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Analysis of Defects in SMAW Welding Joint Using E 7016 Electrode Due To the Direct Cooling Process

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Abstract

Weld defects can cause corrosion and cracks that propagate and can eventually cause a brittle fracture. The problem of brittle fracture is big in welded steel, especially in welded joints; this brittle fracture becomes more important because of stress concentration factors, inappropriate structures and defects in the weld. This study aimed to find out how to use the appropriate electrode for ST 37 material for the direct cooling process using oil and water. Testing for weld defects using the Penetrant Test method and the Magnetic Particle Test by the Welding Inspection team from PT. Superintending Company of Indonesia (SUCOFINDO). The results showed that the results of the welding had welding defects but were still within acceptable limits (Standard Ansi B 31.3). The tensile test results showed that the ST 37 material, whose welding process used the E7016 electrode, was better than the ST 37 material, which used the E 7018 electrode in the welding process with a cooling process using oil and water.

Keywords: Weld Defects, ST37, Electrode, E 7018, Oil and Water

1. Introduction

In general, the strength of the weld results does not match the target because it is vulnerable to welding defects[1] that are formed, even though welding defects are not planned in the welding process, especially in industries that use a lot of welding in their work. As we know, welding defects in construction, if repairs are not immediately carried out, then the area of the defect can cause cracks exacerbated by more widespread crack propagation and corrosion[2] which can cause a brittle fracture, which is detrimental. The problem of brittle fracture is big in welded steel, especially in welded joints; this brittle fracture becomes more important because of stress concentration factors, inappropriate structures and defects in the weld. The occurrence of defects in the welding results is unavoidable due to many factors, including inappropriate electrodes, forced cooling, strong welding currents, lack of fusion or penetration and imperfect shapes[3].

During the welding process, the metal will experience fast thermal cycles, which cause complex metallurgical changes[4], deformations and thermal stress[5]. This is closely related to strength, weld defects and cracks. So that generally has a fatal influence on the construction of materials. Therefore it will experience a change in structure which in itself, the mechanical properties of metal also change. To anticipate the occurrence of defects in the weld area, it is recommended that each welding result be inspected for welding, which aims to see the weld joint area from weld defects, both voids and porosity of the weld area and other forms of defects, with several methods including using: penetrant test, radiography test and magnetic particle test[6].

In this study, the strength of the ST 37 Material welding joint will be investigated, as we know that the weld area often has welding defects in the form of voids, cracks, and excessive slag. The purpose of this study is to find out how to use the appropriate electrode for ST 37 material in the welding process, which is a direct cooling process using oil and water and obtain optimal welding results after going through the results of the inspection of weld defects using the Penetrant Test method, and the Magnetic Particle Test.

Welding is a process of joining metals, in which metals become one as a result of heat with or without pressure[7], based on the definition of Douctche Industry Norman (DIN) is a metallurgical bond at a metal or metal alloy joint which is carried out in a melted or liquid state. Today, welding is widely used in industry for the implementation of construction work, manufacture of factory equipment machinery, piping construction, ship construction, manufacture of pressure vessels and other works[8].

SMAW A feed electrode electric arc welding process uses an electric arc that occurs between the electrode and the local workpiece, then forms an alloy and solidifies into a weld. The covered electrode, which functions as a flux, will burn during the welding process, and the gas that occurs will protect the welding process against the influence of outside air; the wrapped liquid will float frozen on the welding surface, which is called slag.

Electrodes often called welding wires, are used to perform electric welding[9]. The flame arc will arise when the tip of the electrode as a burner is in contact with the base metal, then generates a lot of heat to melt and melt the welding metal. In general, the electrodes can be divided into two kinds, namely:
1. Coated/coated electrodes

2. Plain electrode

The types of welding wire (electrode) can be distinguished in various ways, depending on how it is used and the type of material being welded. But in general, we know the types of electrodes as follows:
1. Mild steel electrodes
2. Nickel electrode
3. Aluminum electrode
4. Cast iron electrode
5. Stainless steel electrodes and others.

ST 37 steel is a very strong and tough construction material with a fine grain structure and can be worked hot or cold. The meaning of ST itself stands for Steel (steel), while the number 37 means a tensile strength of 37 Kg/mm2.

ST 37 steel is included in the low-carbon steel group, widely used in small and medium industries as a construction material[10]. In the market, this steel is in the form of sheets with varying thicknesses and widths. The elements contained in the steel will affect the mechanical and physical properties of the steel concerned. The types of steel are generally determined based on the content of the element carbon contained in the steel material. Steel ST 37 is medium carbon steel equivalent to AISI 1045, with a chemical composition of Carbon: 0.5%, Manganese: 0.8%, Silicon: 0.3%, plus other elements. With a hardness of ± 170 HB and a tensile strength of 650 - 800 N/mm^2.

A welding defect or defect is a condition where the welding is not following established standards based on ANSI, ASME, ASTM, AWS, ISO, and so on. The cause of welding defects can be caused by wrong welding procedures and inadequate preparation and can also be caused by equipment and consumables that are not up to standard. Types of welding defects in welding include several types of internal and visual welding defects. Impurities cause a lack of fusion or penetration of this defect in products due to gas reactions or external elements, such as slag, oxide, tungsten metal or others. This defect usually occurs in the area of the weld metal. While Lack of Fusion is a defect due to discontinuity, there are parts that do not fuse between the parent metal and the filler metal. Besides, this type of defect can also occur in layered welding, which occurs between one welding layer and another. Lack of Penetration: This defect occurs when the weld metal does not penetrate to the bottom of the joint.

Imperfect form. This type of defect gives the geometry of the weld joint that is not good (imperfect), such as: undercut, underfill, overlap, excessive reinforcement and others. The geometric morphology of these defects usually varies.

Types of testing and inspection of weld metal can generally be divided into two parts, namely:
a. Destructive Test (DT).
Destructive testing of welded construction is testing the model of construction or test rods that have been welded in the same way as the welding process used until damage occurs to the model or construction or test rods.
b. Non Destructive Test (NDT) nondestructive testing. This test is carried out without damaging the construction part being tested; this test is carried out to find defects in the welding construction, both external and internal.

In a welded joint, the tensile properties[11] are greatly influenced by the properties of the base metal, the nature of the HAZ region, the properties of the weld metal and the dynamic properties of the joints are closely related to the geometry and stress distribution in the joints. The test carried out is a tensile strength test because it is not only to see similarities between the parent metals in the welding area but also to determine the characteristics of the material to be tested when it is subjected to bending and machining. The following equations can calculate the tensile properties:

Stress $$\sigma = \frac{F}{A_O}(kg / mm^2) \quad (1)$$

Strain $$\varepsilon = \frac{L - L_O}{L_O} x100\% \quad (2)$$

2. Research Methodology

Place of research implementation and manufacture of test specimen forms for joints (groove shape), welding and inspection of weld defects, including examination of matters encountered in SMAW welding, both NDT and DT, carried out at the PT. Arun NGL Workshop using a certified welder.

In this study, the materials to be used are:
1. Steel ST 37
2. AWS E-7016 Ø2.6 mm and Ø3.2 mm electrodes (LB-52U + LB-52 Mfg. Kobe Steel,LTD).

The stages of research start from:
a. The groove (welding joint) used in this study is a single V groove with a bevel angle of α 60^0 as shown in figure 1. The reason for using a single V groove type is that apart from being easy to weld, this groove is also stronger in resisting static and dynamic loads, and the joints' strength is more guaranteed compared to other camps.

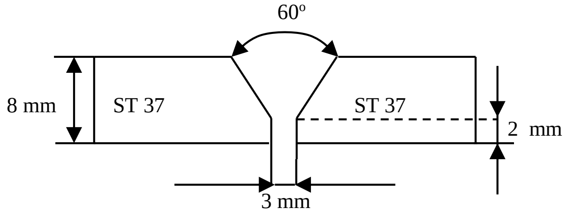

Fig. 1. Single V joint type

a. Welding stages

Before the welding process, the materials to be welded:

1. The cut material is divided into two parts
2. Then, a seam (groove) is formed, with a taper angle of 300 for each specimen.
3. The next stage is the welding process using wrapped electrode arc welding, or SMAW. Welding of these wrapped electrodes uses an AC-polarized current. The deposit sequence is a multiple-layer filling sequence, each layer covering the entire length of the material. The welding method, current, voltage, speed, electrode type, and groove shape determine the welding quality. In addition to the deformation that occurs, the residual stress, which causes the toughness of the metal product, decreases.

b. Weld defect inspection

After all the material is ready to be welded, the next step is to inspect the welding results using three welding defect inspection methods, which aim to see the structure of the weld area, whether there are cracks, voids, inclusions and lack of penetration using the following methods: Penetrant Test, Magnetic Particle Test.

b. Preparation of tensile test specimens

Steps taken: the specimen is cut and formed into a tensile test specimen using a milling machine, according to predetermined dimensions using the AWS standard shown in Figure 2. The number of test specimens made was 15 specimens.

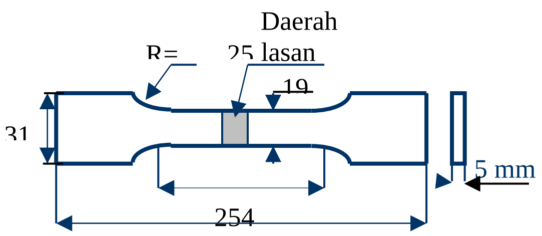

Fig 2. Dimensions of AWS A5.28 standard Static Tensile Test Specimens

3. Results and Discussion

a. Weld defect inspection,

Inspection of weld defects is carried out by non-destructive NDT (Non-Destructive Tests) using the Magnetic Particle Test and Dye Penetrant Test methods from the results of the inspection carried out by the Welding Inspection team from PT. The Superintending Company of Indonesia (SUCOFINDO) of the 15 ST 37 specimens that had undergone welding did not show any weld defects, so they were still within the acceptable limiting criteria (Acceptance Standard Ansi B 31.3).

The next step is that all ST 37 materials that have been welded are immersed following the method used in this study, namely using water and oil. The weld area is inspected using the Magnetic Particle Testing method and the Dye Penetrant Examination Test.

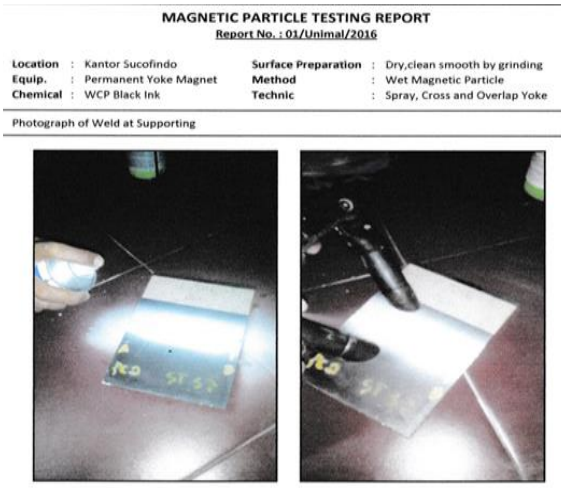

Fig. 3 Examination of welding defects by the Magnetic Particle Testing method, Material ST 37 oil cooling medium

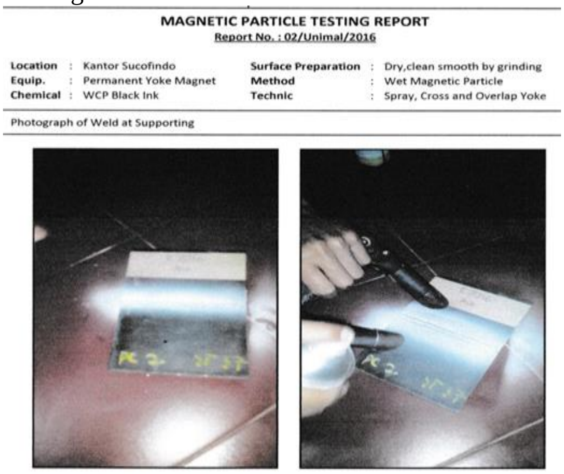

Fig. 4. Examination of weld defects by Magnetic Particle Testing method, Material ST 37 water cooling medium

Figure 3 and 4 above examine weld defects using the Magnetic Particle Testing method in the ST 37 material welds in the welding process using E 7016 electrodes which use cooling media using oil. The inspection results showed that there were no welding defects in the weld area of the material, only a few voids (air cavities) in the context that it was still safe, and there was no doubt about the strength of the weld. Meanwhile, those using cooling media used water. The inspection results showed that the material's weld area contained several mild welding defects due to dirt adhering to the weld area and some Voids (air cavities) and sticky slag in a context that is still safe, and the strength of the weld is not in doubt.

For welding materials using E 7018 electrodes, the test results using dye penetrant with oil and water cooling can be seen in Figures 5 and 6.

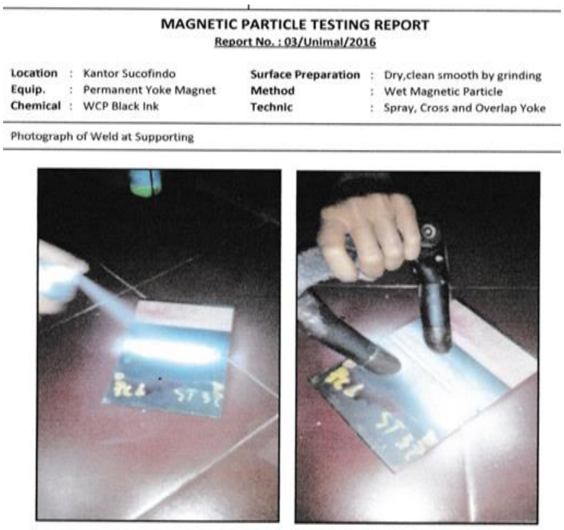

Fig. 5. Inspection of weld defects by Dye Penetrant Testing method, Material ST 37 water cooling medium

Figure 5 examines weld defects using the Dye Penetrant Examination Test method on ST 37 material in the welding process using E 7016 electrodes which use cooling media using oil. The inspection results explained that the weld area in the ST 37 material SMAW welding results was safe from minor welding defects in the form of slight Voids or air voids in the weld area; the results of the examination stated that this was still in the safe category so that the welding material can be used.

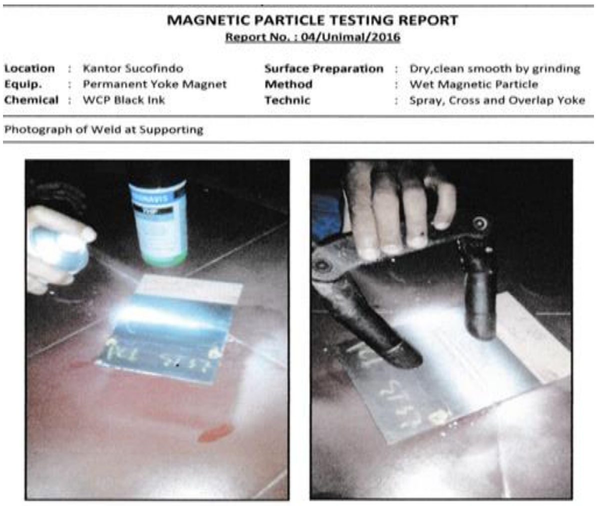

Fig. 6. Inspection of weld defects by Dye Penetrant Testing method, Material ST 37 oil cooling medium

Meanwhile, an inspection of weld defects using the Dye Penetrant Examination Test method in the ST 37 material in the welding process using E 7016 electrodes using cooling media using water. The inspection results show that the weld area on the ST 37 welding material is safe from welding defects; it appears that there is a slight crack in the weld area. Different, in a context that is still safe and has no doubt about the strength of the weld, this is as shown in the following figure 7:

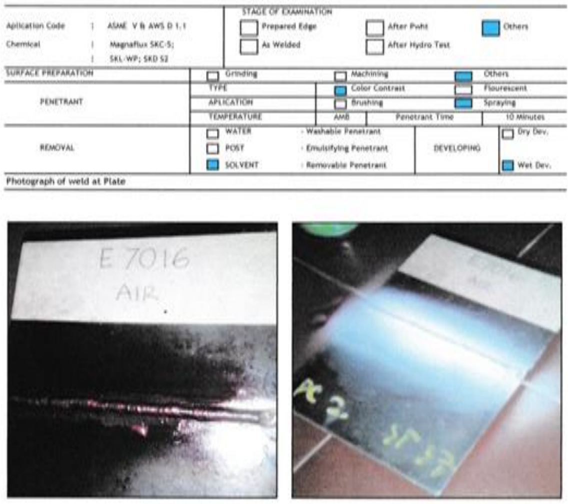

Fig. 7. Inspection of weld defects using the Dye Penetrant Testing method, Material ST 37 using water as a cooling medium

In examining weld defects using the Dye Penetrant Examination Test method, the welding process uses E7018 electrodes with cooling media using water as shown in figure 8. The inspection results showed that the weld area on the ST 37 welding material was classified as safe from welding defects due to strong currents or an unstable cooling process visible in the weld area indicated by several air cavities. Several sticky slags were difficult to remove at different distances, in the context of still safe and not doubt the strength of the weld.

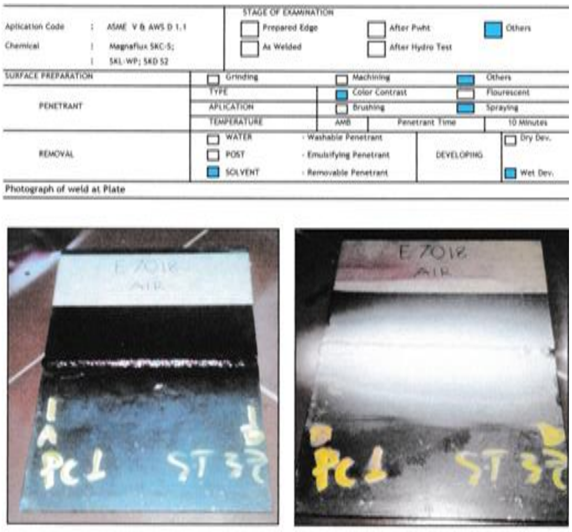

Fig. 8. Inspection of weld defects by Dye Penetrant Testing method, Material ST 37, with water cooling medium

The welding uses E 7018 electrodes with cooling media using oil to inspect weld defects using the Dye Penetrant Examination Test method as shown in figure 9. The inspection results show that in the weld area in the ST37 welding material, there are several parts of a crack caused by slightly excessive penetration, which slightly reduces the strength of the weld area and several voids, but this is still categorized as a safe position in the weld area so that it can be used according to the required load.

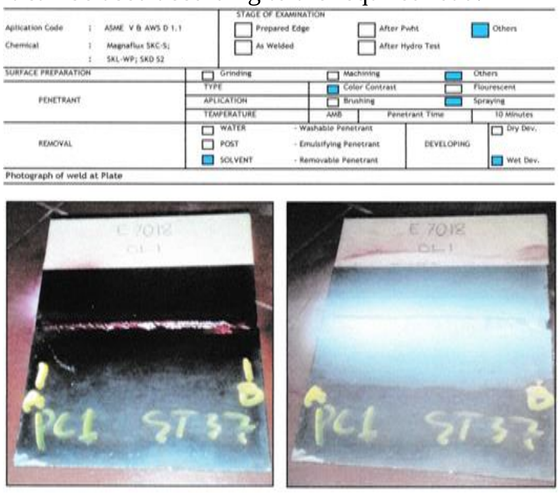

Fig. 9. Inspection of weld defects by Dye Penetrant Testing method, Material ST 37, with oil cooling medium

Tensile Test Results

The results of the tensile test carried out in this study on the results of welding ST 37 materials using E7016 and E7018 electrodes using water and oil cooling media. Each group consisted of 5 specimens, so the test results for each specimen showed a different level of strength value. The overall results of the tensile test of the ST 37 material welding specimens can be seen as follows:

Calculation of Welding Specimens Using E7016 Electrodes With Water Cooling Media

From the tests that have been carried out on welded specimens, the test results data on stress and

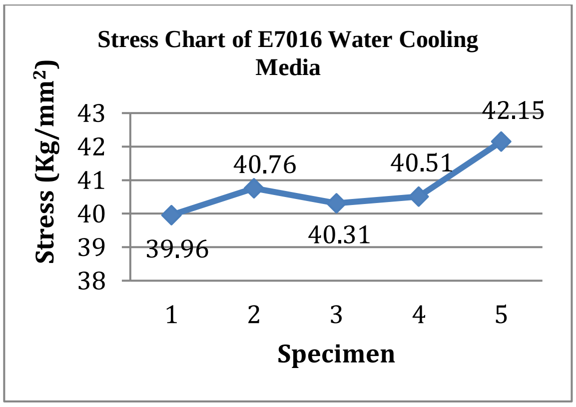

Fig. 10. Stress of E7016 welding specimen testing water cooling media

From figure 10 graphs of the tensile test results on the ST 37 material using the E7016 electrode with water cooling media show that the tensile stress value in the first specimen has a lower tensile stress value of 39.96 Kg/mm2; this is due to less heat received compared to the fifth specimen which has a higher tensile stress of 42.15 Kg/mm^2. In the second, third and fourth specimens, the stress values are almost uniform because the heat received by the three specimens is the same, so the five tensile test specimens, which were welded with E7016 electrodes using water cooling media, obtained an average tensile stress value of 40.74 Kg/mm^2.

Calculation of Welding Specimens Using E7016 Electrodes With Oil Cooling Media

For welding ST 37 materials using E7016 electrodes with Oil cooling media, the results of the tensile test can be seen in the following figure 11.

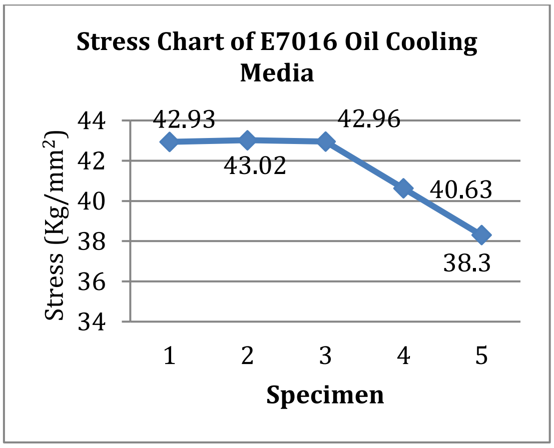

Fig. 11. Graph of E7016 welding specimen testing stress with oil cooling media

Contour graph of Figure 11. The tensile test results on the ST 37 material using the E7016 electrode with oil cooling media show that the tensile stress values in the first, second and third specimens have almost the same tensile stress values. This is due to the movement or swing of the welding handle with the electrode when the welding process is stable so that the width of the welding groove is the same. At the same time, in the fourth and fifth specimens, there is a voltage drop, this is due to the electrode movement being too fast, and penetration occurs during welding so that the voltage value of both specimens decreased. So that the five tensile test specimens that were welded with E7016 electrodes in oil cooling media obtained an average tensile stress value of 41.58 Kg/mm^2.

Calculation of Welding Specimens Using E7018 Electrodes With Water Cooling Media

From the tests that have been carried out on the five welding specimens using the E7018 electrode with water-cooling media, the test results can be seen In the following figure 12.

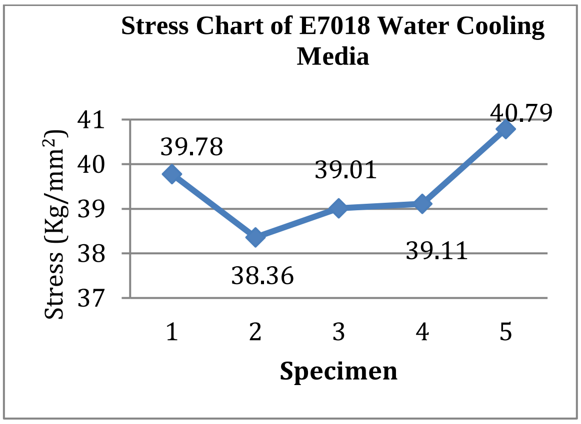

Fig. 12. Graph of Welding Specimen Testing Stress E7018 Water Cooling Media.

In Figure 12, the contour of the tensile stress graph of the test results on the ST37 material welding specimen using the E7018 electrode as a water-cooling medium shows that the tensile stress value on the fifth specimen experienced a higher tensile stress of 40.79 Kg/mm2. The second specimen had a lower tensile stress of 38.36 Kg/mm2. So that the five tensile test specimens that were welded with E7018 electrodes as a water-cooling medium obtained an average tensile stress value of 39.41 Kg/mm^2.

Calculation of Welding Specimens Using E7018 Electrodes With Oil Cooling Media

For the results of the tensile testing of welding specimens using the E7018 electrode, the test results data on stress and strain can be seen in the following figure 13:

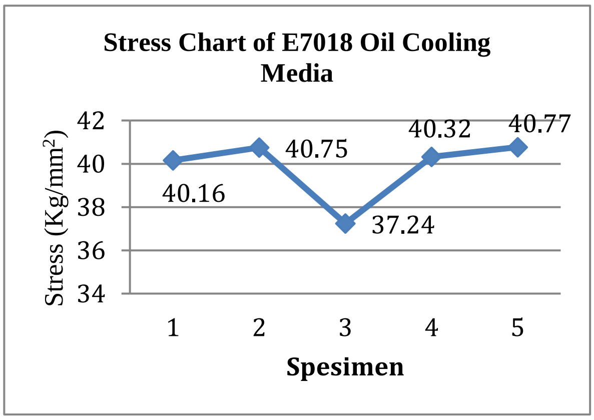

Figure 13. Graph of Testing Voltage for E7018 electrode welding specimens using Oil Cooling Media

In Figure 13, you can see the contour of the tensile stress graph using the E7018 electrode as an oil cooler, showing that the tensile stress value in the fifth specimen experienced a higher tensile stress, which was 40.77 Kg/mm^2. The third specimen has a lower tensile stress of 37.24 Kg/mm^2. So that the five tensile test specimens that were welded with E7018 electrodes in oil cooling media obtained an average tensile stress value of 39.85 Kg/mm^2; this value indicates that the results of the ST37 material welds using oil cooling media, the tensile test results show flexibility in the specimen. The test results show this is because, in general, oil has a slower cooling rate compared to water, or because of this, this cooling medium can provide quenching results with smaller distortion and cracks. This material is suitable for enhancing or adjusting its properties by heat treatment.

4. Conclusion

From the welding research and inspection of weld defects on the ST 37 material that has been carried out, it can be concluded that from the results of inspecting weld defects through non-destructive NDT (Non-Destructive Tests) testing using the Magnetic Particle Test and Dye Penetrant Test methods, from the inspection results by the welding inspection team from PT. The Superintending Company of Indonesia (SUCOFINDO) of the 15 ST 37 specimens which had undergone welding did not show any weld defects, in the sense that they were still within the acceptable limiting criteria (Standard Ansi B 31.3). The results of the tensile test from the ST 37 welding specimen using direct cooling media in the form of Oil and water showed that the welding specimen using Oil as a cooling medium had better results than the ST 37 specimen, which used water as a cooling medium, both in terms of tensile strength, strain and percentage elongation. The use of different electrodes in the ST 37 material welding process shows that the ST 37 material, whose welding process uses electro E7016, results in better welds and tensile strength compared to ST 37 material which in the welding process uses E 7018 electrodes with the cooling process using Oil and water.

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