Optimization of Welding Parameters for Resistance Spot Welding with Variations in the Roughness of the Surface of the AISI 304 Stainless Steel Connection Joint To to Increase Connection Joint Quality

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Optimization of Welding Parameters Resistance Spot Welding with Variations in The Roughness of the Surface of the AISI 304 Stainless Steel Connection To Increase Connection Quality

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Abstract— **Resistance spot welding is widely used in the automobile, ship, and food industries. The quality of the connection is vital because it concerns the durability and safety of the product. However, there are still many connections that have low quality. The quality of resistance spot welding joints is affected by several factors, namely: material preparation, welding time, welding current, electrode pressure given at the time of welding, and treatment after welding. This research was conducted to analyze how to improve the quality of resistance spot welding joints by varying the roughness of the joint surface before welding and current parameters during welding. Experiments have been conducted using stainless steel plate material 304 with a size of 175x25 mm. The material is done variations in roughness before welding by providing a variation of roughness using sandpaper with four types of roughness, namely 0.34, 0.33, 0.24, 0.20 micrometers. Welding parameters are performed using time variations of 5 seconds, 6 seconds, and 7 seconds, with currents of 5 kA, 6 kA, 7 kA, and electrode pressures of 30 psi, 40, and 50 psi. After the specimen is completed welding the shear tensile strength is analyzed with the tensile test machine and Gwyddion software is used to examine the macrostructure of the nugget joint of resistance spot welding. Finding shows that the smoother the weld surface joint, the more the shear tensile strength increased and the contour of the welding nuggets was lower. In addition, the parameters of the welding current, significantly affect the width of the welding nuggets. Based on these two phenomena, it is concluded that the subtlest roughness variation of the joint surface of the joint, raises the quality of the spot welding resistance joint.**

Index Terms— **Resistance spot welding, Welding time, Electrode pressure, Nugget, Surface roughness.**

I. Introduction

The quality of AISI 304 stainless steel joints is affected by resistance spot welding conditions. Resistance spot welding (RSW) parameters are processes that must be considered to ensure a connection between two quality components.[1]. In industry, for AISI 304, resistance spot welding is used. Materials made of stainless steel are commonly used[2]. The chemical, aeronautical, and naval industries [3], [4]. Unfortunately, on the welding joint, AISI 304 stainless steel is less strong. Sometimes, there are defects which reduce the quality of the weld joint [5].

Weld quality is the key to getting a good AISI 304 stainless steel joint. In general, the quality of welding joints is seen from several things, namely: nugget size [6], [7][8], material grain size [9], surface roughness [10][11], tensile shear strength [12], hardness value [13], and failure type [14]. The quality of the AISI 304 stainless steel joint can be mechanically improved with variations in surface roughness before welding. It can also be with the proper selection of currents. According to Kumar et al [1] there are a correlation between the tensile with nugget diameter. According to Luo et al [15] AISI 304 steel surface using photos found nanoparticles with an average of 20 µm on the surface that affected the improvement of the mechanical properties of the joint.

To improve the quality of spot welding resistance welding joints, it is necessary to do: preparation of the material before welding, treatment during welding, and treatment after welding, as has been done by some researchers, namely: surface fiber in welded friction[16], geometry [17], use of NaOH etching and oxalic acid before welding [18], sealing [19], resistance spot welding parameter with focus in electrode force [20][21], resistance spot welding with focus in parameter current [22], the holding time varies[23], and PWHT on the hydrogen [24]. However, research on the correlation of the relationship of material preparation with the selection of suitable currents to improve the quality of welded joints is still limited.

Therefore, The goal of this investigation is to see if there is a link between roughness variation treatment and preparation, with welding current selection for AISI 304 stainless steel material to improve the quality of the joint. This research is important because the preparation of materials with variations in roughness will make the adhesion between the two specimens better, thus having an impact on improving the quality of welded joints.

A. Research methods

This study was consisted of several stages, namely: material preparation, welding, and testing.

Material Preparation

The material used was AISI 304 stainless steel plate. The steel plate was tested for composition using the Oxford Instruments Composition testing machine. The material composition of AISI 304 consists of Oxford Instruments launches The Foundry Master Optimum is a high performance benchtop metals analyzer with a small footprint, with composition from AISI 304 stainless steel investigated was (C = 0.014, Si = 0.34, Mn = 1.62, Cr = 18.3, S = 0.005, P = 0.015, Ni = 10.4, Fe = 69.91) (wt%). Materials AISI 304 stainless steel plate, cut using a sample metallographic Sq-100 cutting machine, with a standard size of AWS D8.9-2002 of 105x45x1 mm as shown in Figure 1. When the metallographic cutting machine was working, it was ensured to use a cooling stream so that the cutting using the machine did not affect the properties of the material.

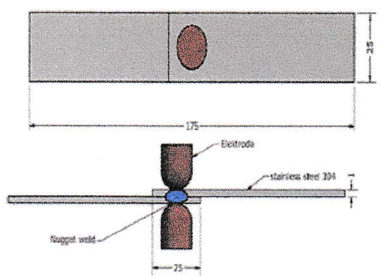


Figure 1 Schematic of test objects used in experiments

Treatment Before Welding

The treatment before welding was in the form of sanding on the surface side, which was connected using a modern sandpaper machine M2500-B by installing sandpaper and sanding time of each specimen for 3 minutes. Measurement of surface roughness used a roughest machine SJ 310 Mitutoyo. Meanwhile, the photo of the equipment was carried out as shown in Figure 2. The roughness of the connection surface used the following variations: (0.34, 0.33, 0.24, and 0.20) µm.

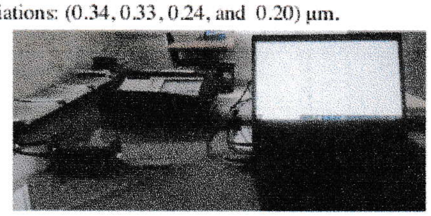


Figure 2. Roughness Test Process With Surftest Sj 310 Mitutoyo

B. Treatment During Welding

The welding process used a resistance spot welding machine with an electrode suppression system using pressurized air that could be adjusted pressure. The current setting system used analogue settings. The setting system welding time used the digital settings as exhibited in Figure 3

Figure 3. Resistance spot welding machine

As for the welding parameter optimization settings, based on the standard AWS C1.1-MC.1:2012, were: for specimens without roughness treatment or base metals with a roughness of 0.34 µm, electrode pressure of 30 Psi, welding current of 5 kA, and welding time of 5 seconds. For specimens with a surface roughness of 0.33 µm, the parameter settings were the same as for the base metal. For a surface roughness of 0.24 µm, the electrode pressure was 40 Psi, the welding current was 6 kA, and the welding time was 6 seconds. For a surface roughness of 0.20 µm, the electrode pressure was 50 psi, the welding current was 7 kA, and the welding time was 7 seconds. Each experiment consisted of 3 specimens. The average value of the three specimens was calculated so that the results were more precise, with a total of 36 specimens. Welding parameters with roughness conditions in detail could be seen in TABLE I.

TABLE I. Welding Parameters and Conditions

Experiment	Welding Parameters Proces			Surface Roughness
	Electrode Force (Psi)	Welding Current (kA)	Weld Time (S)	
1	30	5	5	0.34 µm
2	30	5	5	0.33 µm
3	40	6	6	0.24 µm
4	50	7	7	0.20µm

C. Connection Testing

The quality of the welded sample was tested using the tensile shear method [25] as shown in Figure 4.

Figure 4. Tensile Test Machine

Sample quality for electrode-subjected surface contours was tested using macro photos. The surface contours were then analyzed with gwyddion software[26].

II. RESULT AND DISCUSSION

Welding quality can be analyzed with tensile strength [27][25], macrostructure [28], and surface conditions [29] in the area under electrode pressure with gwyddion software.

A. Connection quality testing with tensile share test

The results of connection quality testing of 36 specimens with each data were taken on average from 3 specimens so that the data displayed was more precise specimens with shear tensile strength and contouring of the connection surface subjected to electrodes are as follows:

a. The relationship between roughness and maximum voltage point in welding parameter settings is as follows: electrode pressure 30 Psi, Current 5 kA, and Time 5 seconds, as exhibited in Figure 5

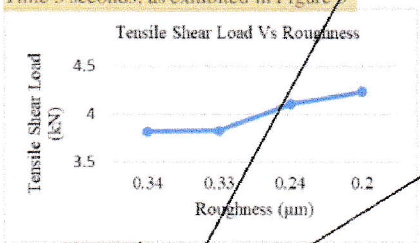


Figure 5 Welding parameters at 5 kA

Figure 5 shows that On the configuration of welding settings, the tensile strength of base metal with a surface roughness 0.34 μm is: electrode pressure 30 Psi, current 5 kA, and time 5 seconds. There is a directly proportional relationship in which the smoother the surface, the tensile strength increases. The highest tensile strength of 4.2 kN is at a roughness of 0.2 μm, meaning that the smoother the display, the higher shear tensile strength value. This is due to the smoother the connection surface, the better the electrical resistance [30], and the heat input to the welding area gets better, so that the welding connection has good quality.

b. The relationship between roughness and maximum voltage point in welding parameter settings are: electrode pressure 40 Psi, current 6 kA, and time 6 seconds as obtained in Figure 6

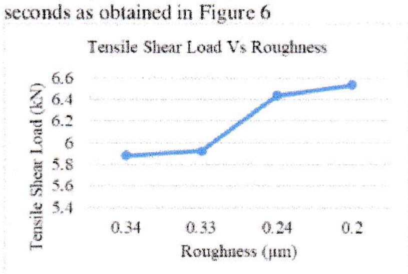


Figure 6. Current welding parameters 6 kA

Figure 6 shows the relationship of tensile strength with the surface roughness of 0.33 μm on the welding parameter sets, namely: electrode pressure of 40 Psi, current 6 kA, and time of 6 seconds. There is a directly proportional relationship where the smoother the surface, the more shear tensile strength increases. The highest tensile strength is 6.5 kN higher than the most optimal research results obtained by Manoj raut [30] as big as 3.8 kN. This is because, in Manoj's research, the look only focuses on optimizing parameters. while in this study, it is focused on optimizing parameters, and the preparation treatment prior to welding with varied surface roughness.

c. The relationship between roughness and maximum voltage point and welding parameter settings, namely: electrode pressure 50 Psi, Current 7 kA, and Time 7 seconds, is shown in Figure 7

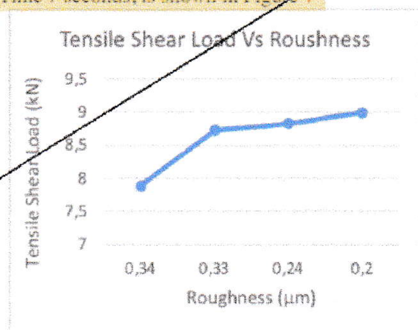


Figure 7. Welding parameters Current 7 kA

Figure 7 shows that there is a relationship between tensile strength with the surface roughness of Ra 0.24 μm at the setting of the electrode pressure welding parameter of 50 Psi, Current 7 kA, and time 7 seconds. Figure 3 also exhibits there is a directly proportional relationship, where the smoother the surface, the more the shear tensile strength increases. The highest tensile strength is 9 kN with the same parameter setting as reported by Tanmoy [21] the tensile strength result obtained is greater with a value of 2.4 kN higher than the tensile strength result encountered by Manoj raut [30] is 3.8 kN. It is due to in the research conducted by Tanmoy and Manoj raut only focused on optimizing parameters, while in this study, it is focused on optimizing parameters, and the treatment of preparations before welding with varied surface roughness.

It can be seen in the Figure 1, 2, and 3, the effect of roughness treatment is very influential on the tensile strength of welding shear where the smoother, the higher the value of the shear tensile strength.

B. Connection quality testing with macrostructures

Test results with macrostructures using macro lens photos, seen in TABLE II

TABLE II. PHOTO MACRO WITH VARIATIONS IN ROUGHNESS

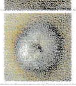
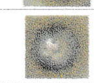
Level of Roughness (μm)	Current (kA)	Time (Second)	Pressure (Psi)	Photo
0.34	5	5	30	
	6	6	40	
	7	7	50	
0.33	5	5	30	
	6	6	40	
	7	7	50	
0.24	5	5	30	
	6	6	40	
	7	7	50	
0.20	5	5	30	
	6	6	40	
	7	7	50	

TABLE II shows the results of photographs using macro cameras, then analyzed using gwyddion software to measure the contours of the surface subjected to electrodes. Connection surface with a roughness of 0.20 µm, a current of 7kA, a time of 7 seconds, and an electrode pressure of 50 psi, it can be obtained that the surface subjected to the electrode gets smoother. It indicates that the smoother the surface of the connection, the contours of the surface subjected to the electrode are better. The details results is shown three dimensional contours, using gwyddion software (Figure 7).

C. Quality testing with gwyddion software analysis

Based on macro photos with high-resolution digital, then in the analysis using gwyddion software, part of the area affected by the electrode.

a. Figure 8 shows that the surface contours of the area subjected to electrode pressure, at roughness Ra 0.34 µm

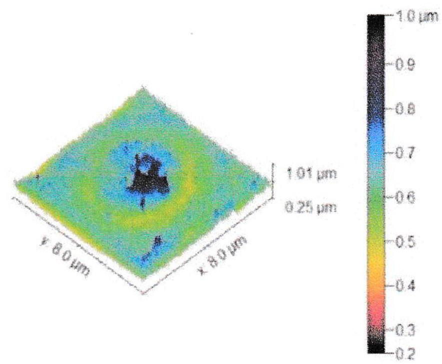


Figure 8. Surface contour Ra 0.34 µm of the area undergoing electrodes

Figure 8. can be seen that the surface contour of the area subjected to electrode pressure at the surface roughness treatment Ra 0.34 µm, electrode pressure 30 Psi, current 5 kA, and time 5 seconds. The surface of the roughest area is in the center subjected to electrode pressure with a roughness value of 1.01 µm. (Figure 8.)

b. Figure 9 shows that the surface contours of the area subjected to electrode pressure, at roughness Ra 0.33 µm

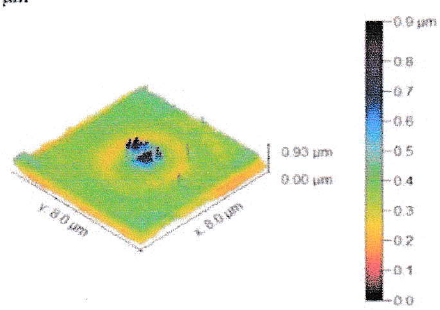


Figure 9. Surface contour Ra 0.33 µm of the area undergoing electrodes

Figure 9 indicates that the surface contour of the electrode undergoing area with a roughness on the surface of 0.33 µm, electrode pressure of 40 Psi, a current of 6 kA, and a time of 6 seconds. With the roughest area is on the edge to which the electrode is subjected, with a roughness value of 0.93 µm.

c. Figure 10 shows that the surface contour of the area subjected to electrode pressure, at roughness Ra 0.24 μm

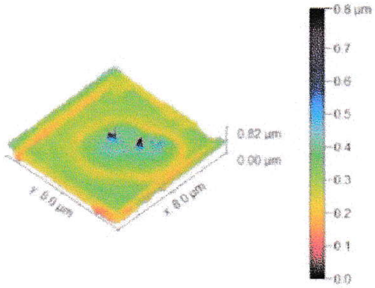


Figure 10. Surface contour Ra 0.24 μm of the area undergoing electrodes

Figure 10. shows that the contour of the area surface subjected to the electrode with the surface roughness of Ra 0.24 μm, pressure 50 Psi, the current of 7 kA, and the time of 7 seconds, with the roughest area is on the edge subjected to the electrode, which is 0.82 μm.

d. Figure 11 the surface contour of the area subjected to electrode pressure, at roughness Ra 0.20 μm

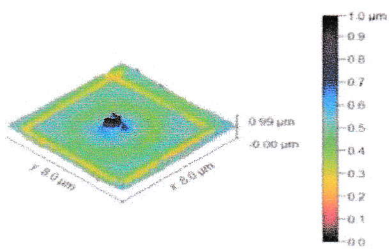


Figure 11. Surface contour Ra 0.20 μm of the area undergoing electrodes

Figure 7. can be seen that the surface contour of the area subjected to electrodes with a surface roughness Ra 0.20 μm, electrode pressure 50 Psi, current 7 kA, and time 7 seconds. The roughest area is on the edge that is subjected to electrodes, which is 0.99 μm.

Figures 8,9,10, and 11 can be seen that in terms of roughness, the contours of the surface are subjected to electrodes, where the smoother the surface of the joint before welding, the lower the roughness in the area subjected to the electrode. This is very good, so that at the time of finishing, such as the vehicle body reduces the use of putty and paint.

Nevertheless, it still needs to be tested for other materials, especially dissimilar materials from the surface. It is essential to find an ideal setting point to get better surface contours.

IV CONCLUSION

Based on the results, the optimization of welding parameters with the treatment of the roughness of the surface of the AISI 304 stainless steel joint, by testing the strength of the weld joint shear pull, macrostructure, and surface roughness of the area that is subjected to electrodes with gwyddion software, it can be concluded that the higher the level of smoothness of the connection surface of the material to be welded, the stronger the connection. The higher the welding current, the higher the tensile strength of the welding joint. The higher the degree of smoothness of the surface of the joint, the more delicate the surface area is subjected to the electrode. Preparation material by the process of treating the surface area of the joint, it improves the quality of the connection from resistance spot welding.

However, in this study is still limited to AISI 304 stainless steel material, so it is recommended to test on other materials, especially dissimilar materials.

AUTHOR CONTRIBUTIONS

In the process of collecting data, the author is assisted by students, especially during the specimen welding process. Pull test data collection is assisted by the BLKI Makassar Tensile test labour.

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Article Error You may need to use an article before this word. Consider using the article **a**.

Prep. You may be using the wrong preposition.

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Prep. You may be using the wrong preposition.

P/V You have used the passive voice in this sentence. Depending upon what you wish to emphasize in the sentence, you may want to revise it using the active voice.

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PAGE 2

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