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Tensile test and hardness test on FCAW-GS welding results of AB/EH36Z35 material in 3G downhill position

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Abstract

Welding is a crucial aspect of the modern construction industry as it allows for efficient and reliable joining of metals. The purpose of this research is to evaluate the FCAW-GS welding process on AB/EH36Z35 material in the 3G downhill position. Additionally, the study aims to analyze the tensile and hardness test results of the welding. The research utilized the FCAW-GS welding method, with tensile testing conducted by the AWS D1.1/D1.1 M:2015 standard. Hardness testing was performed using the Vickers hardness test method with a test load of 10 Kgf, following the ASTM E92:2017 standard. The results of the tensile tests demonstrate that both specimens achieved high tensile strength. Furthermore, the hardness testing indicated no significant changes in material hardness in the HAZ and Line 3 areas. Consequently, this study's findings adhere to the quality standards outlined by AWS D1.1/D1.1M:2015 and ASTM E92:2017, making them a valuable reference for industrial welding processes.

1. Introduction

The increasingly advanced and rapid growth and development of technology in the construction sector cannot be separated from the process of joining metals or what is often called welding. In this case, it has an important role in engineering repairs or repairs to metals which aim to meet the criteria for a combination of certain properties and cost efficiency [1]. The welding method used in this welding construction engineering is flux-cored arc welding gas shielding (FCAW-GS). FCAW-GS is a metal joining process by melting part of the base metal and filler metal with pressure or without pressure and with or without additional metal and produces a continuously welded joint. The gas used as a protector generally uses CO_2 gas or can be a mixture of CO_2 and argon as the protective gas.[2]. The main advantages of FCAW-GS include high welding speeds, the ability to withstand adverse wind and weather conditions, and the ability to create continuous weld joints without the need to replace electrodes, as with SMAW. In addition, the use of flux on the FCAW-GS filler wire can help remove dirt and scale from the metal surface, resulting in clean and strong welding joints [3].

The welding position is an important factor that must be considered during the welding process. One of these is the 3G downhill welding position. With this slightly complicated welding position, a standard welding procedure specification (WPS) is required, which is used as a welding reference[4] to guarantee the quality of the welding results. Tensile testing is used to determine the tensile strength of a material. Tensile strength is the ability of a material to withstand tensile loads against deformation (change in shape). [5]. Welding results with certain welding positions must be tested to determine the suitability of the welding results so that they can be used as WPS. To test the specimens in the tensile strength test, the reference test method AWS D1.1/D1.1 M: 2015 was used.

Hardness testing is one way to determine the strength and durability of a material. The price of the hardness of the material can be analyzed from the amount of load applied to the area of the area receiving the load.[6]. The results of this hardness test show that the welding current and electrode type have a significant influence on the hardness of the weld metal [7]. To test this specimen, the Vickers hardness test method was used to test this specimen, namely, the hardness produced by dividing the force applied to the Vickers indenter by the surface area of the permanent indentation made by the indenter [8]. The ASTM E92:2017 reference test method was used to test the specimens during hardness tests.

This research aims to evaluate the tensile strength and hardness values produced by the FCAW-GS welding process on AB/EH36Z35 material with the 3G downhill butt joint position.

2. Research Methods

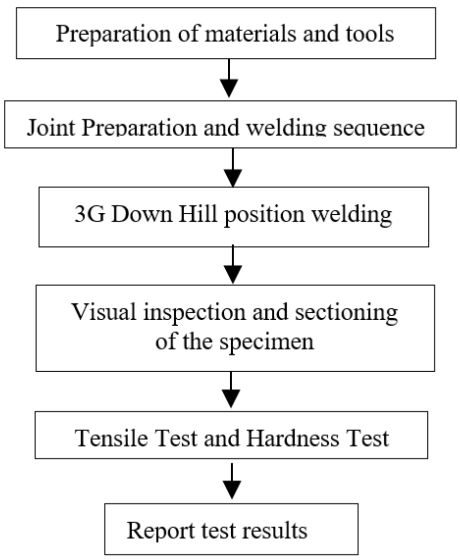

Fig.1 The Research Flowchart

This study adopts an experimental method that concentrates on test result methods. The welding process was executed using the FCAW-GS method in a 3G downhill welding position. The initial phases of the research include preparation, which involves generating the geometry for the butt joint and gathering the necessary tools and materials for the study. The research flowchart is shown in Fig. 1.

2.1. Joint preparation & welding sequence

The following steps were taken to prepare the EH36Z35 steel plate specimens for the 3G downhill welding process. The plate thickness should be 25 mm, and the material dimensions should be 750 mm × 180 mm.

A. Join Preparation:

For this test, a V-groove seam shape should be used, with a size of 60 degrees. The root face size should be between 0-1 mm, and the root gap size should be 0 mm. Additionally, the back gouging method should be employed. Join preparation is as shown in Fig. 2.

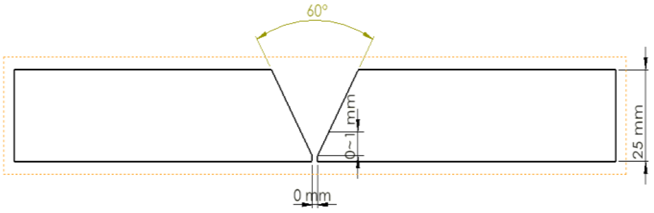

Fig 2. Join Preparation 3G

B. Welding Sequence

- Side A - hotpass weld
- Side A - filler weld
- Side A - capping
- Side B - filler weld
- Side B - capping

The welding sequence is as shown in Fig. 3.

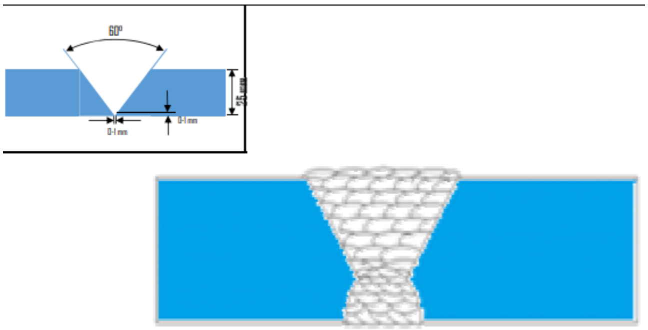

Fig 3. Sequence 3G

2.2 Base Material

The chosen material for this research was an EH36Z35 steel plate with a thickness of 25 mm. The specimen's base material measured 750 mm × 180 mm. Please refer to Table 1 for the chemical composition of the base material.

Table 1. Chemical composition of base metal (%)

Chemical Elements	(%)
C	0.180
Si	0.1-0.5
Mn	0.90-1.6
P	0.035
S	0.035
V	0.05-0.10
Al	0.015
Cr	0.200
Cu	0.350
Mo	0.080
Nb	0.02-0.05
Ni	0.400
Ti	0.020

2.5 Filler Metal

The specifications of Filler metal can be seen in Table 2.

Table 2. Spesification Filler metal

Clasification	AWS E71C-1C ASME E71C-1C
Manufacture.	Kobelco
Trade name.	DW-71T1
Diameter	1.2 mm
Weight.	15 kg

2.6 Technique

The technique used during the 3G downhill position welding process is shown in Table 3.

Table 3. Technique

Number of electrodes	1
Multi or single pass (per side)	Multipass
Stringer or weave bead	Weave bead
Vertical progression	Downhill

2.7 Shielding Gas

The shielding gas used during the welding process is shown in Table 4

Table 4. Shielding Gas

Shielding Gas	CO2
Composition	100%
Flow rate	15-20 l/min

2.8 Heat Treatment

The heat treatment used during the welding process is shown in Table 5.

Table 5. Heat Treatment

Preheating Temperature	65ºC
Preheat method	Heating torch
Interpass temperature	NA
PWHT temperature	NA
Holding time	NA

2.9 Welding Parameter

The welding parameter measurements for welding FCAW-GS in the 3G downhill position and used during the welding process are shown in Tables 6 and 7.

Tabel 6. Welding Parameter 3G

Weld pass	Elektrode type	Diameter filler
Side A - root weld	DW-71T1	1.2
Side A - hot pass weld	DW-71T1	1.2
Side A - filler weld	DW-71T1	1.2
Side A - capping	DW-71T1	1.2
Side B - filler weld	DW-71T1	1.2
Side B - capping	DW-71T1	1.2

Table 7. Welding Parameter 3G

Ampere	voltage	Interpass	Travel speed (mm/min)
180 - 205	27-29	102ºC	370
183 - 208	27-29	110ºC	490
193 - 215	26-28	136 ºC	450
204 - 223	25-27	140 ºC	600
218 - 237	27-28	152 ºC	580
220 - 240	27-28	105 ºC	585

2.10 Tensile testing and hardness test

After the completion of the welding process, the final stage involved visual inspection and cutting of the specimen. Visual inspection was performed to evaluate the quality of the weld, while the specimen was cut according to the testing standards. Tensile testing was carried out using a tensile testing machine to determine the tensile strength of the material. Additionally, hardness testing was performed using a Vickers testing machine to determine the material's hardness and durability. All stages of testing were conducted at the PT. X.

3. Results and Discussion.

3.1 Tensile Test

Tensile testing, also known as tensile strength testing, is the primary method used to evaluate the tensile strength of a material. The strength measures a material’s ability to withstand tensile loads without significant deformation or failure. By applying a given stress to a material, tensile testing can determine how much stress the material can withstand before deformation or failure occurs [8]. The results of the tensile testing are summarized in Table 8.

Table 8. The results of tensile testing

Specimen Code	T1	T2
Measured thickness (mm)	24.59	24.52
Measured width (mm)	20.08	20.10
Effective area (mm^2)	491.96	492.85
Ultimate tensile load (kN)	287.30	288.32
Ultimate tensile stress (MPa)	584	585
Location of failure	Broke at base metal	Broke at weld metal
Type of failure	Ductile failure	Ductile failure

The tensile test results revealed that both specimens exhibited high tensile strength, with an ultimate tensile stress of approximately 584 N/mm² for specimen T1 and 585 N/mm² for specimen T2. This indicates that the material used in the welding process has excellent ability to withstand tensile loads before failing [9]. The test results also indicated that the two specimens failed in different regions, with specimen T1 failing in the base metal and specimen T2 failing in the weld metal. The failure that occurred in both specimens was ductile, indicating that the material was still capable of withstanding continuous loads before experiencing significant [10]. This finding is consistent with previous research which stated that ductile failure commonly occurs in materials that have high tensile strength [11]

Based on the results of the tensile test values, both specimens were included in the acceptance criteria in accordance with the AWS D1.1/D1.1M:2015 test method with a value range of 490-620 MPa. The Tensile Test Results are shown in Fig. 4.

Fig 4. Tensile test results

3.2 Hardness Test

Hardness testing is a crucial method for evaluating the strength and toughness of materials under mechanical loads [7]. In this particular test, the Vickers hardness test method was used with a test load of 10 kgf. According to the ASTM E92-17 standard, the Vickers hardness test method is a reliable approach for determining the hardness of a material. By applying a test load of 10 kgf, this test can provide valuable information regarding the capacity of the material to resist plastic deformation and its ability to endure mechanical loads [12]. The results of the hardness testing are shown in Table 9.

Table 9. The Result Of Hardness Testing

Vickers Hardness Number (HV) Test Load Applied, 10 kgf				
Test Load Location	No	Line 1	Line 2	Line 3
	1	200	190	198
BM	2	203	191	196
	3	196	194	194
	4	190	180	213
HAZ	5	196	188	226
	6	199	193	238
Weld Metal	7	204	198	216
	8	192	190	227
	9	196	200	218
	10	240	211	239
HAZ	11	226	208	226
	12	211	188	201
	13	203	196	200
BM	14	200	196	190
	15	201	198	193

Hardness testing was conducted on the specimens from Lines 1, 2, and 3 based on the test result table shown above. The hardness test values of the three-line specimens were compared against the acceptance criteria as per the guidelines with the reference test method ASTM E92:2017 The hardness testing location points can be seen in Fig. 5

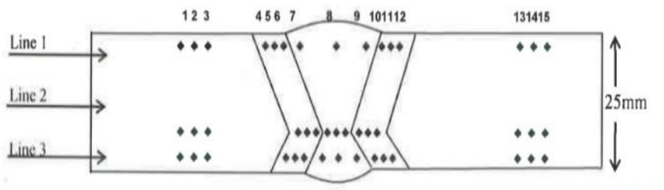

Fig 5. The hardness testing location

and the results of the Vickers hardness test is as shown in Fig. 6.

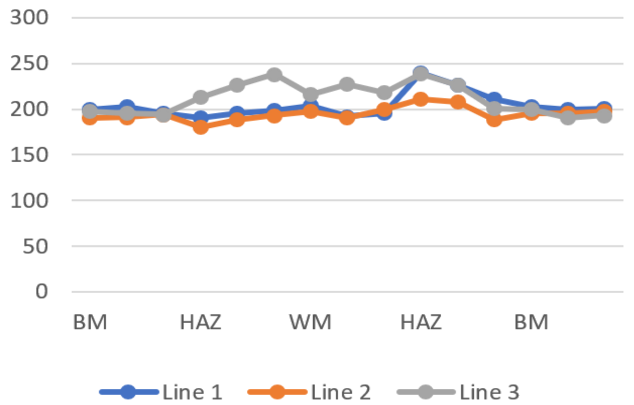

Fig 6. Vickers hardness test chart

According to the hardness test graph, the HAZ (heat-affected zone) area and Line 3 section, which were affected by welding and gouging processes, had the highest hardness values. During the welding process, the HAZ zone experiences sudden heating and rapid cooling due to the large temperature difference between the welding point and the base metal. As a result, a phase transformation occurs which can increase hardness at some HAZ values [13]. Intense heating processes in the HAZ zone can cause redistribution of solid elements, including carbon, present in the metal. This redistribution can lead to changes in the microstructure of the metal, such as the formation of a harder phase than that present in the base metal. Additionally, rapid cooling in the HAZ zone can produce different microstructures, such as martensite or other harder phases, as a result of the extreme cooling conditions [14]. However, there were some variations in violence values between different regions. Despite these variations, the overall hardness values did not change significantly. This is consistent with previous research findings, which stated that welding and gouging processes do not significantly affect the hardness of the surrounding material [15]. Therefore, it can be concluded that the results of the hardness testing met the classification requirements based on the ASTM E92:2017 specifications. Although there are variations in the values in some areas, the overall hardness values remain within the range allowed by the reference standard, indicating that the material meets the specified hardness requirements. The hardness test results are as shown in Fig. 7.

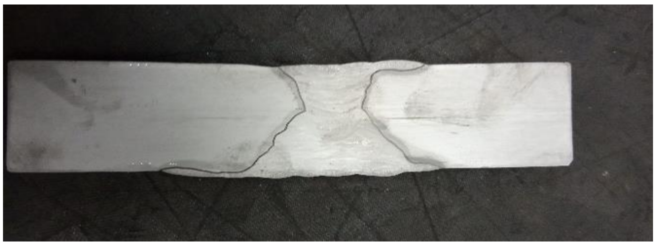

Fig 7. hardness test results

4. Conclusions.

After analyzing data from tensile and hardness tests in the FCAW-GS welding process, using the 3G downhill position on the AB/EH36Z35 material with DW-71T1 filler metal, it can be concluded that the research results meet the quality standards set by AWS D1.1/D1.1M:2015 and ASTM E92:2017. The tensile test results indicated that both specimens achieved high tensile strength, with values of approximately 584 N/mm² for T1 and 585 N/mm² for T2, and both experienced ductile failures. The hardness test showed no significant change in the hardness values surrounding the welding and gouging areas, indicating good welding quality and the material's ability to maintain resistance to mechanical loads. Therefore, the overall results of this study confirm that the FCAW-GS welding process with the given parameters can successfully achieve the expected quality standards and is reliable for relevant construction applications.

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