International Research Journal of Advanced Engineering and Science
ISSN (Online): 2455-9024

# Characteristics of Welding Joint Using SMAW Weld Method and Result DT-NDT on Low Carbon Steel Materials

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***Abstract*— *This research is a study in the field of welding using SMAW welding method on st36 low steel carbon material with variations in electric current and electrode, and tested the welding joint with the method of DT and NDT. The results of the test are analyzed and discussed to produce conclusions, suggestions and research externals aimed at the development of standardized and effective research on patterns or methods of testing in welding connections, it has an impact on further welding research, more specifically in the field of railway manufacturing or other manufacturing. And from the outside it is published to plant insights and information on the field of welding. The methods that will be used in achieving these goals are experimental research in CAD labs and bench work and welding workshops. Specimens are welded by 6G-certified welders. And there are variations on electrodes and DC electric currents. The results of welding (coupon / specimen) in the test in the ged material testing lab. C PNM and in other supporting labs off campus. The Level of Technological Readiness (TKT) to be achieved in this study TKT 4, TKT 4 was achieved with consideration of the context of research on a laboratory scale supported by references to previous research and external designs produced by this study. This study produced data on the characteristics of st36 low carbon materials with the SMAW vertical 3G welding method of the bevel X model.*

***Keywords*— *SMAW, 3G, Electrode, ST36, X bevel, NDT, DT.*

## I. INTRODUCTION

Industry in Indonesia is one of the important components, because with the development of industry, it allows the Indonesian economy to grow rapidly and better, thus bringing changes in the structure of the national economy. The demand to change the economy of the industrial sector makes many industries that also create alternatives to create products that are more efficient than existing ones.

Welding is a metallurgical bond to an alloy metal joint that is carried out in a lumer or liquid state according to *DIN (Deutch Industrie Normen).* From the above statement bias in conclusion that welding is a connection between two objects using heat energy. Factors that affect welding is a welding procedure that is a planning for the implementation of research that includes how to make welding construction according to the plan and specifications by determining all the things needed in the implementation. Welding production factors are manufacturing schedule, manufacturing process, tools and materials required, order of implementation, welding preparation (includes: selection of welding machines, welder designation, electrode selection, use of potent types)

Tensile testing is one of the most widely performed material tests in the industrialized world. Because this test is fairly the easiest and a lot of biased data is taken from this test. Among them that can be obtained from this tensile testing are *Tensile Strength,* Mulur Strength (Yield *Strength or Yield Point), Elongation (Elongation),* Elasticity and Reduction of Cross-sectional Area(*Reduction of Area*). Along with the development of technology, at this time the pull test machine is equipped with electronic devices to facilitate in analyzing the data obtained.

The strong tuning of the welding current will affect the weld results. If the current used is too low will cause difficulty ignition of electric arc, the electric arc that occurs is unstable. The heat that occurs is not enough to melt the electrodes and base materials so that the result is a small and uneven weld rigi and the penetration is not deep. Conversely, if the welding current is too high then the electrode will melt too fast and will produce a wide weld surface and deep penetration resulting in low tensile strength and adding to the fragility of the welding results. The strength of the weld result is affected by arc voltage, current magnitude, welding speed. The determination of the large current in the splicing of metal with arc welding affects the efficiency of the work and weld material.

Welding procedure, it seems very simple but in its implementation many problems that must be overcome where the solution requires a variety of knowledge. In detail it can be said that in the construction planning of a frame or welding connection machine, useful and safe, then every type of welding work begins by compiling these procedures commonly called WPS *(welding procedure specification).* In the specification of welding procedures are loaded things such as welding process and welding type, connection design, basic materials, filler metals, welding positions, protective gases, electrically characteristic welding, and welding currents.

## II. METHODOLOGY

### *1. Flowchart Design*

Research methods are carried out gradually. These stages include literature studies, specimen making, welding processes and testing schemes, discussion and conclusions. Seen in the



Indarto Yuwono, Alfi Tranggono Agus Salim, Rahayu Mekar Bisono, Diaz Pratama, Nurudin, Radiffa Aditama, and Rafli Maulana, "Characteristics of Welding Joint Using SMAW Weld Method and Result DT-NDT on Low Carbon Steel Materials," *International Research Journal of Advanced Engineering and Science*, Volume 6, Issue 4, pp. 92-98, 2021.

figure of the research flow diagram in figure 1.

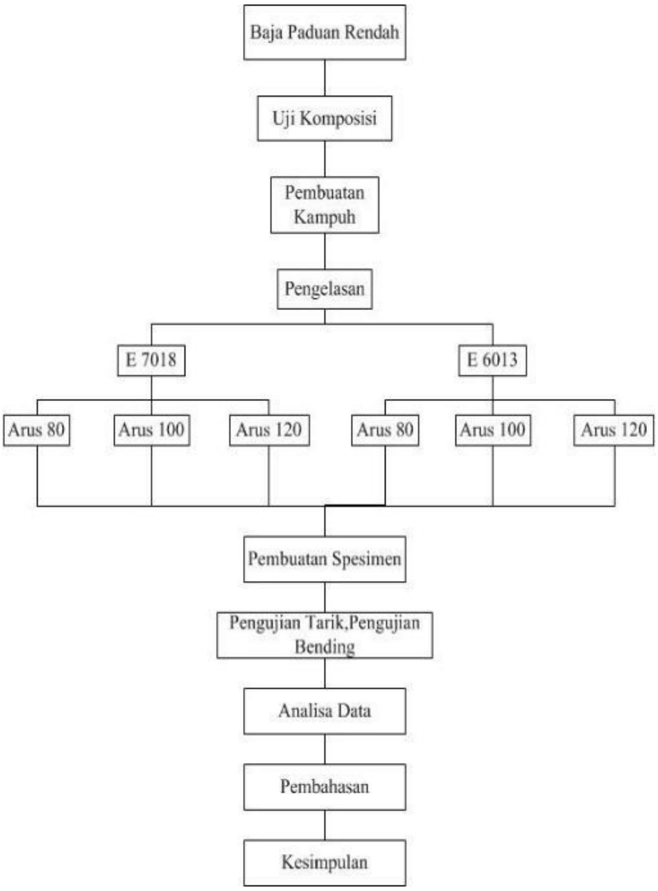


Fig. 1. Flowchart Methodology

2. *SMAW*

Is welding by using an electric flame arc as a source of metal scatter heat. SMAW welding is one type of electric arc welding where this welding process is heating and diluting workpieces and filler metals or electrodes by electric arcs that exist between the parent metal.

a. *Electrode E6013*

It is an electrode made of high titanium oxide flux with an iron powder content of 30%. Using these electrodes the potential for spatter is low and can be used for AC and DC current sources that produce moderate mechanical properties. These electrodes are usually used for welding filet (fillet joint) with a horizontal or vertical position.

b. *Electrode E7018*

This type of hydrogen iron powder flux produces a connection with low hydrogen content so that the sensitivity of the connection to cracks is very low, its toughness is very satisfying. Furthermore, it is revealed that the electrode consists of two parts, namely the webbed (flux) and non-webbed part that is the base for clamping welding pliers. The function of flux is to protect the molten metal from the air environment, produce a protective gas, stabilize the arc.

c. *Destructive Test*

*Destructive test* is a test that is done on a material or specimen until the material is damaged. This test is done to find out the performance of the material in question, one of which is if the material is subjected to work from the outside with a large different style. This test is usually much easier to do.

d. *Tensile Test*

A tensile test is the administration of force or tensile tension to a material with the intention of knowing or detecting the force of a material. The tensile voltage used is the external actual voltage or extension of the test object axis. The tensile test is carried out by means of test withdrawal with a continuous tensile force, so that the material (display) is continuously increased and regular until it breaks, with the aim of determining the tensile value. To find out the tensile strength of a material in the loading of pull can be seen pada line of force that must be squeezed with the axis line of the material so that the loading occurs a straight tensile load. But if the angular pull force is clustered then what happens is a supple style.

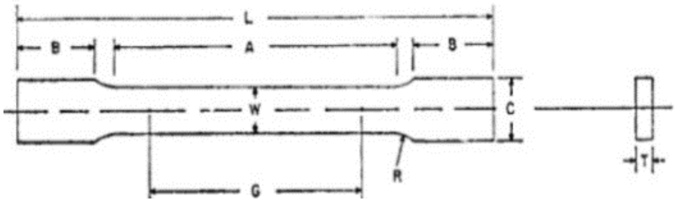


Fig. 2. Size of Pull Test Specimen

The withdrawal of force to the load will result in a change in the shape (deformation) of the material. The process of deformation in the test material is the process of shifting the grains of metal crystals that result in the weakening of the electromagnetic force of each metal atom until the bond is detached by maximum force withdrawal. In the load tensile test is given continuously and slowly increases in, along with that observations are made about the extension experienced by the test object.

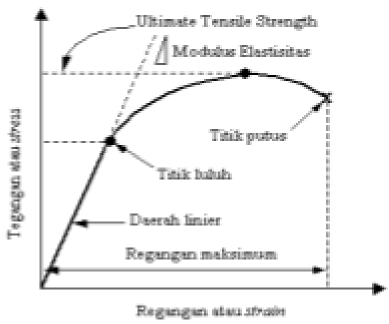


Fig. 3. Pull Test Graphic

A sample of pull test results can show multiple displays of the match according to the level of tenacity.

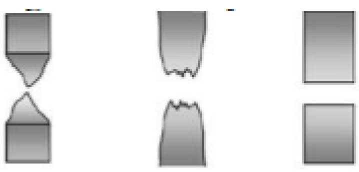

Fig. 4. Pull Test Fault

Tenacious multiplicity gives a stringy (fibrous) and dark (dull) character, while bittersweet multiplicity is characterized by a granular and bright fault surface. Tenacious speeding is generally preferred because tenacious materials are generally tougher and give advance warning before damage occurs, this also occurs in weld joints.

Fig. 5. UTM

*e. Macro Test*

It is a test to see the shape of macro material in the welding area, namely Base metal, Heat Affected Zone, and weld so that the shape of the weld can be seen then the surface must be smooth by machining, grinding, and polishing then in the weld area in etcha with chemical fluids including Acid nitrid, Acid HCl and water, so that the shape of the weld between weld metal, HAZ, and base metal are clearly visible. From the results of this macro test can be known visual quality of welds and the shape of welds. The macro test can be known as follows:

1. Perfect weld filling, no visible slag.
2. Penetration of welding is perfect.
3. Undercut doesn't exist.
4. Weld cracks don't exist.
5. Gas trapped is not there.

*f. Non Destructive Test*

It is a material testing technique without damaging the object being tested. This test is done to keep the material being used is still safe to use and not damaged. Based on damage or defects in the material, NDT can distinguish into 2 types, namely surface crack and inside crack. Preferably, when testing takes place must have determined the target of error testing such as inside crack or surface crack, after it is determined that the NDT test has only begun.

*g. Visual Test*

It is a test that is done on the results of the weld by looking at and observing the results of the weld in plain sight, so it is only seen the outside of the product. This test has a weakness, namely the limitation of vision from the inspector, so that if there is a defect in the results of the weld is not too visible. In the visual test there are several important things including the following:

1. Surface defects in addition to being checked with powder and colored penetrating substances are also examined with amatan.
2. Welding treatment such as sling cleaning, splash cleaning and other treatments should be ascertained by amatan testing.
3. Weld looks are usually shown on weld beads. Unattractive appearances also give doubts to the quality of welds.

*h. Penetrant Test*

This penetrant test can be used to determine fine discontinuities on surfaces such as cracks, holes or leaks. In principle, the testing method with liquid penetrant utilizes capillary power. Liquid penetrant with a certain color (red) seeps into discontinuity, then liquid penetrant is removed from the discontinuity by using developer fluids whose color contrasts with liquid penetrant (white). The detection of discontinuity is by the onset of red patches (liquid penetrant) that come out from within the discontinuity of discontinuity that can be detected with this test is discontinuity that is open to the principle of capillary. Discontinuity detection in this way is not limited to the size, shape of discontinuity direction, structure of the material or its composition. Liquid penetrants can seep into a very small discontinuity gap. Penetrant testing cannot detect the depth of discontinuity. This process is widely used to investigate surface cracks, porous (porosity), layers of material, etc.

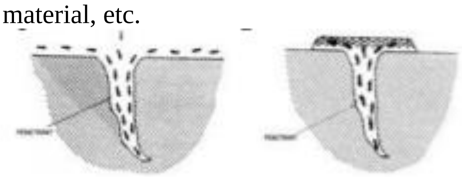

Fig. 6. Capillary Liquid

*i. Tools and Materials*

The materials used are st36 low carbon steel plates and the electrodes used are E6013 and E7018 with a diameter of 2.6. Tools used by SMAW electric welding machine, hand grinder, cyclic or funnel term, tensile test, visual test, macrotest test, penetrant test.

## III. RESULT

The testing phase was conducted on "SMAW Welding Connection Characteristics with X Bevel on Low Carbon Steel Materials NDT and DT Methods". With this test, we can obtain data that can be analyzed to find out the strength of welding materials.

### *A. Visual Test*

The first test is visual testing that is done to detect the presence of defects in the material in areas that are affordable to the normal eye without the use of aids.

### *B. Penetrant Test*

This penetrant test is used to determine the presence of crack defects and holes on the surface of welding results. This penetrant testing method uses capillary pinsip, where this capillarity will later show the location of discontinuity that occurs.

The surface to be tested and the surrounding area that has previously been done cleaning dirt using a steel brush should be cleaned using a cleaning solvent / cleaner.

The next step is the application of developers. Before the application of the developer, the developer can must be shaken first, then, the developer must be sprayed until a thin layer is formed that is flat.

Fig. 7. Penetrant Specimen test

Then the next step is to spray the Cleaner from the remains of the penetrant that is on the surface of the test object by wiping the surface of the material with a dry and clean ramp / wipe until all the remaining penetrant is lost.

Fig. 8. Specimens

Then the last one observes the presence of welding defects or not on the welding surface that has been done penetrant test.

### C. *Tensile Test*

Tensile test can be done if the criteria of the previous penetrant test have been met.

1. Cut the welding specimen in accordance with standard ASME Section IX 2019 QW-462.1(a)

Fig. 9. Tensile Test Specimen Profile

2. Then perform tensile test using MTS Exceed E64 machine

Fig. 10. Multitester Test Tool

3. After conducting the test, the results obtained that the results of the tensile test from welding using the above method can be concluded for the Tens test fault is on Base Metal.

Fig. 11. Pull Test Results

### D. *Tensile Test Strain Calculation Results*

| No | Elektroda | Sebelum (mm) | Sesudah (mm) | Perpanjangan (mm) | Regangan (%) |
|---|---|---|---|---|---|
| 1 | E7018 3,2 | 9.02 | 10.81 | 1.79 | 0.1984 |
| 2 | E7016 2,6 | 8 | 9.65 | 1.65 | 0.2063 |
| 3 | E6013 2,6 | 8.1 | 9.85 | 1.75 | 0.2160 |
| 4 | E6013 80A | 8.1 | 9.55 | 1.45 | 0.1790 |
| 5 | E6013 90A | 8.1 | 9.42 | 1.32 | 0.1630 |
| 6 | E6013 100A | 8 | 9.71 | 1.71 | 0.2138 |

Fig. 12. Pull Test Calculation Results

### E. *Tensile Test Results Data*

For tensile test results obtained 6 different variations, namely:

1. E 6013 2.6-80A

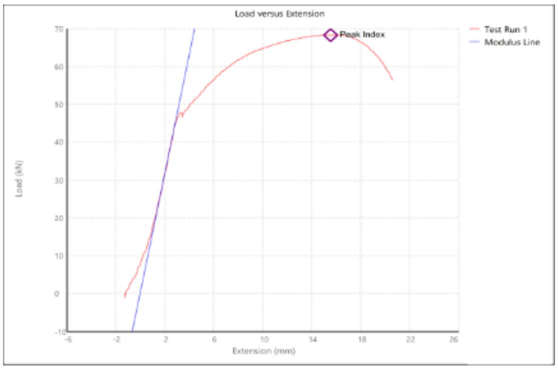


Fig. 13. Draw Test Results Graph

Peak Load results are obtained based on the curve above 68,278 kN using electrodes E6013 diameter 2.6 variation current 80A.

2. E 6013 2.6-90A

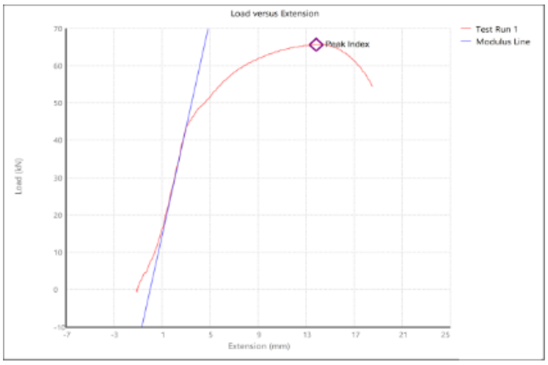


Fig. 14. Tensile Test Results Graph

International Research Journal of Advanced Engineering and Science
ISSN (Online): 2455-9024

Peak Load results are obtained based on the curve above 65,601 kN using electrodes E6013 diameter 2.6 variation current 90A.

1. E 6013 2.6-100A

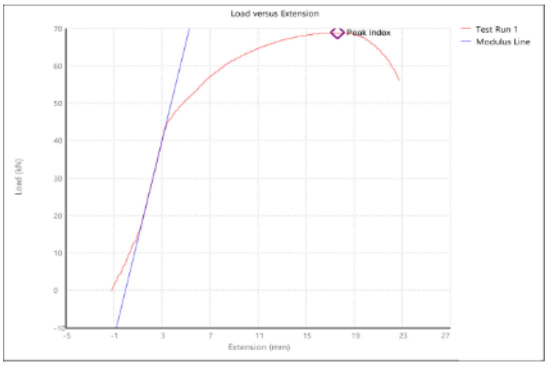


Fig. 15. Draw Test Results Graph

Peak Load results are obtained based on the curve above 68,765 kN using electrode E6013 diameter 2.6 variation current 100A.

2. E 6013 2.6

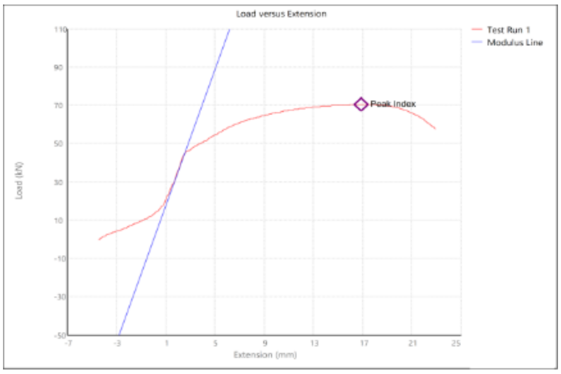


Fig. 16. Draw Test Results Graph

Peak Load results obtained based on the curve above 70,324 kN using electrode E6013 diameter 2.6

3. E 7016 2.6

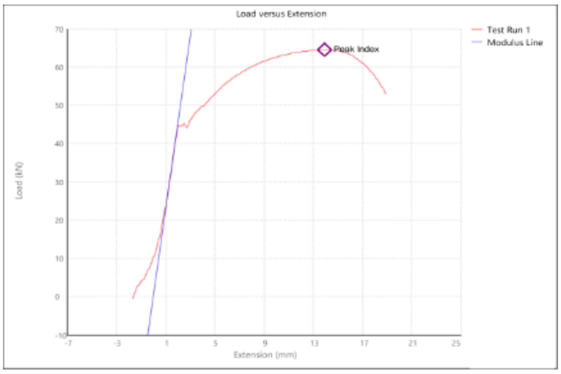


Fig. 17. Draw Test Results Graph

Peak Load results are obtained based on the curve above 64,451 kN using E7016 electrode diameter of 2.6.

4. E 7018 3.2

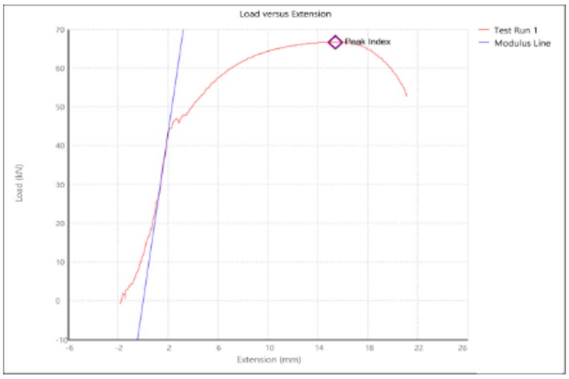


Fig. 18. Draw Test Results Graph

Peak Load results are obtained based on the curve above 66,653 kN using E7018 electrode diameter of 3.2.

*Peak Load Comparison*

Peak load comparison here uses several variations of different electrodes and currents, namely:

| Spesifikasi Elektroda | E 6013 (2,6) 80 A | E 6013 (2,6) 90 A | E 6013 (2,6) 100 A | E 6013 (2,6) | E 7016 (2,6) | E 7018 (3,2) |
|---|---|---|---|---|---|---|
| Peak Load | 68.278 | 65.601 | 68.765 | 70.324 | 64.451 | 66.653 |

From the data above, the graph is obtained in the form of:

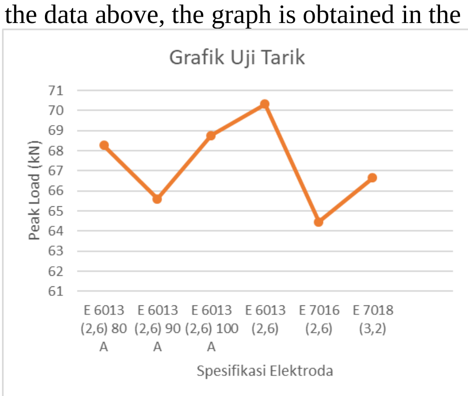


Fig. 19. Pull Test Comparison Graph

F. Macrotest

In macro testing, sampling is done by taking 6 specimens that are done on the surface or root surface. There are two parts to the material after etching and macrotest, namely:

1. A is the weld zone area.
2. B is the base material.

Where the results can be seen in the picture below:

3. E 6013 80A Root

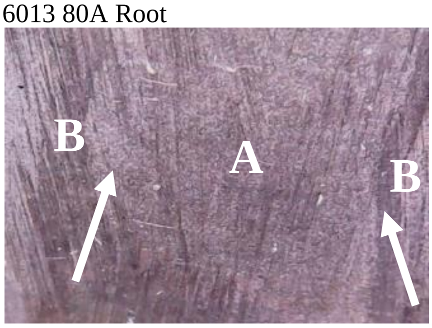


Fig. 20. Macrotest results

1. E 6013 90A Sureface

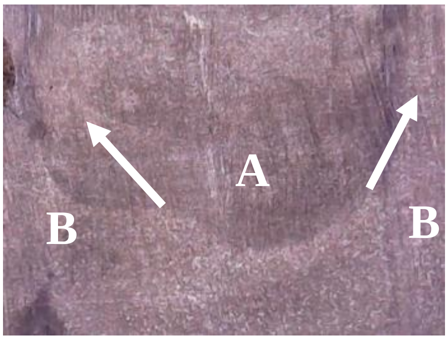


Fig. 21. Macrotest results

2. E 6013 100A Face

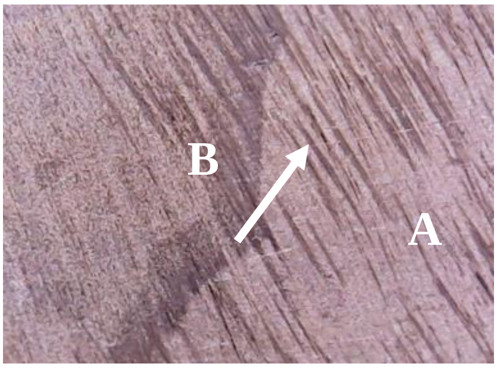


Fig. 22. Macrotest results

3. E 6013 Root

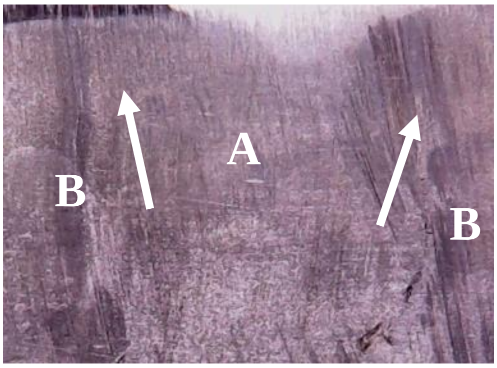


Fig. 23. Macrotest results

4. E 7016 Root

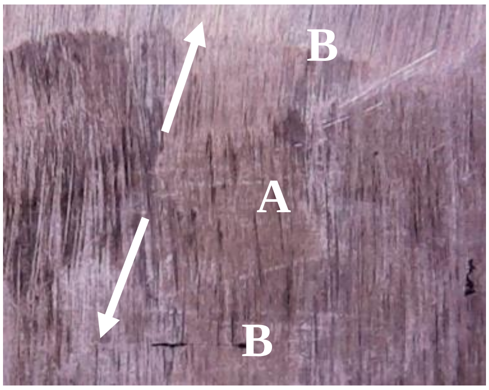


Fig. 24. Macrotest results

5. E 7018 Face

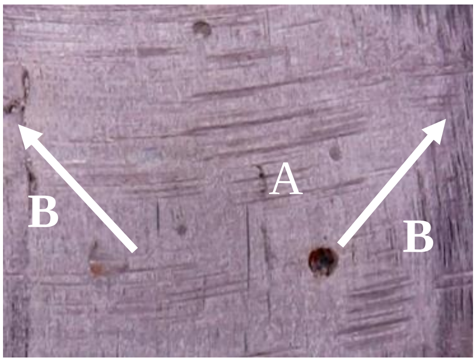


Fig. 25. Macrotest results

## IV. CONCLUSION

From the tests that have been done using some of the above parameters, it can be concluded that the results obtained include:

1. When doing the activity of welding current variations that exceed the specifications of the electrode can result in the occurrence of *undercut*, *splatter*.
2. Large variations in currents can cause high heat absorption and impact distortion.
3. Root *splicing* that uses high currents results in a beasr hole.
4. Visual testing requires great accuracy, patience, and high experience.
5. Different current variations have an impact on visual welding results and *ultimate strength values.*
6. The results of macrotest tests showed there was a defect that the porosity in the welding joint.
7. The results of the tensile strength test showed a stronger tensile and lower mulur load with current variations of 80A=68.287kN, 90A=65,601kN, 100A=68.765kN.

## ACKNOWLEDGMENT

The authors would like to thank “Politeknik Negeri Madiun” in Indonesia (DIPA 2021), for the financial support in this study.

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