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Analysis of Weld Current and Weld Time Resistance of Seam on Mechanical Properties of SUS 304 Material on Train Roof 612

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Abstract— *In the process of fabricating the roof of the 612 train at PT INKA (Persero), the improper use of welding current and time parameters in the resistance seam welding (RSEW) method results in less than optimal welding joints and welding results that do not fuse (fusion). This study aims to analyze the effect of variation in welding seam current and time on 1 mm thick stainless steel 304 (SUS 304) material on mechanical properties, nugget diameter, microstructure, and shear stress. The research method used involved current variations of 11 kA, 13 kA, 15 kA, 17 kA, and 19 kA with welding speeds of 650 mm/min, as well as welding time variations of 50 ms, 60 ms, 70 ms, 80 ms, and 90 ms with currents of 14 kA. The results showed that at currents of 11 kA and 13 kA and at 50 ms and 60 ms, the nuggets were not identified. The smallest nugget diameter is produced at a current of 15 kA of 3.7 mm and a time of 70 ms of 4.65 mm, while the largest diameter of the nugget is produced at a current of 19 kA of 7.69 mm and a time of 90 ms of 6.41 mm. The microstructure of the nuggets formed is made up of austenite and ferrite. The lowest shear voltage occurred at a current of 11 kA of 164.33 MPa and a time of 50 ms of 238.67 MPa, while the highest was achieved at a current of 17 kA of 275.67 MPa and a time of 90 ms of 273.33 MPa. The conclusion of this study is that variations in welding current and time affect the size of the nugget diameter, microstructure, as well as shear stress which increases with increasing welding current and time, but too high a current can weaken the strength of the material.*

Keywords— *Welding Current, Welding Time, Welding Seam Resistance, Mechanical Properties, SUS 304.*

I. INTRODUCTION

The development of the transportation industry is important in economic development in developed and developing countries. Transportation is an infrastructure that supports accessibility, especially in the railway industry [1]. In the midst of technological developments in the railway manufacturing industry, the quality and feasibility of railway production are highly concerned because they concern the success of the products produced [2]. The railway manufacturing industry is required to pay attention to the implementation of its production process [3].

PT INKA (Persero) is involved in the production stage of the New Generation 612 Stainless Steel train. The production of the 612 train body consists of a roof, mascara, sidewalls, end walls, front section, lower frame, and bollards [4]. The roof of the train is an external structural part that has an important role in maintaining the comfort and safety of passengers and protecting the inside of the train. The production process of railway roofs requires a welding process that is suitable for the characteristics of long and thin materials.

The most common type of attachment on a rail roof is a welded seam weld (RSEW). Resistance seam welding is the process of welding electrical resistance using a rotating wheel-shaped electrode and resulting in a series of overlapping point welds along the workpiece joint [5]. This process is used for fast, accurate, and very useful long welding in the production process [6].

Based on field observations at PT INKA, it was found that the problem in weld seam welding with SUS 304 material is that the weld is detached because fusion is not formed. This is affected by the parameters of the welding seam that are not suitable during the welding process. SUS 304 welding using resistance seam welding has welding parameters that are considered to produce optimal welding. The welding seam current parameter has the greatest influence on the strength and quality of the weld, as the amount of heat (heat input) generated is directly proportional to the welding current [7].

This study aims to identify the variation of welding current and seam welding resistance, as well as its effect on the mechanical properties of SUS 304 material. The research was carried out by paying attention to the use of welding parameters, namely current and time as a reference and suggestion of the optimal welding current and time used in the welding process of weld resistance seams at PT INKA (Persero)

The results of this study are research data including shear strength values (MPa), macro structure (nugget diameter), and microstructure (type and percentage of grains (%)) to show the appropriate welding seam parameters for SUS 304 material with a thickness of 1 mm according to the research object, namely the roof of the 612 Railway at PT INKA (Persero).

II. METHOD

This study uses an experimental quantitative method of Resistance Seam Welding (RSEW) with SUS 304 material 1 mm thick. This study used welding current variations of 11 kA,

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13 kA, 15 kA, 17 kA, and 19 kA, while the welding time variations were 50 ms, 60 ms, 70 ms, 80 ms, and 90 ms, with a constant welding speed of 650 mm/min. The results of this study used a quantitative approach related to the influence of welding current and stitch time variations on nugget diameter, microstructure, and shear stress resulting from each variation.

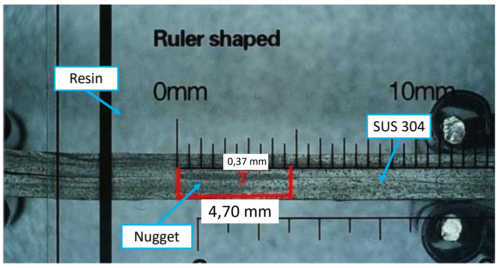

Picture 1. Seam Welding

The seam welding process seen in Figure 1 is carried out using two electrodes in the form of wheels that are electrically connected by squeezing material at the lap joint, so that it experiences welding with continuous results. Welded specimens are visually and penetrally tested to detect welding defects prior to testing. Cut the material according to the specified cutting plan using a gap shearing machine and proceed with the formation of the specimen for testing using ASME BPVC Part IX and ASTM E3 standards.

The coupon test is carried out by smoothing the surface of the specimen on a grid of 80 to 5000. Followed by polishing to produce a shiny surface of the test piece using a polishing cloth with the help of an autosole. The etching process is necessary to highlight the welding area more clearly by using aqua regia liquid. Specimens that have been ready to be tested by the Material Testing Laboratory Campus 2 of the Madiun State Polytechnic which aims to analyze the influence of variations in weld seam parameters. The tests carried out are macro inspection, micro inspection, and tensile test.

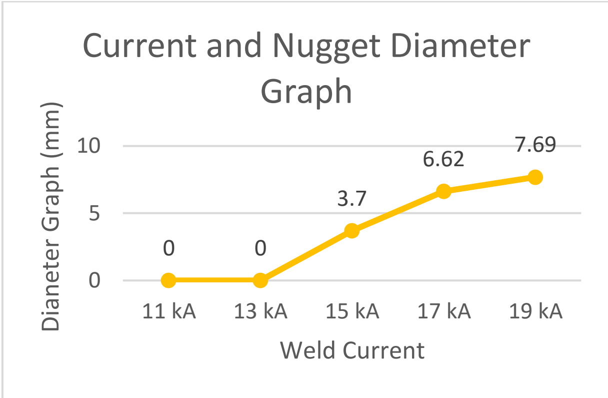
III. RESULTS AND DISCUSSION

The macro examination uses the ASME BPVC Part IX standard with 10x magnification to measure the diameter of the nuggets formed at each variation. Nugget diameter measurements as shown in Figure 2.



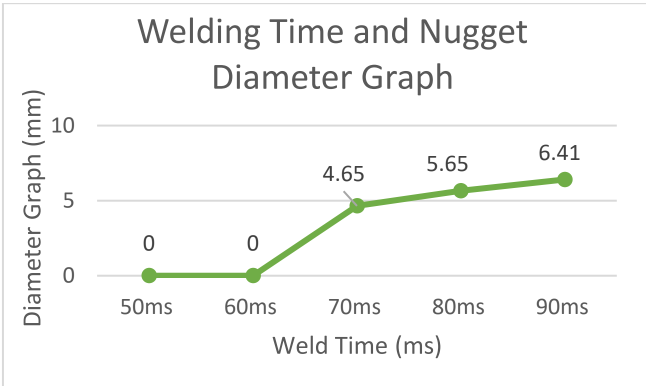
Picture 2. Macro Examination

The influence of current parameters and welding time on the weld seam affects the width of the nugget diameter [6]. It was concluded that the higher the current variation, the higher the diameter of the nugget produced (Syahputra, 2020).



Picture 3. Graph of the Relationship of Current Variation to Nugget Diameter

Based on Figure 3, the result data shows the correlation between the current variation and the nugget diameter of the seam welding process. At currents of 11 kA and 13 kA, no nuggets were identified. This is because the heat input provided is not enough to melt the connected metal. The test with the smallest nugget diameter was generated at a current of 15 kA with a nugget diameter of 3.70 mm and the largest nugget diameter was produced at a current of 19 kA with a nugget diameter of 7.69 mm.



Picture 4. Graph of the Relationship of Time Variation to Nugget Diameter

A graph of the relationship between the welding time variation and the nugget diameter is seen in Figure 4 of the welding time variation and the nugget diameter. In the 50 ms and 60 ms welding time variations, no nuggets were identified so no size was produced. The smallest nugget diameter was produced at a variation of 70 ms with an average of 4.56 mm and the largest nugget diameter was produced at a variation of 90 ms with an average of 6.41. From these results, it can be concluded that the higher the variation in welding time used, the larger the diameter of the nugget produced [8]. The graph of the relationship between the diameter of the nugget with the variation of current and setting time increases with higher parameters [9]. The strong welding electric current has an effect on how quickly heat is conducted. The higher the current and welding time, the greater the heat generated. The value of transmitted heat (heat input) is getting higher so that it has a big impact on the formation of nuggets.

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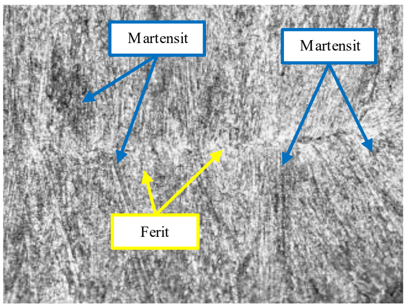
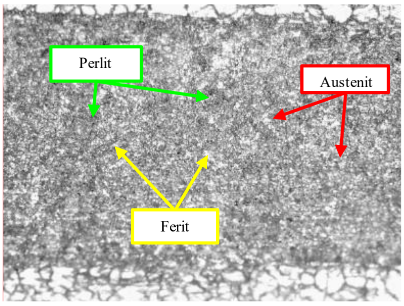
Micro examination is carried out to determine the microstructure formed on the SUS 304 material after the welding process. Based on the results of micro examination at a current of 19 kA, it can be seen in Figure 5.



Picture 5. Micro Examination 19 kA

Observation of the formed SUS 304 microstructure was carried out using the Olympus BX53M Series Microscope with 200x magnification. The structures formed in the nugget region of SUS 304 material are mostly composed of martensitic grains with a small amount of ferrite. The martensitic structure in austenitic microstructures is due to the greater the current, the higher the heat input, causing the austenitic microstructure to turn into martensitic [9].

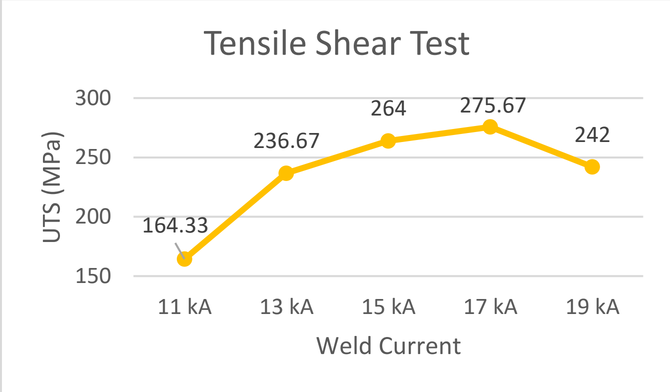


Picture 6. Micro Examination 90 ms

Based on the results of micro examination on the variation in welding time of 90 ms at the observation point, it can be seen in Figure 6: In the nugget area, the structure of ferrite and perlite is formed with a magnification of 200x. Applied time and distribution of austenite-ferrite composition in the specimen. The changes in the microstructure formed are affected by high temperatures [10].

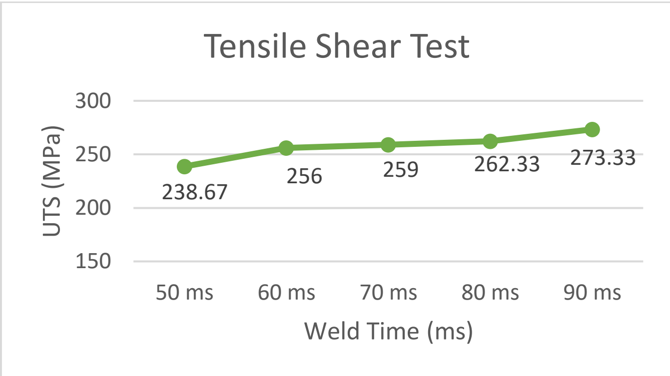
Tensile shear test is a method of testing the value of shear stress on seam welding by pulling a force on a specimen perpendicular to the opposite direction [8]. In this study, testing is carried out using ASME BPVC Part IX standards. The tensile shear test yields the highest tensile strength (MPa). After the testing process, the specimen is damaged or broken as a result of the test due to the maximum tensile force. From the tensile shear test, the Highest Tensile Strength (MPa) at each current variation is seen in Figure 7.

The welding current has a significant influence on the load applied during the testing process [9]. Excessive welding current results in welds that have low strength and unwanted distortion [7]. The high current level causes the metal to melt during the welding process, which leads to the formation of holes and increases the potential for cracking [11]. This is related to microstructures at 19 kA currents, 19 kA structures are dominated by martensitic structures because the given current level is high, causing the material to become brittle [12].



Picture 7. Graph of the Relationship of Current Variation to Shear Voltage

Figure 8 shows the results of the tensile shear test on the variation of welding time which has a significant influence on the load applied during the test process [6].



Picture 8. Graph of the Relationship of Time Variation with Shear Voltage

Based on the test results, the lowest shear stress is with a welding time variation of 50 ms equivalent to 238.67 MPa and the highest shear stress is with a welding time variation of 90 ms equivalent to 273.33 MPa. Welding time affects the resulting shear stress due to the increase in the final tensile strength of the shear test along with the increase in the variation in the welding time used. The increase in shear strength is due to the increase in the diameter of the resulting nugget as the welding time increases. Increased current and welding time increase UTS value [10].

It is concluded that current and welding time are the parameters that influence the results of welding. Increasing the flow and welding time increases the amount of shear stress, while additional flow decreases the amount of shear stress.

IV. Conclusion

In this study, the macro examination produces welding current and time that affect the size of the nugget diameter, the higher the variation in current and welding time, the larger the diameter of the nugget formed. This is due to the higher heat

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input directly proportional to the welding parameters. Based on the results of the macro examination, the recommended welding current for SUS 304 material with a welding time of 60 ms is 17 kA and a current of 14 kA is 90 ms with the characteristics of overlapping nuggets so that they are resistant to leakage, and produce the highest shear stress of any variation in welding current and time. An increase in current variation and welding time occurs, a decrease in austenite and an increase in ferrite that causes the material to become ductile. The high number of martential structures in the material causes the material to become brittle. This change is due to the increased heat input of the welding parameters.

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