Analysis Of Pre-Heating Temperature Effect On Shielded Metal Arc Welding (SMAW) Of BKI Grade (KI-A) Plates to The Tensile Strength and Hardness

Erifive Pranatal[1]*, Noveta Fernaldinatan[1], Norita Prasetya Wardhani[1], Adi Kurniawan Yusim[2]
[1]*Institut Teknologi Adhi Tama Surabaya, Surabaya*
[2]*Universitas Diponegoro, Semarang*

Email: [1]*erifive@itats.ac.id

Received: 2023-05-29 Received in revised from 2023-06-05 Accepted: 2023-06-05

Abstract

This study aimed to analyze BKI Grade (KI-A) plate material using the pre-heat process to determine tensile strength and hardness. The method involved welding with shielded metal arc welding (SMAW) type. The pre-heat variations used several temperatures, such as 50ºC, 120ºC, 220ºC, and without heat treatment. The tensile strength obtained specimen without pre-heating had the lowest tensile strength of 442.64 MPa, and the specimen with pre-heating to 220ºC had the highest average tensile strength of 450.11 MPa. The result showed that tensile strength was proportional to the pre-heating temperatures given. The hardness observation found that the hotter the pre-heating temperature obtained, the higher the hardness value of the base metal and HAZ would obtain. It was different with weld metal which would decrease. From those two parameters, it could be concluded that the most optimal pre-heat temperature was 220ºC. The hardness test result found that the specimen that had the highest hardness value in the base metal area and the HAZ was the specimen that was pre-heated at 220ºC. It could be determined that the most appropriate pre-heating temperature for welding BKI Grade (KI-A) plates was a temperature of 220ºC.

Keywords: *BKI Grade (KI-A) Plates, Shielded Metal Arc Welding (SMAW), Pre-heating*

1. Introduction

In the 4.0 industrial revolution era, welding is a technology that makes industrial metal important. Welding technology gas developed rapidly now and industries in Indonesia need welding technology development based on code or standards. Generally, the metal joint process was classified based on the primary mechanism of the metal joint and energy sources. Welding is a metal and nonmetal collaborative process of heating related materials. Welding could be defined as a splicing process connecting several materials by heating at a specific temperature. One variable affecting the quality of welding result is the nature or element of the metal itself [1][2].

During the welding process, the metal will experience a thermal cycle. The thermal cycle is the heating and cooling process which takes the process in the welding area quickly, resulting in a metallurgical process. Welding result quality is caused by deformation, such as the type of defects produced, joint strength, tensile strength, and metal microstructure [3].
The welding technology is a technique, and this technique is widely used to connect materials and steel construction. Welding processes have several types, which are classified based on the system and their essential characteristics. Shielded electric arc welding is the most widely used welding method [4].

Shield Metal Arc Welding (SMAW) is a welding technique using an electric current, and the form is an arc. The material or electrode material is coated by flux (welding slag) because it uses this technique. This layer aims to protect the core material of the electrode so that oxidation does not occur [5][6].

The heating process causes the influence of material properties during the welding process. In the Shield metal arc welding (SMAW) process, an essential reference should be considered: the amount of electric current used in the welding process. This case is needed attention because the amount of electric current determines how hot the electrode is used. The higher the electric current used, the greater the heat input generated to melt the electrodes. Otherwise, the lower the electric current used, the lower the heat generated to melt the base metal and electrodes [7].

One of the causes of brittleness can be bonded with several materials before the materials are connected; these materials are pre-heated. Pre-heating can be interpreted as a part of the heat treatment process before the materials are welded, and the aims are to reduce moisture from the welding area and to reduce temperature gradients. It can minimize problems such as weld defects and excess residual stresses [8]. Welding material with a thickness of less than 19mm [9], the welder must pre-heat with a predetermined minimum temperature. The aim is to overcome welding defects, welded joint stresses, and HAZ structural changes [10].

Over time, carbon steel plate materials have been widely used in the shipping world, especially the BKI Grade KI-A type. The number of uses and functions of the BKI Grade KI-A type was tremendous as a hull plate material and construction material in the ships. Based on these experiences, the study is needed for proper heat and current treatment of materials.

The purpose of this research are:1. Analyze the effect of variations in preheating temperature on tensile strength in plate welding BKI GRADE (KI-A) 2. Analyze the effect of variations in preheating temperature hardness in BKI GRADE plate welding (KI-A) 3. Analyze the best preheating temperature for SMAW welding using BKI GRADE plates (KI-A).

2. Method

Provide sufficient detail methods to allow the work to be reproduced. Methods already published should be indicated by a reference: only relevant modifications should be described.

The material used in this test used BKI Grade KI-A plates with a length of 6100 mm x 1830 mm x thick of 10 mm. It was included in the material certificate issued by PT Sapta Sumber Lancar, the distributor of the plate material used. Based on the size sent, the BKI Grade KI-A plate would be carried out in a cutting process to make a smaller space called a test piece.

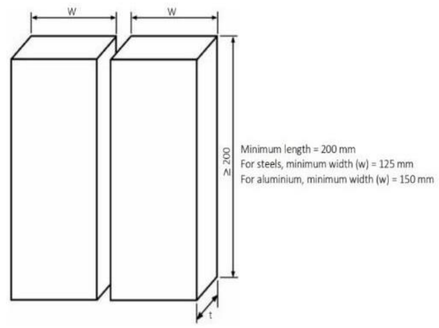


Figure 1. The size of the *Test Piece Butt Joint Well*

The cutting of the Test Piece Butt Joint Well referred to BKI Vol VI Sec 3. Based on this cutting, the size of the test piece has a length of 220 mm, a width of 150 and a thickness of 10 mm according to the thickness of the plate to be tested. The number of making test pieces was four joints according to the objective variation variable. The bevel angle used was 60º, and it was made using a milling machine at the Politeknik Negeri Perkapalan Surabaya.

2.1. Pre Heating Process

Before the welder carries out the welding process on the test plate material of BKI KI-A the first time, the welder must make do heat treatment process, which means there is no heat treatment process. Pre-heating is a way to heat a part or all of the metal, which would be a welded process and the aim was to reduce temperature differences between the welding area and other areas of the workpiece

[11]. The pre-heating process used test material heating with a flame mixed with oxygen gas and acetylene gas at temperatures of 50 º, 120 º and 220 º. The test material was heated to the cooled temperature.

2.2. Welding Process

After the pre-heating process had been conducted with heat variations and bevel angel formation, the researchers conducted the welding process to the BKI KI-A using Shielded Metal Arc Welding (SMAW) at PT Galangan Kapal Madura with specifications of welding procedures. The form of the Butt Joint design was a single V groove. BKI GRADE (KI-A) is the base metal connected using an ESAB E6013 electrode with a welding position of 1G/PA. The current type used was DC (Direct Current) with the polarity DCSP (Direct Current Straight Polarity). The amperage was 110 A to 150 A, and the voltage set was 20– 26 Volt. The travel speed must be 88 – 150 mm/minute to produce good welding results.

2.3. Testing Process

To know the tensile strength and hardness, the writers conducted a testing process as follows:

1. Visual Test

   The visual test was carried out on the welding result by observing the welding result with the naked eye, so we just saw the outside of the product. The level determines welding joint quality according to requirements of specification, design, and standards which have been determined. Visual inspection only used the power and sharpness of the eye to detect abnormalities, discrepancies and surface defects in welded joints.

2. Tensile Strength Test

   Tensile strength was an essential mechanical property influencing manufacturing or construction work [12]. There are several specimens in the tensile test. Tensile Test is a method used as a strength tester of a material by applying a load (static force) that is in the same direction and applied slowly or quickly. To find the mechanical properties value, especially tensile strength, you could find the equation:

σy (Yield Strength)

$$\sigma_Y = \frac{Fy}{A0}\ N/mm \quad (1)$$

σy (Ultimate Strength)

$$\sigma_Y = \frac{Fult}{A0}\ N/mm \quad (2)$$

Note: Fy = Maximum Strength (Mpa), Fult = Maximum Yield (Mpa), A0 = Tensile Area (mm²)

3. Vickers Strength Test

   Vickers Method as a hardness test was done by pressing the material or test specimen with a diamond indenter. The forms were pyramid shape, a rectangular base and an angle was 136 degrees from the opposite surface. Indenter Pressure would produce an imprint or indentation on the test material surface. The way to know data from the test material hardness was by pulling the average diagonal of the trace using a microscope.

3. Results and Discussion

3.1. Visual Testing

Visual testing was accomplished to detect defective materials in the reachable area using the normal eye and without tools. The authors realized the inspection visual by adjusting the welding parameters with the parameters listed on the WPS. Those parameters were the current type used, the amount of amperage that must follow the WPS, the electrode type used, the shielding gas type, the welding technique, and the welding speed. There were the visual inspection results of each specimen can look at Table 1 and Figure 2:

Table 1. Visual Test Results

a. Without pre-heating

Welding Defect	Size (mm)			*Aceptance Criteria* (mm)			*Accept*	*Reject*
	P	L	t	P	L	t		
Undercut	3	0,5	0,5	< 3	< 1	< 1	✓	
Excess	-	-	2,5	-	-	< 4	✓	

b. With pre-hetiang 50°C

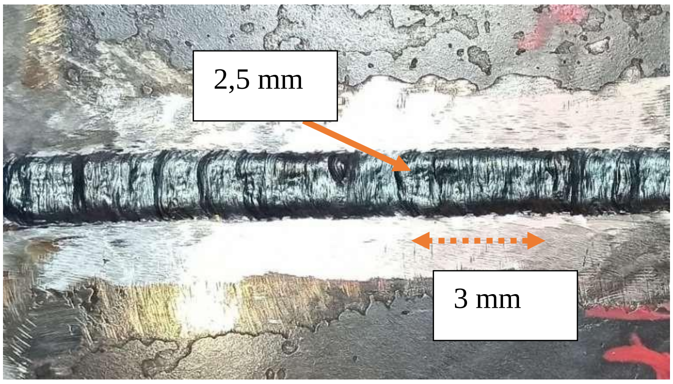
Welding Defect	Size (mm)			*Aceptance Criteria* (mm)			*Accept*	*Reject*
	P	L	t	P	L	t		
Underfill	6	-	0.5	-		<2	✓	

c. With pre-hetiang 120°C

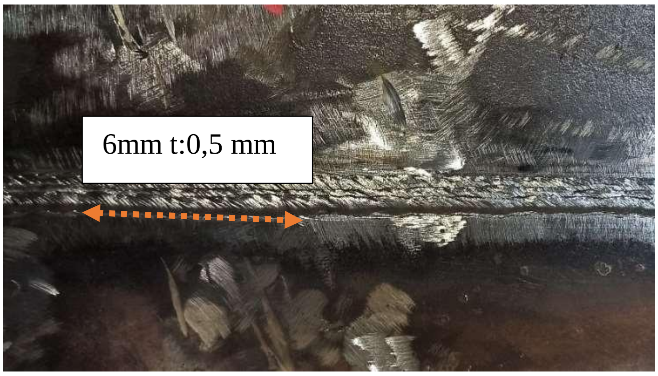
Welding Defect	Size (mm)			*Aceptance Criteria* (mm)			*Accept*	*Reject*
	P	L	t	P	L	t		
Porosity	18	8	-	<19	<9.5	-	✓	

d. With pre-hetiang 220°C

Welding Defect	Size (mm)			*Aceptance Criteria* (mm)			*Accept*	*Reject*
	P	L	t	P	L	t		
Underfill	0.5	-	0.5	-		<2	✓	

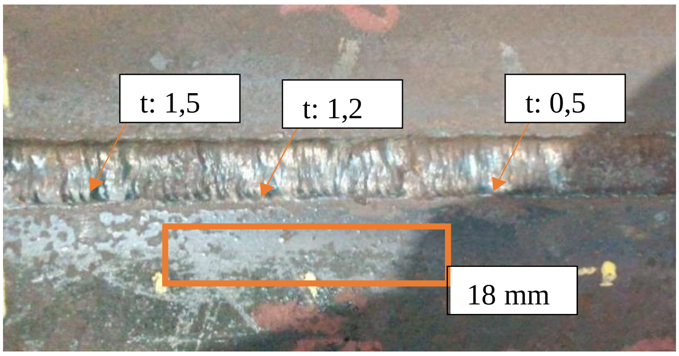


a. Without pre-heating



b. With pre-hetiang 50°C

c. With pre-heating 120 °C



d. With pre-heating 220º C

Figture 2. Examination of specimen at temperature:

After the visual had been tested on the specimen without pre-heating, the visuals were heated at several temperatures, such as 50ºC, 120ºC and 220ºC. It showed various kinds of undercut defects, excess, underfill and porosity. The image description was categorized as acceptable because the defect size was below the acceptance criteria.

3.2. Tensile Strength Testing

The tensile test is one of the tests to determine a material property. By pulling a material, we found out how the materials reacted to the pulling force and knew how much the material increased in length until the materials fractured. The experimental tools for tensile strength have a firm grip and high stiffness. Tensile testing referred to a standard. The tensile test in this study referred to the ASME IX standard.

The tensile test result was a graph. The graph explained the result of the tested material's yield stress and maximum stress can look at Table 2 and Figure 3. From that graph, we know the fault area identity occurred from the specimen test. The following table describes each test's results and the tensile test's calculation results for each specimen.

Table 2. Tensile Test Calculation Results

Tensile Test							
Test Piece Code	Visual	Area	Fy (KN)	Fu (KN)	Yield Strength (MPa)	Tensile Strength (MPa)	Breaking
Non	Good	192,46	55,49	85,19	288,32	442,64	Weld Metal
50	Good	189,46	56,03	84,68	296,31	447,83	Base Metal
120	Good	187,13	56,52	84,13	302,04	449,58	Base Metal
220	Good	186,62	56,98	84,00	305,33	450,11	Base Metal

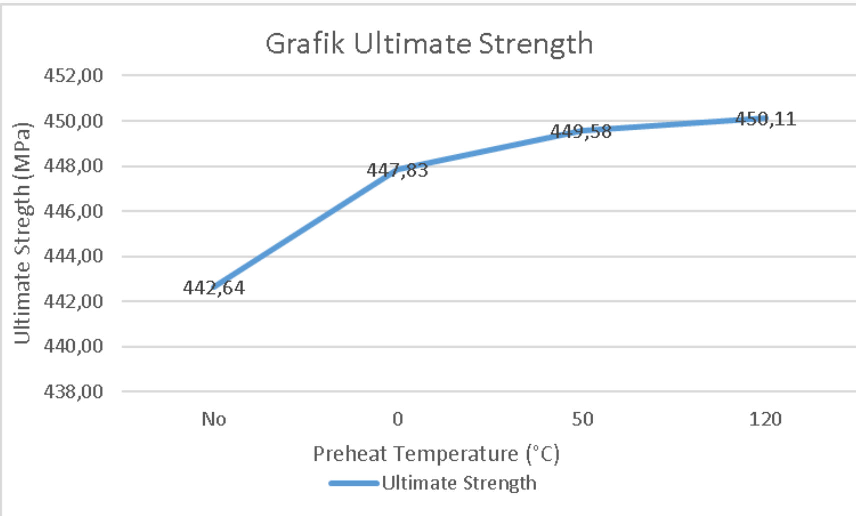


Figure 3. Yield Strength Specimen Graph

The result described that pre-heating treatment affected the tensile strength of BKI Grade KI-A steel. This study obtained a specimen which did not give pre-heating and had the lowest tensile strength of 442,64 MPa. One of the test materials fractured the weld metal. Specimen with

50ºC pre-heating had a tensile strength value of 447,83MPa. Specimen with 120ºC pre-heating had a tensile strength value of 449.58 MPa. Specimen with 220ºC pre-heating had the highest average tensile strength of 450.11 MPa.

The tensile strength increased in direct proportion to the specimen without pre-heating treatment to pre-heating temperature of 220ºC. Increasing tensile strength was in line with the pre-heating temperature given. The cause was the influence of higher pre-heating temperature. So, the higher the pre-heating temperature, the deeper the penetration occurs during welding. It made the base and weld metal blend better and formed a wider HAZ.

3.3. Tensile Strength Testing

Hardness is one of the mechanical properties of a material. The hardness of the material must be known, especially for materials that use frictional force and plastic deformation. Plastic deformation is a condition of a material when force was given to the material. So the microstructure would not return to its original shape. In this study, hardness testing was executed in the nine points in each specimen, and the details were three points on the base metal, three on the HAZ and three on the weld metal. The data obtained from the hardness test results were as Table 3:

Table 3. Hardness Test Calculation Results

Hardness Test									
Location	Vickers Hardness								
	Weld Metal			HAZ			Base Metal		
	1	2	3	1	2	3	1	2	3
Non	158,01	160,02	160,51	142,17	140,89	143,56	140,4	140,41	141,25
Average	159,51			142,21			140,69		
50º C	152,27	156,06	151,81	144,68	141,7	144,67	142,06	142,45	141,71
Average	153,38			143,68			142,07		
120º C	154,08	145,32	157,53	155,1	148,62	151,81	152,31	145,54	142,12
Average	152,31			151,84			146,66		
220	147,53	153,56	149,41	161,02	154,16	152,28	165,11	161,3	152,98
Average	150,17			155,82			159,80		

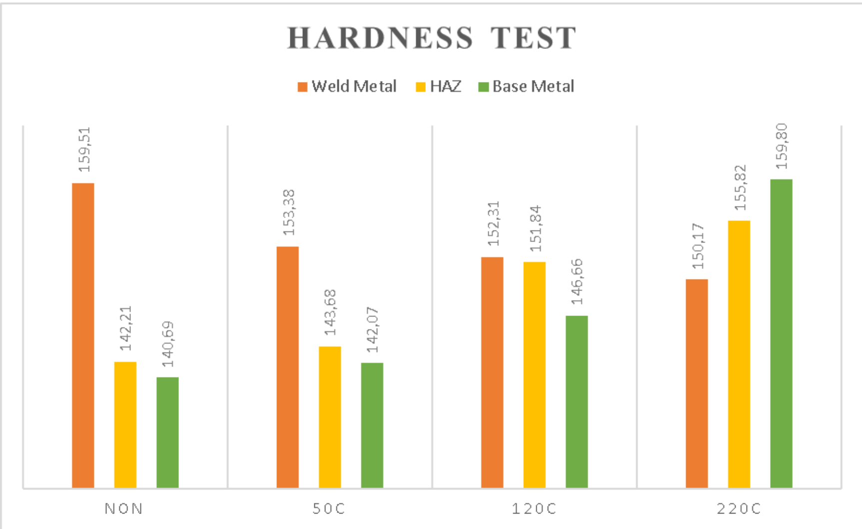


Figure 4. Graph of Hardness Test Results

Figure 4 showed pre-heating treatment influenced the material's mechanical properties, especially hardness. The material experienced an increase in the hardness value on the metal base and

HAZ because the specimen received a heating effect in the pre-heating process. The hotter temperature received, the harder the specimen was treated. In the weld metal area, the higher the pre-heating temperature given, the lower the hardness received from the metal. Because the higher pre-heating temperature was given, the welding machine gave the lower heat input to weld metal. The specimen getting the highest pre-heating temperature was 220ºC. It made the weld metal area became softer. The heat input from the welding machine was lower because the temperature influence was already high.

4. Conclussion

Based on the titled "Analysis of the Effect of Pre-heating Temperature on Shielded Metal Arc Welding (SMAW) of BKI Grade (KI-A) Plates on Tensile Strength and Hardness, the conclusions could be drawn:

1. The mechanical test result was tensile strength and hardness. It showed that pre-heating specimens had the lowest average tensile strength value of 442.64 MPa, specimens pre-heated at 220ºC had the highest average tensile strength value, and the value was 450.11 MPa.
2. The hardness test result found that the specimen that had the highest hardness value in the base metal area and the HAZ was the specimen that was pre-heated at 220ºC. The specimen with the lowest hardness value in the weld metal area was given a pre-heating treatment.
3. The results of a series of tests have been carried out, and the data were processed. It could be determined that the most appropriate pre-heating temperature for welding BKI Grade (KI-A) plates was a temperature of 220ºC.

References

[1] Waaddulloh, M., Sulardjaka, S., dan Dwi Haryadi, G. 2020. *Pengaruh Arus dan Tegangan Pengelasan SMAW Baja Karbon Rendah Grade A dan Baja Karbon Rendah Grade B terhadap Sifat Mekanik*. JMPM (Jurnal Material dan Proses Manufaktur), 4(2), 103–114. https://doi.org/10.18196/jmpm.v4i2.11450

[2] Wiryosumarto, H Dan Okumura, T. 2000. *Teknologi Pengelsan Logam.* Cetakan Ke 8. Pradnya Paramita. Jakarta.

[3] Wiyono, T., 2012. *Penentuan Pengelasan Dissimiliar Allumunium Dan Pelat Baja Karbon Rendah Dengan Variasi Waktu Pengelasan Dan Arus Listrik*. Jurnal Foundry Vol. 2 No. 1 April 2012 ISSN 2087-2259 :20 – 25.

[4] Anggraeni, Safira Dwi., Pratikno, Herman., Setyo Hadiwidodo, Yoyok. 2016. "*Studi Perbandingan Proses Pengelasan SMAW Pada Lingkungan Darat dan Bawah Air Terhadap Ketahanan Uji Bending Weld Joint Material A36*". Surabaya: Institut Teknologi Sepuluh Nopember (ITS).

[5] Sukaini, T., dan Fandi, 2016. *Teknik Las SMAW*, edisi pertama, Kementerian Pendidikan & Kebudayaan Direktorat Jenderal Peningkatan Mutu Pendidik & Tenaga Kependidikan Sukmadinata, (2017), Metode Penelitian Pendidikan, Bandung: PT Remaja Rosdakarya

[6] Mizhar, S., dan Pandiangan, I. H, 2014. *Pengaruh Masukan Panas Terhadap Struktur Mikro, Kekerasan dan Ketangguhan pada Pengelasan Shielded Metal Arc Welding (SMAW) dari Pipa Baja Diameter 2,5 inch.* Jurnal Dinamis, II (14), 16–22.

[7] Arif, Nuzulul, Erifive Pranatal, Iftika Philo Wardhani, and Renanda Bayu Harsi. "The Effect of *Root Gap on Bending Test Using FCAW Welding On SS 400 Steel Materials At 3G Position." Journal of Applied Sciences, Management and Engineering Technology 3, no. 2 (2022): 42-50.*

[8] Windu Baskoro Hadi. 2015. "*Analisis Pengaruh Variasi Temperatur Preheat terhadap Distorsi, Lebar HAZ, dan Struktur Mikro padaSambungan Butt Joint Single V dengan Metode Pengelasan FCAW dan SMAW*". Surabaya: Institut Sepuluh November. Windu Baskoro Hadi. 2015.

[9] Larsen, Ingrid Lande, and Rein Terje Thorstensen. "The influence of steel fibres on compressive and tensile strength of ultra high performance concrete: A review." *Construction and Building Materials* 256 (2020): 119459.

[10] Scott, F. 2000. *Taking Your Weld's Temperature. Jurnal Modern Steel Construction*

[11] Qin, Wenbo, Jiansheng Li, Yaoyao Liu, Jiajie Kang, Lina Zhu, Dengfeng Shu, Peng Peng, Dingshun She, Dezhong Meng, and Yusheng Li. "Effects of grain size on tensile property and fracture morphology of 316L stainless steel." *Materials Letters* 254 (2019): 116-119.
[12] Sathish, T., and A. Muthulakshmanan. "Design and simulation of connecting rods with several test cases using AL alloys and high Tensile steel." *International Journal of Mechanical and Production Engineering Research and Development* 8, no. 1 (2018): 1119-1126.