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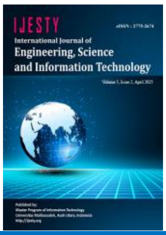

Study of the Effect of Post Weld Heat Treatment on the Bending Strength of Weld Joints in SMAW and GMAW Methods in Root Bend Areas and Face Bend on ASTM A106 Grade B

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Abstract

This study evaluates the effect of Post Weld Heat Treatment (PWHT) on the bending strength of raw materials and welding joints using SMAW and GMAW welding methods. Tests were conducted on root and face bends to compare bending strength before and after PWHT treatment. The test results show that in the root bend area, the base material without PWHT has a bending strength of 3983.16 MPa, while in SMAW and GMAW welding, the bending strength is 3788.39 MPa and 2695.96 MPa, respectively. After PWHT was applied, the bending strength of the base material increased to 4739.76 MPa, while that of SMAW and GMAW welding increased to 4131.62 MPa and 5193.39 MPa, respectively. In the face bend area, the base material without PWHT showed a bending strength of 3077.70 MPa, with SMAW and GMAW welding producing bending strengths of 2654.28 MPa and 2259.32 MPa, respectively. After PWHT, the bending strength of the base material increased to 3289.05 MPa, while SMAW and GMAW welding recorded 2641.47 MPa and 3498.07 MPa, respectively. This study's results indicate that PWHT significantly improves bending strength, especially in the base material and weld joints in the root bend area.

Keywords: *Post Weld Heat Treatment, Bending Strength, SMAW, GMAW, Root Bend, Face Bend.*

1. Introduction

In recent years, welding has been widely used in industries such as oil, gas, petrochemical, marine, nuclear reactors, military and aerospace. Two welding methods are commonly used in the industrial world, namely Shield Metal Arc Welding (SMAW) and Gas Metal Arc Welding (GMAW) [1]–[3]. Welding is commonly used to connect materials in the oil and gas sector. Carbon steel pipe with a maximum carbon content of 0.30% and a minimum tensile strength of 415 MPa is ASTM A106 Grade B material often used in this application and is widely used as a pipe that distributes oil and gas to various industries [4].

During welding, the heat source moves continuously along the joint area, causing a non-uniform temperature distribution in the metal. This non-uniform temperature distribution causes the welded and the non-welded regions to undergo uneven expansion and shrinkage. Strain is caused by this thermal imbalance, which contributes to the formation of residual stresses around the welding area [5]. These residual stresses do not dissipate and can cause distortion or changes in geometric shape that can compromise the structural integrity and performance of the welded joint. So, in this welding problem, the reduction of residual stresses is significant in welded joints for applications in these fields because this is often visible from the welding heat results [6].

Although residual stresses are an integral part of welding, there are certainly ways to reduce them, such as by performing post-weld heat treatment. These residual stresses can reduce the quality of a material and make it more complex and more brittle, which is undesirable [7]. This can be overcome by increasing the hardness of the material by rapidly reducing the temperature after welding to 815^{O}C-870^{O}C. To minimize the effect of residual stresses caused after welding and improve mechanical properties is the purpose of Post Weld Heat Treatment (PWHT) [8][9]. Post-weld heat Treatment (PWHT) can reduce residual stresses and improve the microstructure of post-welding materials. The cooling medium used in the Post Weld Heat Treatment (PWHT) process plays a vital role in determining the welding results, especially in heat distribution and final mechanical properties of the material [10]–[12].

Heat treatment aims to increase ductility and eliminate internal stresses, refine crystal grains and increase tensile stress and hardness of the material. This can be achieved as desired if attention is paid to influencing factors such as heating temperature and cooling media [13][14]. Several studies have shown that varying the temperature and duration of Post Weld Heat Treatment (PWHT) provides a very significant change in the strength and durability of the material [15]–[17].

Chendri Johan et al. (2023) show that the bending strength of SMAW welding on St 42 steel material by varying the current in the V camp with SAE 20W-50 oil coolant results in the higher the current, the higher the bending strength value [18].

M. Femi Imanudin Purba (2020), with the title "The effect of temperature variations of PWHT and without PWHT on the hardness properties of ASTM A106 grade B steel in the SMAW welding process that the hardness value that is almost close to the hardness value of the specimen without heat treatment is a specimen that receives heat treatment with a temperature of 400^{O}C by reaching 30 minutes.

This study aims to analyze the effect of post-weld heat treatment (PWHT) with quenching media used is oil with a density of 0.35 gr/ml and a viscosity of 0.269 Pa.s on mechanical properties, especially bending strength, which is very well used as a coolant for ASTM A106 Grade B steel because it has a value at a hot temperature of 100^{O}C to improve the mechanical properties of carbon steel produced from Shield Metal Arc Welding (SMAW) and Gas Metal Arc Welding (GMAW).

2. Research Method

This research uses an experimental method at the Material Test Laboratory of the Mechanical Engineering Department of Medan State Polytechnic with a scientific approach that aims to reveal the causal relationship between the independent and dependent variables through controlled procedures. This method is quantitative, and the main focus of this experiment is to evaluate the effect of Post Weld Heat Treatment (PWHT) at 500 with a holding time of 60 minutes on the mechanical properties of ASTM A106 Grade B pipes. Tests were conducted to determine the material's bending strength, aiming to understand the effect of thermal parameters on its characteristic properties for chemical requirements. The tube pipe is in the table below.

Table 1. Chemical Requirements Tube Pipe ASTM 106 Grade B

Carbon max %	**Manganese %**	**Phosphorous max %**	**Sulfur max %**	**Silicon min %**
0.30	0.29-1.06	0.025	0.025	0.10

The bending test is one of the testing methods used to visually evaluate material quality. In addition, this test also serves to measure the strength, toughness, and elasticity of welded joints, both in the weld metal and Heat Affected Zone (HAZ). In carrying out the bending test, several factors must be considered, including giving the right load, determining the appropriate specimen dimensions, and testing conditions that must be controlled accurately. Standards that are often used are ASTM E190-14 and ISO 7438:2016. The ASTM E190-14 standard specifies the dimensions of a bend test specimen as shown in Figure 1 below: 152 mm total length, 12.5 mm width, and 10 mm thickness. Meanwhile, ISO 7438:2016 provides general guidance on the bend test methods on metallic materials but does not explicitly stipulate the specimen dimensions [19]. The standard dimensions of an arch experiment or test are as follows:

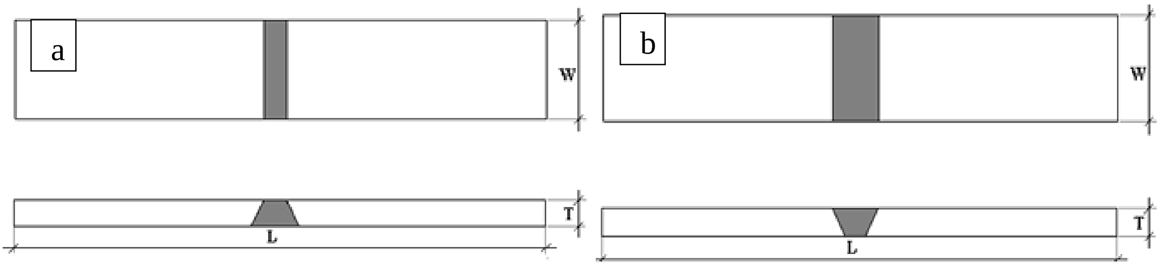

Fig 1. Test specimens: a) root bend and b) face band top and side views

3. Result and Discussion

In this study, the welding process was carried out with two welding methods, namely Shield Metal Arc Welding (SMAW) and Gas Metal Arc Welding (GMAW), with a welding current of 140A and with electrodes for SMAW E-7018 and GMAW ER70S-6. After the welding is complete, the bending test is carried out. The test results can be seen in Table 2 below.

Table 2. Bending Test Results

Variations	Specimen	Raw Material	SMAW	GMAW	Description
Without PWHT	1	1470,69	1225,64	1016,04	Root Bend
	2	1364,14	1223,46	864,29	

	3	1148,33	1339,29	1085,63	
	Average	3983,16	3788,39	2965,96	
	1	1620,8	1425,88	1085,63	
	2	1456,9	1228,4	1173,69	Face Bend
	Average	3077,7	2654,28	2259,32	
	1	1664,52	1335,38	1844,22	
	2	1495,83	1387,12	1604,05	Root Bend
	3	1579,41	1409,12	1745,12	
PWHT	Average	4739,76	4131,62	5193,39	
	1	1635,25	1369	1676,82	
	2	1653,8	1272,47	1821,25	Face Bend
	Average	3289,05	2641,47	3498,07	

Based on the average results in bending tests such as Figure 2 in the Root Bend and Face Bend areas in Shield Metal Arc Welding (SMAW) and Gas Metal Arc Welding (GMAW) welding, no specimens were broken on both bent surfaces, and there were no cracks. From the average bending test without PWHT in the root bend area, it is found that the Raw material has a bending strength of 3983.16 Mpa, while SMAW welding has a value of 3788.39 Mpa and GMAW welding has a bending strength value of 2695.96 Mpa. With PWHT, it is found a b that the Raw material has a bending strength of 4739.76 Mpa, while the SMAW welding has a value of 4131.62 Mpa, and the GMAW welding has a bending strength value of 5193.39 Mpa.

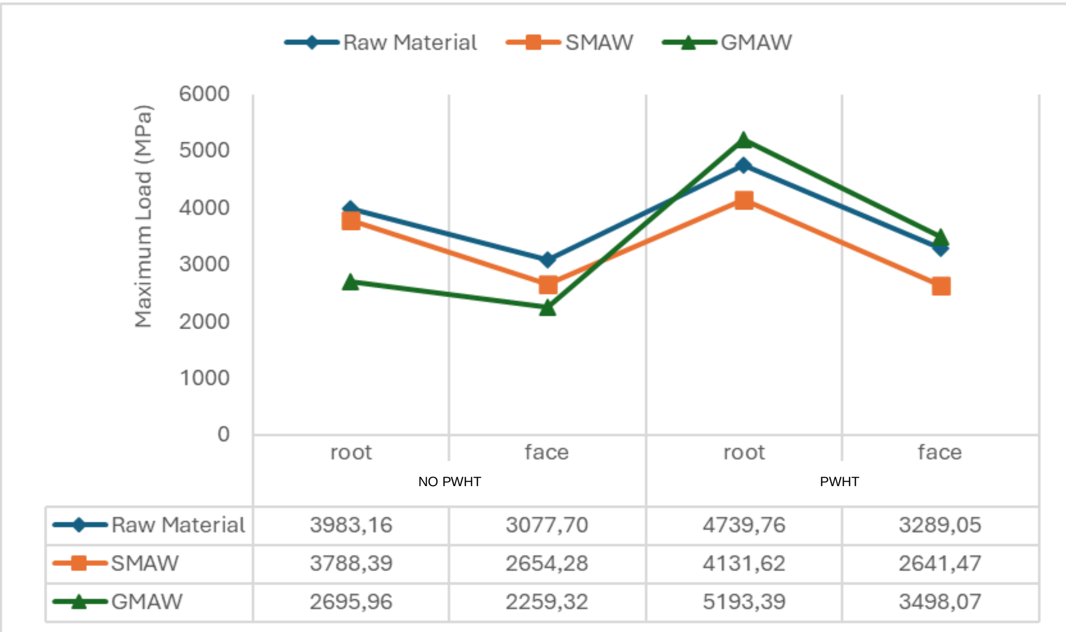

Fig 2. Graph of Average Value of Bending Test Results

The average maximum bending load in the Face Bend area of the bending test without PWHT found that the Raw material has a bending strength of 3077.70 Mpa, while the SMAW welding has a value of 2654.28 Mpa and the GMAW welding has a bending strength value of 2259.32 Mpa. With PWHT, it is found that the Raw material has a bending strength of 3289.05 Mpa, while the SMAW welding has a value of 2641.47 Mpa, and the GMAW welding has a bending strength value of 3498.07 Mpa.
Performing PWHT at 500OC for 60 minutes in the root bend and face bend areas increases the bending strength value of both SMAW and GMAW welding. Thus, applying PWHT to the welding process, especially SMAW and GMAW, can improve the quality of welding joints, reduce cracks due to residual stresses generated from welding and increase the ability of the material to withstand bending loads properly [20][21]. Of course, this will make PWHT a significant step in improving durability and performance when using welding materials.

4. Conclusion

1. In Raw Material, the bending strength increased with PWHT in both areas (root bend: 3983.16 MPa to 4739.76 Mpa and face bend: 3077.70 MPa to 3289.05 MPa).
2. The bending strength of the SMAW welding root bend increased with PWHT (3788.39 MPa to 4131.62 MPa) but was almost unchanged in the face bend (2654.28 MPa to 2641.47 MPa).

3. The bending strength of GMAW welding at the root bend increased significantly with PWHT (2695.96 MPa to 5193.39 MPa) at the face bend also increased (2259.32 MPa to 3498.07 MPa).
4. The influence of PWHT is more significant on GMAW, especially in the root bend area.
5. The strength at the GMAW face bend is lower than that of SMAW, although there is an increase after PWHT.
6. GMAW welding with PWHT obtains the best bending strength, especially in the root bend area.

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