Journal Of Metallurgical Engineering And Processing Technology, Vol. 4, No. 1
August 2023, pp. 23-30
P-ISSN: 2723-6854, E-ISSN: 2798-1037

Experimental Analysis of Magnetic Particle Inspection on S355J2 Steel Weld Joints

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Abstract

NDT (Non-Destructive Test) is a form of testing carried out on materials or objects without causing permanent damage to these materials or objects. This study aims to determine the NDT Magnetic Particle Inspection testing process that is carried out and find out the results of the inspection of S355 J2 steel specimens with the NDT Magnetic Particle Inspection test method as the basis for determining the GMAW Welder Qualification. Welding of S355 J2 Steel is performed by a certified welder using GMAW welding using a single V-butt joint at an angle of 30 degrees. NDT Visual Test and Magnetic Particle Inspection are carried out during material testing. Data & output shows welder PT. INKA qualified with the standards set by the company, namely AWS D1.1 and ASTME E 709. So the Welder can be allowed to work on a Project because it is considered to have met the required Welder qualification standards.

Keywords: MPI, S355 J2, WPQR, Welding GMAW, Physical metallurgy

Introduction

In the era of the Industrial Revolution 4.0, the LRT (Light Rail Transit) project used for the Jabodebek area (Jakarta-Bogor-Depok-Bekasi) is one type of project currently being implemented. Metal welding in the LRT project is designed by determining the applicable parameters. Each welding result will have quality based on several factors (Khotasa, 2016)

Several factors affect the quality and characteristics of the connection. First, the type of material that plays an important role in regulating its mechanical and chemical properties. Furthermore, the type of welding process used, such as GMAW (Gas Metal Arc Welding), SMAW (Shielded Metal Arc Welding), or other variants, will affect how high the temperature is generated as well as the use of additional materials such as electrodes or welding wire. Temperature during the welding and cooling stages has a significant impact on the microstructure and mechanical joint properties. The cooling rate, sooner or later, will result in variations in the microstructure (Wiryosumarto, 2000).

According to (Alip, 1998) welding is the activity of joining two or more parts of an object by melting some of the main metal and fillers with or without pressure and additional metal and creating a continuous connection. The heat is needed to melt the metal parts that will be connected to the electrodes as a filler or filler (Suwahyo, 2011).

(Patil, NR, 2008) said NDT (Non-Destructive Test) is a form of testing carried out on materials or objects without causing permanent damage to these materials or objects (Mujiyanto, 2008). NDT can be used to test materials such as concrete, steel, iron, and other materials.

The magnetic test is a non-destructive test method (NDT) that can detect surface and subsurface defects in a ferromagnetic material (Karadeniz et al., 2007). The working principle of the Magnetic Test is that an electric current is used to generate a magnetic field in the material, and the direction of the magnetic field will be deflected so that a magnetic flux leak occurs when it passes through a defect. Magnetic flux leakage will attract ferromagnetic grains on the surface so that the location of the defects can be shown (Sri Widharto, 2013).

PT. INKA (Persero) implements company standards to maintain product quality and quality. One of the standard applications of the fabrication process is GMAW welding. Before working on a project, the quality of the welders is determined so that it can be seen who is eligible to work on the project (Rahmatika, 2021). The purpose of writing this journal is to know the NDT Magnetic Particle Inspection testing process that was carried out and to find out the results of the S355 J2 steel specimen inspection using the NDT Magnetic Particle Inspection testing method as the Basis for Determining GMAW Welder Qualifications. The quality of the weld results depends on the quality of the material to be welded, the suitability of the process being carried out, and the expertise of a welder or welder (Ahmad, 2019).

To achieve consistently high-quality welds, a standard with certain parameters is needed. One of the parameters used to evaluate the quality of the weld results is the Welding Procedure Specification (Amalia & Rahmatillah, 2022)

Research Methods

Methods This research was carried out by collecting several theories related to welding, WPS, and NDT Magnetic Particle Inspection Testing and its standards. The data obtained in this study are primary data and secondary data. Primary data was obtained from NDT Magnetic Particle Inspection tests conducted by researchers during practical work at PT. INKA (Persero). Secondary data was obtained from company archives in the form of information about the welder and WPS used. The Test Material is S355 J2 Steel Plate which has been GMAW welded by a Welder, and then an NDT Magnetic Particle Inspection test is carried out as the basis for determining GMAW Welder qualification data.

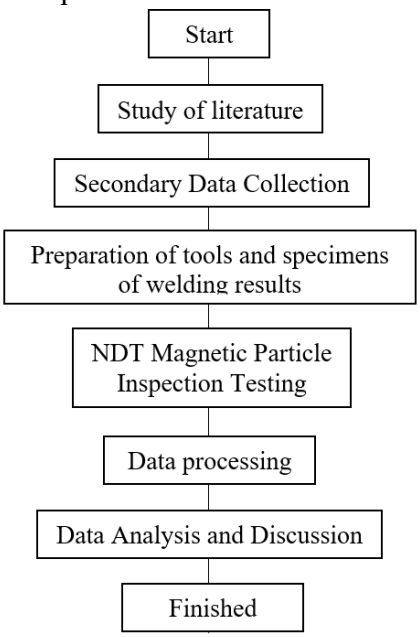

Figure 1. research flow chart

S355J2 is a low-carbon manganese steel that has moderate tensile strength as well as easy weldability and excellent

impact strength. This material is usually supplied in the untreated or normalized state. The filler used is AWS ER 70-S-6. In this study, the researchers discussed of the results of the Magnetic Particle Inspection test for S355J2 steel welding joints as a basis for determining GMAW Welder qualifications. The criteria used are international welding standards from AWS (American Welding Society) D1.1 and ASTM E 709.

1. AWS D1.1

This study uses AWS D1.1 as a welder qualification for steel materials. Some provisions that must be considered in AWS D1.1 for welding S355 J2 steel are:

a) Type of Welding Process and Thickness
b) Type of Filler and Electrodes
c) Position at the time of Welding
d) Testing of welded joints
e) Identification of Welded Joints on Specimens
f) Parameters of Welded Connections on Specimens

2. The Welding process of test material

Welding uses GMAW Welding Type with ER 70 S-6 Electrodes with 82% argon gas and 18% CO_2.

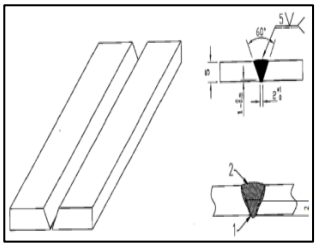

Figure 2. Illustration of a Welding Connection
(Source: Ahmad Abi, et al. 2019)

Information:

a) Shape : Single V Groove
b) Specimen length : 250 mm
c) Material Thickness : 12 mm
d) Root Opening : 12 mm
e) Welding size : 1.2 mm
f) Root Face : 0 mm
g) Size Of Weld : 12 mm
h) Grove Angle : 30°

Welding Parameters

a) Type of Current : AC
b) Electric Current : 158-206 A
c) Volts : 17-19 V
d) Gas Type : AR 82 %+CO_2 18%
e) Gas Flow : 15-17 L/min
f) Gas Cup Size : 10 mm
g) Filler : AWS ER 70S-6
h) Welding Position : 1G, 2G, and 3G

Results of Research and Discussion

After conducting several visual tests, it was found that defects in welded joints were generally obtained at the beginning and end of welding, defects on Visual inspection were Corn melt and End crater (EC) with a size smaller than 0.5 mm. The cause of corner melt and end crater defects is that there is a temperature mismatch between the material and the welding electrode. visual inspection code according to EN ISO 6520-1, if there is no Incomplete Fusion (IF) and Incomplete Penetration (IP) on inspection, thus the material can be accepted according to visual inspection and can be tested to the next stage, namely Magnetic Particle Inspection with the specified standard, namely ASTM E 709.

Table 1. Visual Testing Variables

Material	Position	Thickeness	Test Face	Test Root
S355 J2	1G	12 mm	P	IP, P, Crk

S355 J2	1G	12 mm	P	IP, P, Crk
S355 J2	2G	12 mm	P	IP, P, Crk
S355 J2	2G	12 mm	P	IP, P, Crk
S355 J2	3G	12 mm	P	IP,P, Crk
S355 J2	3G	12 mm	P	IP, P, Crk

(Source: Personal Documents)

Table 2. Magnetic Particle Inspection Test Variables

Material	Position	Thickeness	Test Sub surface	Test Penetration
S355 J2	1G	12 mm	P, IF	EC
S355 J2	1G	12 mm	P, IF	EC
S355 J2	2G	12 mm	P, IF	EC
S355 J2	2G	12 mm	P, IF	EC
S355 J2	3G	12 mm	P, IF	EC
S355 J2	3G	12 mm	P, IF	EC

(Source: Personal Documents)

Table 3. Test Result Data with Magnetic Particle Inspection

Material	Defect Location	Defect	Defective Size
12 mm 1G	Face	P	1,2 mm
	Root	IF	1,1 mm
12 mm 1G	Face	P	1,4 mm
	Root	IF	-
12 mm 2G	Face	P	1,1 mm
	Root	P+IF	0,9 mm
12 mm 2G	Face	-	-
	Root	P+IF	-
12 mm 3G	Face	-	-
	Root	IF	0,2 mm
12 mm 3G	Face	-	-
	Root	IF	-

(Source: Personal Documents)

Table 4. Welder Qualification Status Data from Test Plate Specimens

Welder	WPS	Posisi	VT	MT	Status
Lukas Setya Pratama	WPS-GM-211-0055	1G	Accepted	Accepted	Terkualifikasi
Saipul Iksan	WPS-GM-211-0055	1G	Accepted	Accepted	Terkualifikasi
Yoga Aji Ramadhan	WPS-GM-211-0007	2G	Accepted	Accepted	Terkualifikasi
Ribut Setyanto	WPS-GM-211-0007	2G	Accepted	Accepted	Terkualifikasi
Suparmin	WPS-GM-211-0007	3G	Accepted	Accepted	Terkualifikasi
Wiji Sucipto	WPS-GM-211-0007	3G	Accepted	Accepted	Terkualifikasi

From the test results, data is obtained in Table 3 Magnetic Particle Inspection which states the occurrence of surface defects at 1G and 2G welding positions in most materials. The defect found on the examination was an incomplete fusion-type defect located at the root of the weld. The biggest porosity (P) -type defects were found on the weld surface on 12 mm material with 1G position. In addition, surface porosity-type defects and defects at the root of the weld were found. The porosity-type defects in the material have a diameter of 1.2 mm. In addition, porosity-type defects were also found in 12 mm materials with the 2G Welding position. In these materials, the porosity-type defects have a diameter of 1.1 mm. By using 12 mm material with 3G welding, no porosity-type defects were found. However, incomplete fusion-type defects were found in the 0.2 mm material using the 3G Welding position.

The acceptance criteria for the test results with Magnetic Particle Inspection in the 'Guide to Weld Inspection for Structural Steelwork' show that the capacity for porosity-type defects in each type of connection is acceptable if it does not exceed 2 mm in diameter. In addition, the number of defects does not exceed 5 holes with a material length of 100 mm crosswise and does not exceed 10 holes for a material length of 100 mm longitudinally.

Referring to the data from the NDT Visual Test and Magnetic Particle Inspection test results, it can be analyzed that the welding done by this Welder had good results. Based on the Magnetic Particle Inspection test standard, it is

known that the range of permitted Overlap defects is > 0.5 mm, Linear misalignment defects is permitted > 2 mm, Root concavity defects are permitted > 0.5 mm, for Crack (Crk) defects is permitted > 0.5 mm, for Shrinkage Groove defects which are permitted > 0.5 mm (AWS D1.1). It is known that the results of the welding done by the Welder found no defects in the form of Spatter, Underfill, Undercut, and Porosity which resulted in reduced strength of the material.

From the Welder Qualification Status Data table from the Test Plate Specimens above, the specimens that the researchers tested have passed the NDT test in the form of Visual Test and Magnetic Particle Inspection and are in accordance with the standards used, namely AWS D1.1 and ASTM E 709. With the passing of all specimens, data is obtained that the welder used by PT. INKA (Persero) is a welder who has been qualified and complies with the applicable Standards. So that the Welder can be allowed to work on a Project because it is considered to have met the required Welder qualification standards.

Table 5. Visual Test Results Data

Thickness	Welding Position	Welding Defect	Information
12 mm	 Position 1G	At the end of the weld, defects appear, caused by a given temperature mismatch. No defects other than at the end of the weld.	Accepted (This criterion is declared acceptable because it meets the requirements described in the AWS D1.1 standard)
	 Position 1G	At the end of the weld, defects appear, caused by a given temperature mismatch. No defects other than at the end of the weld.	Accepted (This criterion is declared acceptable because it meets the requirements described in the AWS D1.1 standard)
12 mm	 Position 2G	At the end of the weld, defects appear, caused by a given temperature mismatch. No defects other than at the end of the weld.	Accepted (This criterion is declared acceptable because it meets the requirements described in the AWS D1.1 standard)
		At the end of the weld, defects appear, caused by a given temperature mismatch. No defects other than at the end of the weld.	Accepted (This criterion is declared acceptable because it meets the requirements

	 Position 2G		described in the AWS D1.1 standard)
12 mm	 Position 3G	At the end of the weld, defects appear, caused by a given temperature mismatch. No defects other than at the end of the weld.	Accepted (This criterion is declared acceptable because it meets the requirements described in the AWS D1.1 standard)
	 Position 3G	At the end of the weld, defects appear, caused by a given temperature mismatch. No defects other than at the end of the weld.	Accepted (This criterion is declared acceptable because it meets the requirements described in the AWS D1.1 standard)

(Source: Personal Documents)

Conclusion

GMAW Welder Qualifications with reference to standard criteria from AWS D1.1 can be used as a reference in determining the Basis for Determining GMAW Welder Qualifications on S355 J2 material. Based on the data and discussion, it can be concluded:

1. Examinations carried out for GMAW welding at PT. INKA (Persero), namely the Non-Destructive Test method (Visual Test and Magnetic Particle Inspection). The Visual Test process carried out, can be used to observe the conditions of the welding results such as weld defects (Spatter, Overlap, Underfill, Undercut, Porosity and Cracking) and carried out Taking pictures with the help of a Smartphone camera. After carrying out the Magnetic Particle Inspection testing process which is used to strengthen the conclusions from the Visual Test results by observing the conditions of the welding results such as defects (Porosity, Pin Hole, Under Cut, Surface Underfill, Surface Crack and Slag Inclusion) then take pictures with the help of a Smartphone camera.
2. From the examination using the Non-Destructive Test method (Visual Test and Magnetic Particle Inspection) on the results of the welding of the S355 J2 specimen, there were no welding defects. Complies with WPS-GM-211-0007 and WPS-GM-211-0055. Machine condition factors, appropriate electric current settings, welder accuracy and skills, and proper and good material selection

are factors that influence the success of this GMAW welding.

3. From the results of the inspection, it was stated that the Welders Lukas Setya Pratama, Saipul Iksan, Yoga Aji Ramadhan, Ribut Setyanto, Suparmin, and Wiji Sucipto had met the welding qualification standards set by PT. INKA (Persero), so that they are allowed to participate in projects that are being carried out by PT. INKA (Persero)

Acknowledgements

This research can be completed because there are various parties who have helped. The author gives thanks to PT. The Railway Industry (INKA) and the Metallurgical Engineering Study Program at the Yogyakarta "Veteran" National Development University, as well as various parties that the author cannot convey one by one.

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