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Analysis of Welding Results on Stringer Tertiary Screen Using NDT Magnetic Particle Test Method at PT. PAL Indonesia

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***Abstract* - Welding is the process of joining materials in the manufacturing industry. To maintain the quality of welding results in accordance with established standards, it is necessary to inspect or inspect the product. To find out whether or not there are defects in the product before the next process is carried out, or before the product is marketed, an inspection is usually carried out using a non-destructive testing (NDT) method, namely testing materials without damaging the material being tested. Several types of non-destructive testing, namely, visual checking, penetrant test, radiographic test and magnetic particle test. This article discusses about the welding analysis of stringer tertiary screen at PT PAL Indonesia. To check whether there are defects in the welded joints in the stringer tertiary screen, a visual check and magnetic particle test have been carried out. Based on interpretation using ASME section IX, the test results show that there are several defects such as spatter on the base metal and wormholes which are unacceptable. The finding of this defect has been followed up with re-welding repairs as recommended. For spatter defects, repairs are carried out with the help of an air chipping hammer which functions to clean the spatter from the base metal, then for wormhole defects repairs are carried out by dismantling the weld and re-welding. The results of repeated visual checks and magnetic particle tests after repair showed that the defects had been successfully eliminated. Thus, the welding results on the stringer tertiary screen are acceptable.**

Keywords: Welding, Magnetic Particle Test, ASME.

I. INTRODUCTION

A vibrating screen at PT PAL Indonesia is a tool used to separate the size of material resulting from the crushing process based on the size of the openings in the sieve which are expressed in millimeters (mm) or can also be expressed in mesh units. The vibrating screen discussed in this research is a type of tertiary screen, namely a sieve with several levels of mesh as depicted at Figure 1. One of the important components of a vibrating screen is the stringer which is used as a support for the mesh and the sieving process later.

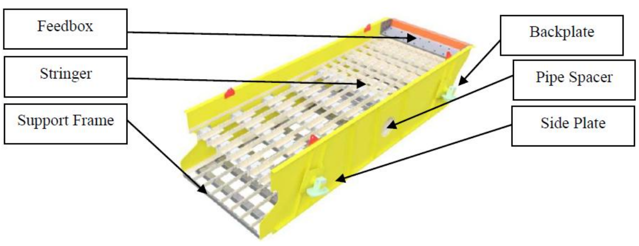

Figure 1: Assembly Tertiary Screen

Figure 2: Stringer Tertiary Screen

The stringer of tertiary screen is depicted at Figure 2. The stringer is the part that supports the sieve material from a sieving machine. Material of Stringer tertiary screen is ST 41 low carbon steel plate with 12 mm thickness. This part consists of a combination of steel plates called stringers which are connected via the FCAW (Flux Cored Arc Welding) welding process. In FCAW welding, it cannot be denied that there are still many imperfect welding (defects) occurring.

FCAW welding is a type of electric welding those supplies welding wire filler mechanically directly into an electric arc that forms between the tip of the welding wire filler and the base metal. The steel used is low carbon steel which is also called mild steel, this mild steel is steel that is easy to weld, and can be welded using all welding methods. The ability of a type of media to cool specimens can vary.

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Cooling media is a substance whose function is to determine the cooling speed of the material that has been tested in heat treatment. (Ari Ardiansah, et al, 2019). The FCAW scheme can be seen in the following at Figure 3.

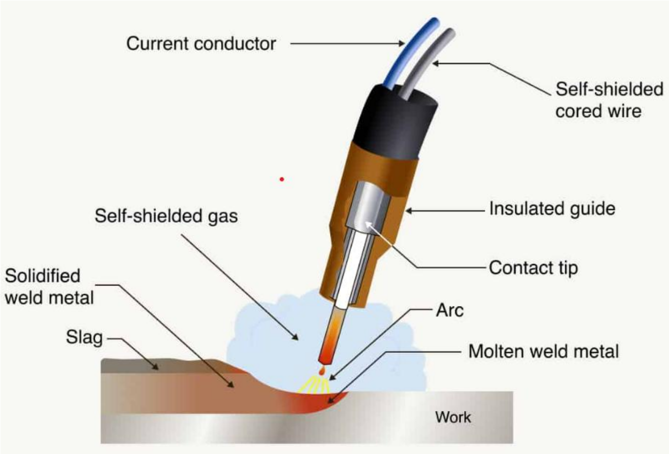

Figure 3: Flux Cored Arc Welding (FCAW)

Welding really helps the work process for both simple constructions and those with a high level of difficulty. Welding technology is very much needed in the industrial world as well as for general engineering and other construction fields related to joining and welding. To keep pace with advances in welding technology, it is also necessary to support the readiness of human resources, so that technology can be in balance with the actors, namely human resources (Bakhori, 2021).

Welding is a process that involves many factors such as humans, chemical reactions, procedures, work objects, and the welding equipment itself, so it often causes welding results to not be optimal. Welding results that are not optimal with certain parameters can be categorized as welding defects. Welding defects are conditions where the welding carried out does not comply with established standards based on ANSI, ASME, ASTM, AWS, ISO standards, and so on. Some welding defects that are often found are cracks, porosity, spatter, undercut, incomplete penetration and slag inclusion. These welding defects should be avoided as much as possible because they will have an impact on the strength of the joint and the durability of the weld itself. Poor welding techniques and procedures cause defects in the weld which cause discontinuities in the weld (Bakhori, 2021).

There are two ways to evaluate the welding results, namely the method of damaging the workpiece and the method of not damaging the workpiece. Non-destructive tests on workpieces include visual observation, magnetic particles, ultrasonics, radiography and liquid penetration. To determine the physical properties of welds using damage tests, namely, impact tests, bend tests, tensile tests and hardness tests. The Magnetic Test method is an NDT or non-destructive testing method which is quite simple but has the advantage of speed and accuracy in detecting welding defects on the surface.

Welding errors will affect the structural integrity of the welded structure. As a result, welds require regular inspection/examination to monitor and assess their condition whether they are fit for purpose or have lost some of their integrity due to aging issues and to take action when defects are noticed before they cause failure. Inspection is important because it is useful for checking whether there are any deviations/contradictions from the design made. In industry, inspections are also useful as quality control to maintain consumer confidence. Welding inspection is an important practice to assess the integrity of structures and their components in many industrial applications including piping systems in the oil and gas, nuclear, electricity and petrochemical industries (Aqdar Fitrah and Balfas).

The types of defects that occur as a result of the welding process include the following:

a) Porosity and Wormhole

This defect is a defect caused by gas trapped in the weld area in an amount that exceeds the boundary conditions. This defect condition is in the form of a group of cavities in the weld area caused by air trapped during the welding process. Wormholes and porosity have almost the same characteristics. Wormholes are usually shaped like worms and are found around the weld area, while porosity is usually round or irregular and found in the welded metal.

b) Spatter

Conditions where the welding results are defective in the form of metal particles that are splashed during welding in the form of small metal grains that stick to the material.

c) Crack

Cracks occur in the weld area or in the HAZ area. Generally caused by rapid cooling after welding. In carbon steel, excess carbon elements can also be a cause. Cracks are cracks in the weld metal, either in the direction or transversal to the weld line, which are caused by internal stress, cracks in the weld metal can reach the base metal, or cracks occur entirely in the base metal around the weld.

d) Concavity

A concave face or concavity is a welding imperfection so that the results of penetration welding are concave in shape. This concavity defect is usually caused by the capping amperage being too high, the capping welding speed being too

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high, the seam angle opening being too large, the electrode being too small and the welder's work being completed too quickly.

e) Undercut

Conditions where the welding results are defective in the form of a tear on the side of the welding area that exceeds the tolerance limit. Undercut defects often occur in all electric welding processes. The cause of the undercut defect is the use of very high amperes along with a very fast welding travel speed which does not give the filler metal a chance to fill the weld line completely.

f) Cold Lap

Cold lap is a condition where imperfect fusion occurs on the surface and inside. This defect is caused by the metal temperature being too cold, the capping amperage being low, and the swing being inconsistent. Overcoming this defect is by dismantling the entire welding line and then making it welded again and welded according to the WPS.

g) Incomplete Penetration

Incomplete Penetration is a defect that occurs because the gap is too narrow, the electrode is too high, the amperage of the welding machine is not fixed, the gap is not uniform, the seam is dirty and the electrode is too large. Overcoming this defect is by gouging the defective part and re-dialing it according to the WPS.

Tests carried out without damaging the physical structure of the object being tested to determine the presence of damage or defects in a material are better known as Non Destructive Tests (NDT). The following are types of non-destructive testing:

a) Visual inspection

Visual inspection is a very simple test without requiring special equipment, usually only using magnifying glasses, a flashlight and other supporting tools. To carry out visual testing, you only need to observe the material specimen. Very effective for detecting macroscopic defects or large surface defects, for example defects in poor welding results.

b) Liquid (Dye) Penetrant Test

Liquid penetrant test is one of the most widely used non-destructive testing methods for various needs. The working principle of this method is based on the ability of liquid to enter the cracks in the surface of the defect. With this method, defects on the surface will be visible. The method is to apply a light colored liquid to the surface of the material being inspected.

c) Magnetic Particle Test (MPI)

Magnetic particle test is one of the methods used in non-destructive testing (NDT), with this method defects on the surface and below the surface of an object made of ferromagnetic material can be identified and inspected. The working principle of this magnetic particle inspection method is to magnetize the material to be tested. If there are defects that are perpendicular to the direction of the magnetic field, it will cause leaks in the direction of the magnetic field. This magnetic field leak indicates a defect in the material. The method used to detect a leak in the magnetic field is by sprinkling magnetic particles or powder on the surface of the test object. The magnetic particles or powder that has been sprinkled will then gather precisely in the area where there is a magnetic field leak.

d) Eddy current test

Eddy current test is a non-destructive testing method that applies electromagnetic principles to carry out tests or inspections. that is, there is a coil that carries an electric current which functions to generate a magnetic field inside it. If the magnetic field is applied to a metal object to be tested, it will generate eddy currents. The eddy current induces a magnetic field in the coil and changes its impedance if there are defects in the test object. Indications that there are defects or defects can be seen when sprinkling magnetic powder on the surface of the material. The eddy current method is almost similar in principle to the Magnetic particle inspection testing method, however the electric field used is in the form of alternating electric current (AC), when there is defect the electric field will change and the impedance measuring device will read or detect if there is a defect or disabled.

e) Ultrasonic testing

Ultrasonic testing is a non-destructive testing method that utilizes waves or vibrations at high frequencies. Ultrasonic Tests can be used to determine the depth of a defect or specific defect which includes the size and location of the defect. In ultrasonic testing, equipment or other tools are used, namely a probe to produce high frequency vibrations and a couplant is needed, namely a coating liquid on the surface of the test object. The working principle of Ultrasonic testing is by firing vibrations or waves with a high frequency, namely 0.25-10 Mhz. The wave will propagate through the test object and then the wave will be reflected back if the wave detects a defect in the test object.

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f) Radiographic testing

Radiographic testing is a type of non-destructive testing that uses gamma ray and X-ray radiation. The working principle is that the X-rays will be emitted at the test object and penetrate the surface of the material. When it penetrates a plane or object, some of the light that penetrates will be absorbed so that the intensity of the light will decrease. The final intensity of the beam is then recorded and recorded on sensitive film. If there are defects or flaws in the test object, the intensity of the light recorded on the film varies. The results of this film recording will show the location and parts of the material that are defective.

II. MATERIAL AND METHOD

The initial stage carried out in this research was conducting a field study in the form of field observations, collecting field data followed by a study of literature related to welding. Conduct direct observations of the tertiary screen manufacturing process. This observation aims to find out directly how the assembly process works in the field and understand the problems more clearly.

Regarding tertiary screen manufacturing, the type of welding used in the manufacturing industry is welding using the FCAW (Flux Cored Arc Welding) method. FCAW welding is a type of electric welding that supplies welding wire filler mechanically directly into an electric arc that forms between the tip of the welding wire filler and the parent metal. The steel used is low carbon steel which is also called mild steel, this mild steel is steel that is easy to weld, and can be welded using all welding methods. The ability of a type of media to cool specimens can vary. Cooling media is a substance whose function is to determine the cooling speed of the material that has been tested in heat treatment. One of the important parts for the tertiary screen produced by PT PAL Indonesia is the stringer. The stringer is the part that supports the sieve material from a sieving machine. This part consists of a combination of steel plates called stringers which are connected via the FCAW welding process. In FCAW welding, it cannot be denied that there are still many welding imperfections (defects).

Literature studies are carried out by collecting and utilizing information related to the material and methodology of the research. At this stage the author looks for literary sources that can be used as references to help with this research process. The literature taken comes from scientific journals, theses, theses, and books related to the topic raised, namely welding defect analysis. To carry out a literature search, the author used the help of Google Scholar, ScienceDirect, and also other trusted journal websites. In collecting literature, the author tries to use references from trusted sources so that the references presented will be valid.

Regarding field data collection, the author collected field data including tertiary screen specifications, welding procedures and processes to then observe the welding results. The welding results are then observed to identify possible defects that have occurred. Interpretation of defects that occur is carried out using ASME IX standards. This is done to identify the type of defect that occurs and determine the acceptance criteria. The final stage is to determine whether the welding results are accepted, rejected with repairs or completely rejected without repair. The repair methods to be carried out are also discussed in this research.

The most important in NDT is by providing magnetic powder to the surface being tested. The choice of material for magnetic powder is based on considerations of the type of surface of the test object. Ferromagnetic powder material is very good for rough surfaces, while ferromagnetic wet material is very good for smooth surfaces. When applying magnetic powder, calibrate the direction of the magnetic field using a yoke and pie gauge, as shown in Figure 4. Defects will appear if they are perpendicular to the direction of the magnetic field.

Figure 4: Providing magnetic powder

After that is the magnetization process, namely providing a magnetic field to the surface being tested using a yoke by adjusting the shape and size of the object. When magnetizing, use a rubber blower to blow off the magnetic powder so that defects are more easily visible.

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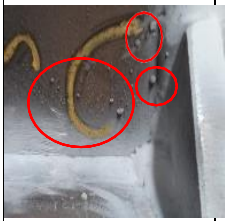
III. RESULT AND DISCUSSION

The acceptance criteria for Magnetic Particle Test testing have a standard, namely the ASME Section IX Article 1 standard. Where all surfaces tested are considered unacceptable if the inspection shows indications that exceed the limits specified as follows:

1) Relevant linear indication (> 1/16 inch or 1.5 mm)
2) Relevant rounded indication, where the size is > 3/16 inch (5 mm).
3) Four or more relevant rounded indications are lined up in a line, separated from each other at a distance of ≤ 1/16 inch (1.5 mm), from end to end.

The test results on the stringer using the Magnetic Particle Test method are interpreted and evaluated to determine whether the discontinuity can be accepted or rejected. Table 1 shows the results of interpretation and evaluation based on ASME Section IX Article 1 standards.

Table1: Interpretation of Test Results by NDT using Magnetic Particle Test (MPI)

Picture	Interpretation		Evaluation	Remark
	Indication	Size		
	Linier	5mm	Rejected	Wormhole
	ounded	Distance between indication: ≤ Ø 1,5mm	Rejected	Spatter
	Rounded	5,1mm	Rejected	Spatter
	Rounded	1,2mm	Accepted	Spatter
	Rounded	Distance between indication: ≤ Ø 1,5mm	Rejected	Spatter

Based on the results of the interpretation in table 1, the magnetic particle test was carried out with almost the same aim as the penetrant test, namely to identify defects on the surface of the welded ST 41 low carbon steel plate. The test results showed rounded and linear indications with acceptance standards. Accepted/rejected in accordance with ASME Section IX Article 1 QW 195. In this test, the same material was used, namely low carbon steel plate ST 41 in accordance with that used in the production of tertiary screens on stringer components.

From the results obtained in magnetic testing of stringers with ST 41 steel material, several visual defects were found, namely spatter and wormholes. Spatter defects are welding splashes like grains of sand that stick to the surface of the weld. Usually caused by the current being too large and the distance between the electrode and the parent metal being too far. From the tests it was found that several spatter defects with different diameters ranging from Ø0.8 – Ø5.1 mm, after these defects were found, repairs were carried out to remove the spatter defects using air chipping hammer or what is usually called a spatter, because if the defects are left and if there are too many then the area where the spatter used to be will experience cracks and be one of the causes of corrosion in the material.

Figure 5: Spatter Removal Process with Air Cipping Hammer

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Figure 6: Defect Removal Process with Grinding

Apart from that, a defect was found in the form of a wormhole which was indicated to be linear and exceeded the tolerance limit. Wormhole defects are in the form of small holes in the weld metal which are usually caused by the electrode used being too wet or the surrounding air when welding being very humid, if left unchecked it can become a source. corrosion because the part is not exposed to paint and can reduce the strength of the material, therefore the wormhole defect must be removed by grinding and welding again on the part that is indicated as a defect.

IV. CONCLUSION

Based on the previous discussion, it can be concluded regarding the results of welding stringer tertiary screens, as follows:

1) When interpreting the test results, several spatter and wormhole defects were found. Spatter defects will make the weld look ugly, starting surface rust while wormholes can weaken the joint, look bad, and start surface rust. Such spatter and wormhole defects cannot be accepted (rejected) in accordance with ASME Section IX Article 1 acceptance standards, so these two defects need to be repaired and re-inspected to ensure that the indications of defects found have disappeared.
2) Spatter is a condition where the welding results are defective in the form of metal particles that are splashed during welding in the form of small metal grains that stick to the material. Welding defects in the form of spatter can be characterized by the presence of lumps of filler metal scattered over the workpiece, sometimes these lumps stick to the workpiece and are difficult to clean. The causes of welding sparks are damp electrodes, dirty seams, too strong shielding gas, galvanized layer, too high capping amperage. Meanwhile, wormholes are a type of welding defect where there are small holes around the weld area. This usually occurs because gas is trapped in the liquid metal during the welding process, and when the gas comes out of the crystallized metal, it forms a hole that looks like a wormhole.
3) Spatter defects can be overcome by cleaning the workpiece surface with an air capping hammer, chisel or steel brush. It is not recommended to use a grinder because it can erode the workpiece surface. This type of defect can be avoided by first checking the welding machine, both the settings and the electrode. The welder must also understand each setting that must be used in the welding being carried out. Meanwhile, overcoming wormhole defects is by grinding them until the filling is welded again.

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