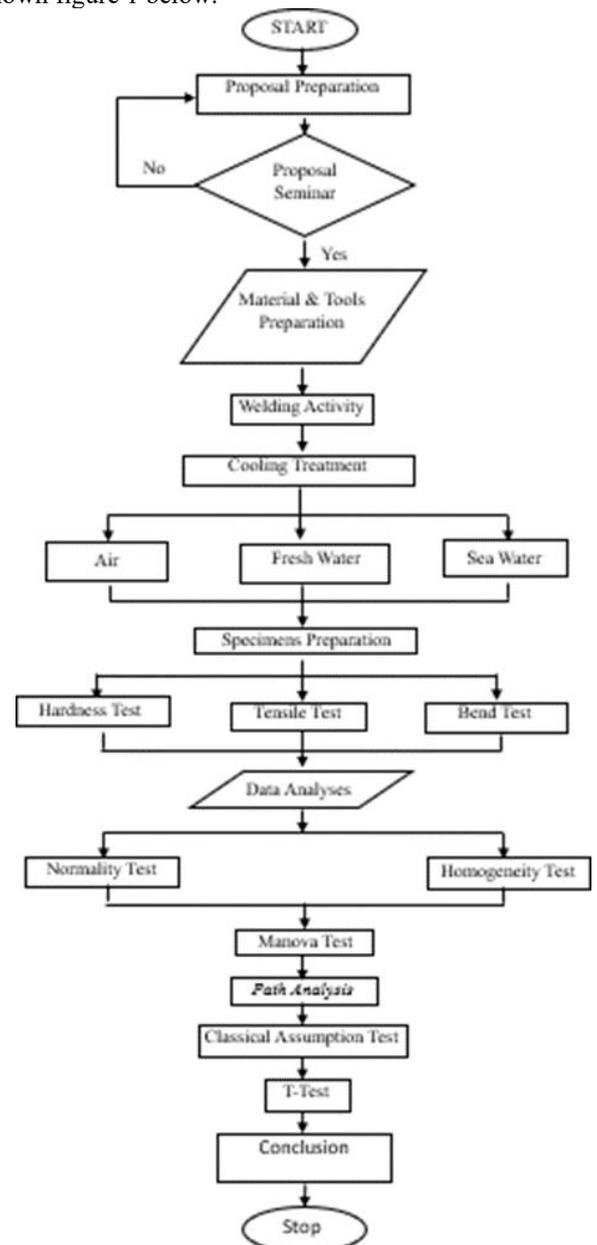
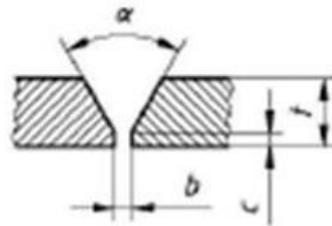


Figure 1. Flow Framework Diagram

C. Material and Tools preparation [8]

The test material used was Aluminum 5083 with dimensions of 300 x 150 x 6 mm, consisting of 9 pairs or

18 pieces of material. The welded joint design was prepared according to Figure 2 below.



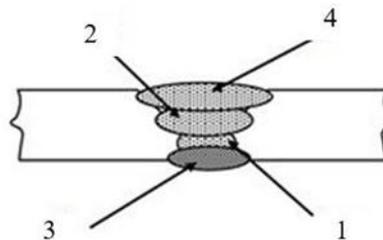
Remark:

$\alpha = 60^\circ$      $t = 6 \text{ mm}$   
 $b = 2 \text{ mm}$      $c = \pm 2 \text{ mm}$

Figure 2. Single Butt Joint

- Welding Machine Preparation  
The welding machine used is a 315 Ampere 3-phase ACDC GTAW welding machine.
- Welding Equipment Preparation  
The equipment used includes a hand grinder, pliers, and a steel brush.
- Personal Protective Equipment  
The personal protective equipment includes a welding torch, mask, gloves, apron, and hand covering.

- Measuring Tools  
The measuring tools used are a steel ruler, welding gauge, vernier caliper, and amperage clamp.
- Welding Joint Preparation  
The material was cut and scrapped then formed into a 1-2mm root face using a grinder, after that tack welding is performed. The welding process is carried out in the sequence as shown in Figure 3 below.



Remark:  
 1. Root weld  
 2. Filling weld  
 3. Back weld  
 4. Capping

Figure 3. Welding Sequence.

In accordance with the provisions of BKI, Classification and Construction Regulations, Volume VI, Welding Regulations, 2022, the test specimen size requirements for butt joint welding are a minimum length of 200 mm and a width of 150 mm for

aluminum. Taking test coupons for tensile test material specimens, bending tests and hardness tests, based on BKI provisions, the location is determined as shown in Figure 4 [17].

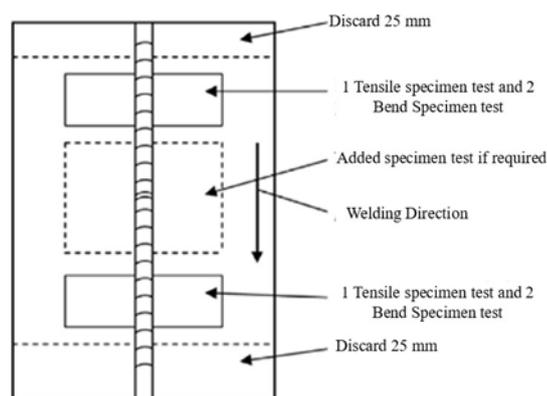


Figure 4. Specimen Test location.

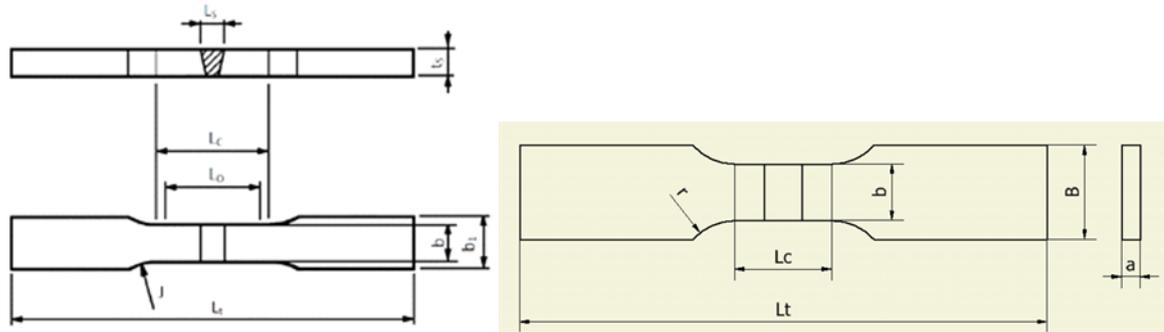


Figure 5. Tensile Test Specimen.

TABLE 1.  
TENSILE TEST SPECIMEN DIMENSION

Initial		Dimension (mm)
a/ts	: Specimen thickness	6
b	: Specimen width	20
Lc	: gauge length	weld +80mm
B/b1	: head width	25
Lt	: total length	300
r	: radius at shoulder r	25

#### D. Bend Test Specimen [17,20,21,22]

Making and preparing the bend test material specimen according to Figure 6 below. The width of the

bend test specimen (b) of the aluminum alloy material must be  $\geq 2ts$  or cannot be less than 20 mm.

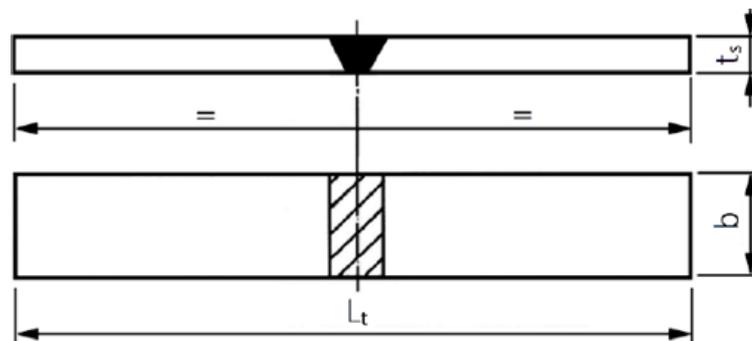


Figure 6. Bend Test Specimen.

TABLE 2.  
BEND TEST SPECIMEN DIMENSION

Initial		Dimension (mm)
ts	: Specimen thickness	6
b	: Specimen width	20
R	: Ø Roll	$\geq 20$
l	: Distance between roll	25
Lt	: total length	300

#### E. Hardness Test Specimen [17,21,22]

Shape and dimension of the hardness test specimen is the same as the shape and dimension of the bending test specimen, as shown in Figure 6 and Table 2 above.

#### F. Data Analysis

Path analysis is a part of regression analysis that is used to analyze causal relationships between variables where independent variables influence dependent variables, either directly or indirectly. The path model

used in this study can be described in the following structural equation:

$$Z = \beta_{zx_1}X_1 + \beta_{zx_2}X_2 + \beta_{zx_3}X_3 + \quad (1)$$

$$Y1 = \beta_{y_1x_1}X_1 + \beta_{y_1x_2}X_2 + \beta_{y_1x_3}X_3 + \beta_{y_1z}Z + \epsilon_2 \quad (2)$$

$$Y2 = \beta_{y_2x_1}X_1 + \beta_{y_2x_2}X_2 + \beta_{y_2x_3}X_3 + \beta_{y_2z}Z + \epsilon_3 \quad (3)$$

The MANOVA test is the final analysis using Minitab software version 22. According to Syafrizal et al. [18], MANOVA is a development of the analysis of

variance (ANOVA) to measure the mean difference for two or more dependent variables based on one or more categorical variables that act as predictors. Basically, MANOVA (Multivariate Analysis of Variance) is a statistical analysis technique used to test the average differences between two or more groups on two or more dependent variables simultaneously.

### III. RESULTS AND DISCUSSION

#### A. Spesimen Test

The GTAW welding process was carried out with a flat welding position (1G) Butt Joint Single V-Groove 60°. The test material was prepared with a plate size of 300mm x 150mm x 6mm, after being cut using a cutting machine as many as 18 pieces or as many as 9 pairs of test material plates. The test material was each used as a tensile test specimen, a bending test and a hardness test. After the plate had

been cut, the next process was making a weld bevel. The bevel angle used was 60° using a milling machine. The plate was welded with a 1G (Down Hand) welding position using the GTAW welding process and the filler metal used an ER 5356 electrode with an electrode diameter of 2.4 mm. Before welding, the material was cleaned with acetone first to remove the alumina oxide layer that could interfere with the weld metal melting process. After welding is completed and cooling treatment is carried out, each test material is cut to be formed into tensile test specimens according to Figure 5, bending test according to Figure 6 and hardness test according to the specimen taking location in Figure 4. Based on the implementation of the research process that has been carried out, as per Table 3 below, the following summary of test results data was obtained [19].

TABLE 3.  
 RESULT DATA OF COOLING MEDIA (AIR, FRESH WATER & SEAWATER) TREATMENT

X		Z	Y1	Y2
Cooling Media	Treatment of Cooling Media (X123)	Hardness Test (Z)	Tensile Test (Y1)	Bending Test (Y2)
Air(X1)	X1.1 Ud V0	66	198	71
	X1.1 Ud V0	58	248	74
	X1.2 Ud V1	51	203	23
	X1.2 Ud V1	58	208	63
	X1.3 Ud V2	58	245	54
	X1.3 Ud V2	59	288	62
Fresh Water (X2)	X2.1 AT V0	54	271	65
	X2.1 AT V0	51	275	63
	X2.2 AT V1	47	269	72
	X2.2 AT V1	51	271	54
	X2.3 AT V2	48	288	72
	X2.3 AT V2	56	286	72
Sea water (X3)	X3.1 AL V0	64	216	66
	X3.1 AL V0	51	226	64
	X3.2 AL V1	59	234	64
	X3.2 AL V1	46	256	65
	X3.3 AL V2	50	275	64
	X3.3 AL V2	54	271	66

According to the test results above, the average test results were 54.4 HRB for the hardness test, 251.6 Mpa for the tensile test and 63.0 Kg/mm<sup>2</sup> for the bending test.

#### B. Welding and Cooling Treatment Data

The experimental data on welding Aluminum 5083 with ER 5356 filler metal, followed by a cooling treatment process, produced recorded data, test parameter records and welding and cooling results as in Table 4 as follows:

TABLE 4.  
 WELDING AND COOLING TREATMENT DATA

Description	Remark
a. Base metal	Specification : Almg 5083, thickness 6 mm
b. Filler metal	AWS Class : ER 5356, Ø : 2,4mm
c. Welding position	Down hand/1G
d. Groove/bevel	V-Groove, 60°
e. Shielding Gas	Argon
f. Cooling media Treatment	Air : Normal/ Directly cooling treatment 1 <sup>st</sup> Cooling blowed speed 2,8 m/s 2 <sup>nd</sup> Cooling blowed speed 4,2 m/s Fresh water : Normal/ Directly cooling treatment Fresh water Volume 15 Liter, flowed speed 0,025lt/s Fresh water Volume 15 Liter, flowed speed 0,042lt/s Sea water : Normal/ Directly cooling treatment Sea water Volume 15 Liter, flowed speed 0,018lt/s Sea water Volume 15 Liter, flowed speed 0,025lt/s

Normally distributed. In the bend test (Y2) the data distribution was obtained P Value > 0.150, so that P Value > 0.05, then the data was declared Normally distributed. Likewise, for the hardness test value (Z) the P Value = 0.075 was obtained, so that P Value >

0.05, then the data was also declared Normally distributed. The conclusion from this Normality test is that all data is normally distributed. The Normality test data as per figure 7 below.

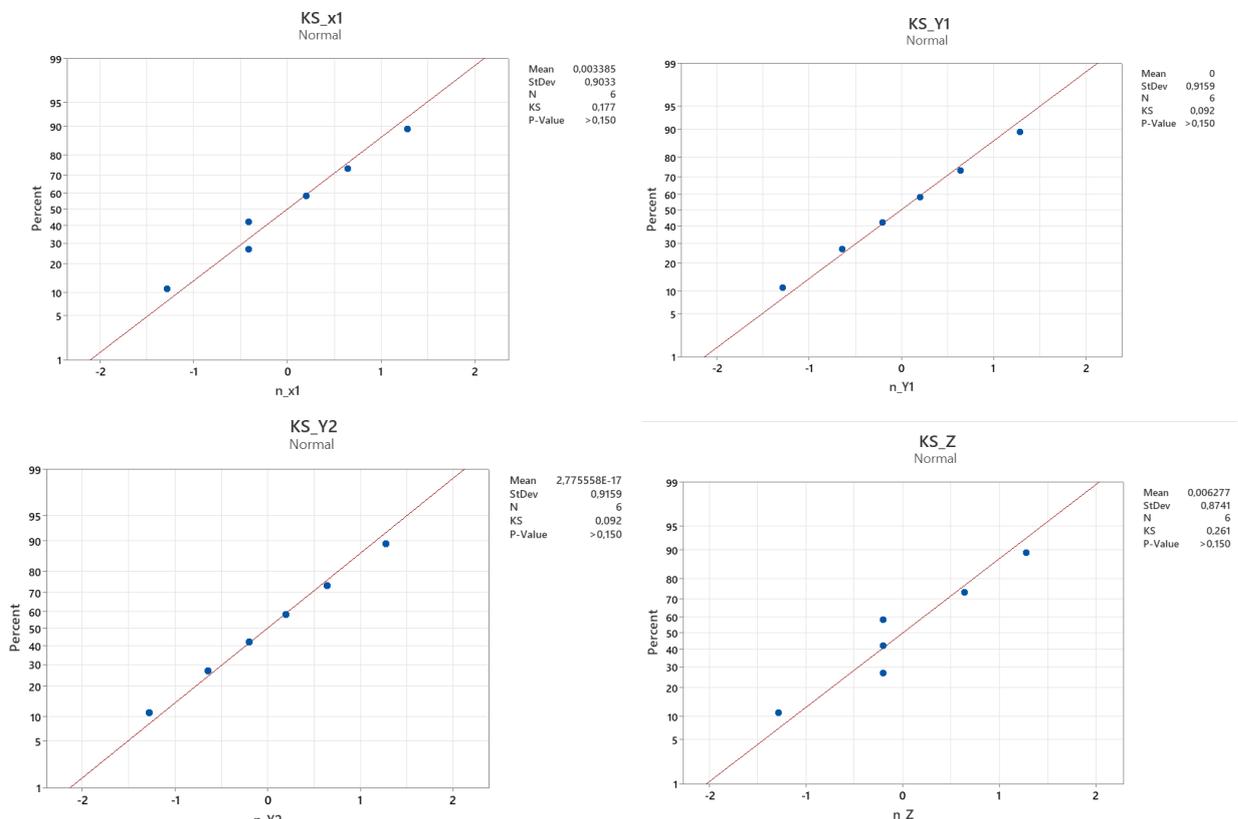


Figure 7. Normality Test Data

C. Anova and Manova Analyzed

1) Data Normality Test (Kolmogorov Smirnov)

Based on the Normality test (Kolmogorov Smirnov) through multivariate analysis, the data distribution for the Tensile Test (Y1) was obtained with P Value > 150, so that P Value > 0.05, then the data was declared variance of two or more data groups is the same (homogeneous) or not. The

conditions for the homogeneity test are: if the Levene Test P-Value <0.05, then the data variance is not homogeneous or the homogeneity test assumption is not fulfilled and if the Levene Test P-Value >0.05, then the data variance is homogeneous.

The results of the homogeneity test as per figure. 8 below.

Test and CI for Two Variances: n\_x1; n\_Y1

Test

Null hypothesis  $H_0: \sigma_1 / \sigma_2 = 1$   
 Alternative hypothesis  $H_1: \sigma_1 / \sigma_2 \neq 1$   
 Significance level  $\alpha = 0,05$

Test				
Method	Statistic	DF1	DF2	P-Value
Bonett	0,00	1		0,972
Levene	0,00	1	10	0,991

Test and CI for Two Variances: n\_x1; n\_Y2

Test

Null hypothesis  $H_0: \sigma_1 / \sigma_2 = 1$   
 Alternative hypothesis  $H_1: \sigma_1 / \sigma_2 \neq 1$   
 Significance level  $\alpha = 0,05$

Test				
Method	Statistic	DF1	DF2	P-Value
Bonett	0,00	1		0,972
Levene	0,00	1	10	0,991

Test and CI for Two Variances: n\_x1; n\_Z

Test

Null hypothesis  $H_0: \sigma_1 / \sigma_2 = 1$   
 Alternative hypothesis  $H_1: \sigma_1 / \sigma_2 \neq 1$   
 Significance level  $\alpha = 0,05$

Test				
Method	Statistic	DF1	DF2	P-Value
Bonett	0,01	1		0,941
Levene	0,17	1	10	0,688

Figure 8. Homogeneity Test Data

Based on the Levene test of two variances between air cooling treatment (X1) and the tensile strength test value (Y1), which is  $0,991 > 0,05$ , then the data is homogenic. With a bend test value (Y2) of  $0,991 > 0,05$ , then the data is homogenic. With a hardness test value of  $0,688 > 0,05$ , the data is homogenic.

After the test data is declared normal and categorized as homogeneity, it is continued with regression analysis as Figure 7, Figure 8, and Figure 9 to determine the effect of cooling treatment on the hardness test value, tensile test value and bending test value as follow:

Regression Analysis: n\_Y1 versus n\_x1

Coefficients

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	-0,003	0,242	-0,01	0,991	
n_x1	0,827	0,293	2,82	0,048	1,00

Regression Equation

$$n_{Y1} = -0,003 + 0,827 n_{x1}$$

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
0,592414	66,53%	58,16%	37,34%

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	1	2,7902	2,7902	7,95	0,048
n_x1	1	2,7902	2,7902	7,95	0,048
Error	4	1,4038	0,3510		
Lack-of-Fit	3	0,5760	0,1920	0,23	0,871
Pure Error	1	0,8278	0,8278		
Total	5	4,1941			

Figure 7. Regression Analysis for Tensile Test

Regression Equation

$$n_{Y2} = 0,001 - 0,357 n_{x1}$$

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
0,958405	12,40%	0,00%	0,00%

Coefficients

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	0,001	0,391	0,00	0,998	
n_x1	-0,357	0,475	-0,75	0,494	1,00

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	1	0,5199	0,5199	0,57	0,494
n_x1	1	0,5199	0,5199	0,57	0,494
Error	4	3,6742	0,9185		
Lack-of-Fit	3	0,3894	0,1298	0,04	0,985
Pure Error	1	3,2847	3,2847		
Total	5	4,1941			

Figure 8. Regression Analysis for Bend Test



Figure 9. Regression Analysis for Hardness Test (Z)

If the p-value is less than 0.05, the results of the regression analysis are considered statistically significant. This means that the independent variable being tested has a significant effect on the dependent variable, and we can reject the null hypothesis (which

states there is no effect). Conversely, if the p-value is greater than 0.05, the results are considered insignificant.

Figure 10 shows the results of tensile testing, bending testing and hardness testing on 5083 aluminum material after the GTAW welding process and cooling treatment with air cooling media.

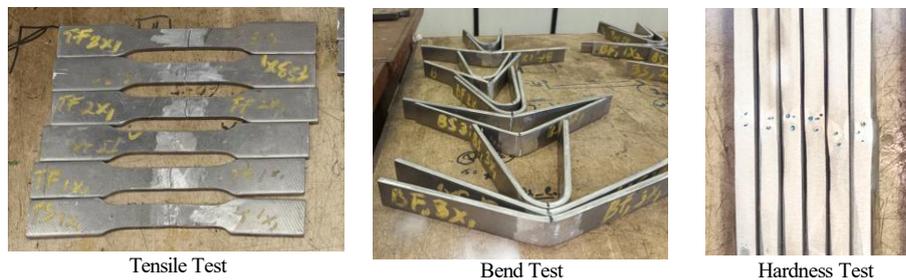


Figure 10 Result test with air cooling treatment

#### IV. CONCLUSION

This research analyzed based on regression calculation. Then  $n_{X1}$  its meaning air media cooling treatment (X1) has P-Value  $0.048 < 0.05$  is considered significant effect for tensile test value in 58,16%, and the rest is influenced by other factors outside this research. An analyzed of  $n_{X1}$  its meaning air media cooling treatment has P-Value  $0.494 > 0.05$  is considered insignificant effect to Bend test (Y2) value and is completely influenced by other factors outside this research. And analyzed of  $n_{X1}$  its meaning air media cooling treatment has P-Value  $0.857 > 0.05$  is considered insignificant effect to Hardness test (Z) value and is completely influenced by other factors outside this research.

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