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DAFTAR LAMPIRAN

Optimization Parameter Resistance Spot Welding Dissimilar Material-A Review

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Abstract. At this time in the industry, especially the automotive industry requires the connection of different materials, to improve driver safety and flexible design during mass production, the connection of plates on the car body generally uses resistance spot welding, because resistance spot welding produces a good connection and is easy to operate. The selection of resistance point welding parameters greatly determines the quality of the joint. Many experimental studies have been published on how to obtain the optimal connection, but there is no published literature review on the selection of the most optimal parameters at this time. Therefore, the authors conducted an optimization analysis of the resistance spot welding method for dissimilar materials in the last 20 years, this was done to obtain recommendations for the selection of optimum parameters to obtain optimum welding quality. We conducted a literature review of empirical studies focusing on welding parameter selection, validation, and optimal results of welding parameters published around the last twenty years (2001-2021). Based on the literature analysis over the last 20 years, we have identified about 50 studies relevant to the objectives of this study and then we further analyzed them both manually and with the VOSviewer software. After analyzing the research, we found that from several types of resistance spot welding parameter selection by researchers, the most influential parameter selection is current. Based on the findings of this review, we provide recommendations for researchers and guidelines for practitioners in the field of dissimilar joint resistance point welding that the current most dominant study is current parameters.

Keywords: welding parameter, resistance spot welding, welding method, dissimilar materials, welding current.

INTRODUCTION

Resistance spot welding (RSW) is very much needed in the industry because the welding process is relatively clean and efficient[1], widely used in the automotive industry[2], it is used to connect vehicle body sheets[3], automotive BIW sheets[4] even now widespread use in several industrial sectors[5]. To obtain a quality welding joint, the determination of the resistance spot welding parameters of the dissimilar material is very decisive[6], several welding parameters such as welding current, welding time, electrode force, electrode holding time density,[7] preheat current, preheat time, thermophysical properties, electrode diameter, and electrode shape. In order to get the optimum connection, so that the vehicle is safer as a solution to respond to passenger safety requirements[8]. Five important stages in the resistance spot welding process are mechanical deformation, heating, smelting combustion, and solidification[9]. Several reviews of the existing literature M. Vigneshkumar et al[6] reviewed the challenges and possibilities in spot welding of dissimilar metals, in their review focusing on eliminating defects in dissimilar material joints, with thorough metallurgical analysis in recent research publications. Eva S. V. Marques et al[10] reviewed the comparison between finite elements with experimental tests of dissimilar material joints. Kang Zhou & Ping Yao reviewed recent advances in resistance spot welding with process analysis and welding quality control. M. Hamedi & M. Atashparva reviewed the electrical contact resistance modeling in resistance spot welding. S. M. Manladan et al[11] reviewed the resistance spot welding of aluminum alloys. A. Al-Mukhtar[12] reviewed the welding of resistance spot welding about the welding process and its failure mode. Sushree Sefali Mishra[13] reviews ferrous-nonferrous and stainless-non-stainless steel joining. N. T. Williams & J. D. Parker[14] reviewed the resistance spot welding of model steel plate joints and the control of weld nugget changes. However, no literature has reviewed the focus on the parameters of dissimilar welding materials so that it can facilitate researchers in the field of resistance spot welding in the selection of parameters, it is very necessary to publish a literature review on the most influential parameters in determining the quality of welded joints, therefore the author tries to analyze from several technical journals, literature review and vosviewer software to map the selection of the most widely used parameters today.

METHODOLOGY

To review journal the optimization parameters for resistance spot welding of dissimilar materials, we combined the methods used by M. Vigneshkumar et al[6], Jianfeng Wen et al[15], and Ida et al[16]. These three authors represent the latest journal reviews for the field of resistance spot welding, software engineering, and the field of VOSviewer software. With the following arrangement for the initial analysis an explanation with a review of the type of connection, the method of parameter selection, the method of testing the connection, and the results of the research of the most influential parameters. The literature search sources that we reviewed are Science Direct, Web of Science, and Google Scholar with a total of about 550 articles, similar articles were deleted in the phase 1 search, then the phase 1 selection got 500 candidate articles, then from the articles on select those that are relevant to the resistance spot welding dissimilar material which is then obtained 150 articles, some articles have previously been obtained namely the review literature is entered so that it becomes 160 relevant articles, then sorted again that fits the review theme, namely parameter optimization welding to produce 50 articles, then the relevant literature is exported into RIS data, then processed in the VOSviewer software into visual data. The general process flow can be seen in Figure 1. For the technical journal review process, the optimum quality of resistance spot welding joints, it is necessary to select the right parameters, there are several spot welding parameters, namely: welding current, welding time, electrode force, electrode holding time density,[7] preheat current, preheat time, thermophysical properties, electrode diameter, and electrode shape[17]. Many experimental studies on dissimilar joints have been carried out, including the following: such as the connection of maild steel with stainless steel by Debashis Mishra et al[18], galvannealed and DP600 steel by Kaushal Kishore et al[19], IF270, TRIP 690, DP 780 and TRIP 980 by Saurabh Akulwar et al[20], aluminum alloy (AA3003) with galvanized steel (GI DP780) by Jin hee bae et al[21], DP600/AISI304 by Alejandro Espinel Hernández et al[17], aluminum 6061 with steel GA440 by Young-Gon Kim[22], AISI 304/316L by M. Vigneshkumar[23], galvanized mild steel with 5083 Al alloy by Daxin Ren[24], dual phase steel DP600 and AISI 304 stainless steel by SH Mousavi Anijdan et al[7], Low Carbon Steel/Aluminum/Stainless Steel by Siva Prasad Murugan et al[25], austenitic stainless steel (AISI 304) sheets and ferritic stainless steel (AISI 430) by Mohammad Hosein Bina et al[26], Austenitic Stainless Steel and Low Carbon Steel by MRA Shawon et al[27], Mg with Ti by Fei Liu et al[4], Nimonic 263 with Hastelloy X RSW by M. Bemani et al[28], (WC–10Co) and high strength steel (RM80) by Gang Chen et al[29], ferritic AISI 430 and austenitic AISI 304 stainless steel by Yu Zhang et al[30], Aluminum with Steel by Amberlee S. Haselhuhn et al[31]. The research described above varies the welding parameters. However, an in-depth review of the literature review using post viewer software to map the use of the most parameters does not yet exist, therefore the authors mapped experimental studies over the last 20 years, based on the following reviews: type of resistance spot welding welding, type of dissimilar material connection, parameters welding used, the method of testing the connection and the optimum research results are obtained.

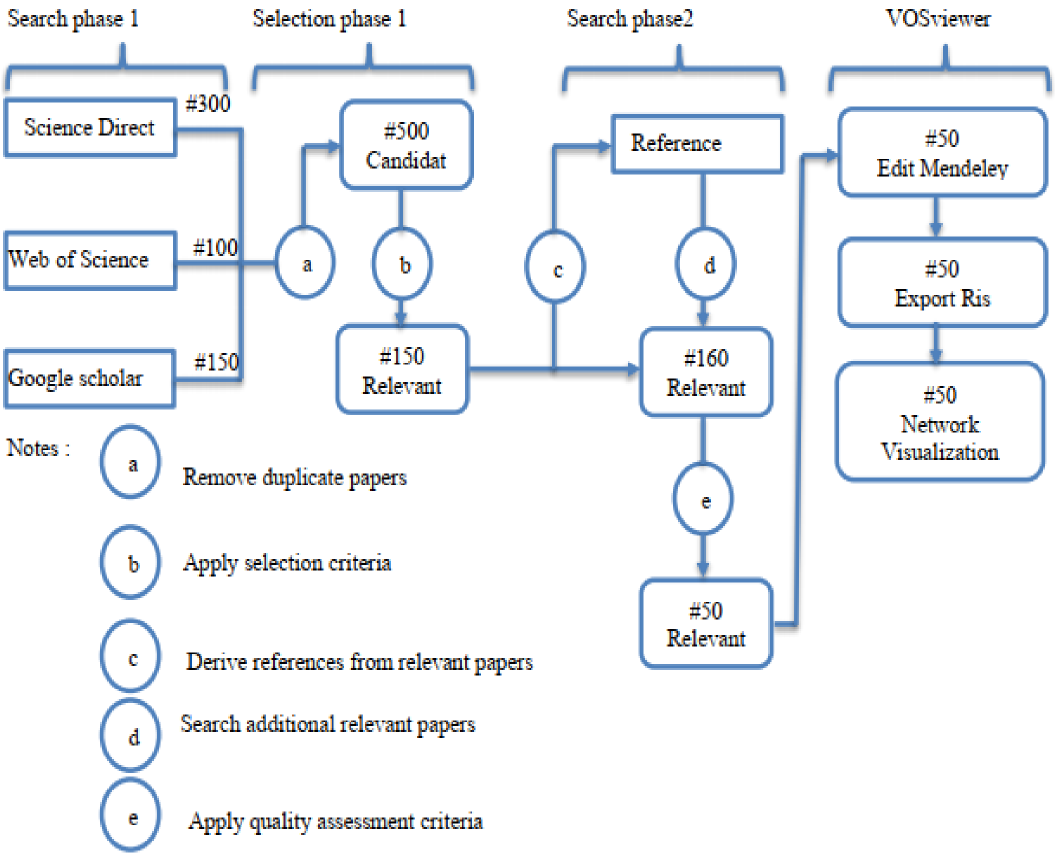


Figure 1. Literature source selection process & Vos viewer analysis

RESULTS AND DISCUSSIONS

Debashis Mishra et al.[18] examined the dissimilar materials of mild steel and stainless steel, with resistance spot welding, the experimental design of the Taguchi L9 approach with three current level factors, namely 9500 amperes, 10000 amperes, and 10500 amperes. With optimum validation of welding nuggets of joints. The results showed that the optimum 4 mm welding nugget was achieved at a current of 9500 amperes. Kaushal Kishore et al[19] focused on studying dissimilar galvannealed and DP600 steel materials with welding parameters, namely constant electrode pressure of 2.8 kN, welding current varied between 6 kA to 10 kA, and welding time of 150, 225, and 300 ms as shown in table 3. with maximum validation voltage Pull. The results showed that the current 9 kA and welding time of 225 ms was the optimum condition.

Saurabh Akulwar et al[20] examined four different types of automotive materials, namely IF270, TRIP 690, DP 780, and TRIP 980 using a current variation of 5 to 15 kA, welding time 12,2,12, electrode pressure force 3, 4.8 and, 5.5 KN, press time 60 cycles. , Hold time 90 cycles. With the validation of tensile shear strength, failure mode, nugget diameter, metallography, and hardness. The results showed that with increasing welding current the four automotive materials experienced an increase in weld diameter and tensile strength until expulsion occurred, expulsion occurred at a current of around 9-10 kA. Jin hee bae et al[21] investigated the dissimilar material connection between aluminum alloy (AA3003) and galvanized steel (GI DP780) using a welding parameter of 3 kN electrode force, welding time 59,100,200,300, 341, welding current 10,12,16,20,22. The joint strength is evaluated using shear tensile strength. The optimum condition of the connection is at a welding time of 300 ms, a current of 20kA with a shear tensile strength of 5.14 kN.

Alejandro Espinel Hernández et al[17] analyzed the DP600/AISI304 dissimilar joint using welding parameters of 3, 4, and 5 kA. currents, welding times of 300, 400, and 500 ms. The method of testing the weld results uses a photo of the surface roughness response compared to the shear tensile strength. The results of the analysis show that the optimal connection strength is at a current of 4 kA and a time of 300 ms with an error percentage of about 2.38 percent. Young-Gon Kim[22] investigated the dissimilar joint strength of 6061 aluminum with GA440 steel. Using welding current parameters 8-12 kA, time 180-360 ms, and electrode pressure 1.9-2.7 kN. The strength of the welded joint was tested by shear tensile strength and FE SEM. The results showed that the joint strength decreased by increasing the electrode pressure and increased in direct proportion to the increase in welding current and time.

M. Vigneshkumar[23] investigated austenitic stainless steel sheet of grade AISI 304/316L with various parameters of welding current 6,7,8,9 kA., welding time 4,6,8,10. The test method is to compare the simulation results with direct testing of nugget diameter and shear tensile strength. The test results showed that the largest nugget diameter was 4.81 mm at a current of 6 kA with a welding time of 4 cycles. Daxin Ren[24] examined the connection between galvanized mild steel and 5083 Al alloy using normal welding current parameters resistance spot welding 6.8, 8, 9.2 and clinch resistance spot welding 10,12, 14., normal welding time resistance spot welding 100,130,160 and clinch resistance spot welding 150,200,250., normal electrode pressure resistance spot welding 100,150,200 and clich resistance spot welding 200,250,300. The method of testing the results of the weld with the tensile shear test and failure mode. The results showed the most influential current, then time, and finally electrode pressure.

S.H. Mousavi Anijdan et al[7] investigated the connection of dual-phase steel DP600 and AISI 304 stainless steel. Parameter selection based on the Taguchi method, namely current 8,10,12 kA, welding time 14,15,16, electrode pressure 3,4,5. Holding time after welding 30,40,50. The connection strength was analyzed by shear tensile strength, fracture mode, and SEM. The results showed that the most influential sequentially were welding current, holding time after welding, welding time, and electrode pressure. optimum current 8 kA, welding time 16 cycles, electrode pressure 5 kN, and holding time after welding 40 cycles. Siva Prasad Murugan et al[25] investigated Low Carbon Steel/Aluminum/Stainless Steel. The parameters used are 10-16 kA current, welding time 12-20 cycles, electrode force 300 kgf. The joint strength is tested by shear tensile strength, failure mode, and microstructure. The results showed that by increasing the welding current, increasing the diameter of the nugget also increased the shear tensile strength.

Mohammad Hosein Bina et al[26] investigated the joints of austenitic stainless steel (AISI 304) sheets and ferritic stainless steel (AISI 430). The parameters used are welding current 0.4, 0.8, 1.2, and 1.6 s., welding current 3.75 kA, and constant electrode pressure. Tests were carried out in macrostructure, microstructure, microhardness, shear tensile test, and failure mode. The results of the investigation showed that the weld strength increased with the increase in the diameter of the nugget which was directly proportional to the increase in the welding current. M. R. A. Shawon et al[27] investigated the material dissimilarity between Austenitic Stainless Steel and Low Carbon Steel. Welding parameters used current 3,5,7,9 kA, welding cycle 30,90 cycles, and electrode pressure 4 kN. Testing with macroscopic, microscopic, SEM, and Mechanical techniques. They found that the increase in current was directly proportional to the increase in the tensile strength of the welded joint.

Fei Liu et al[4] investigated the dissimilar junction of Mg and Ti using current parameters of 14, 14.5, 15, 15.5 kA, electrode pressure of 0.22 Mpa, and welding time of 200 ms. Welding results were analyzed by microstructure, hardness, tensile shear strength, and surface failure. The results showed the maximum shear tensile stress at a current of 14.5 kA, electrode pressure 0.22 Mpa, welding time 200 ms, and electrode pressure 4.79 kN. M. Bemani et al28 Discussed the dissimilar material match between Nimonic 263 and Hastelloy X RSW. Welding parameters are 6-10 kA current. Testing with tensile strength, surface hardness, SEM, and EDS. The results of the discussion by increasing the welding current can improve the mechanical properties of the welded joint.

Gang Chen et al[29] investigated (WC−10Co) and high strength steel (RM80). The process parameters for welding are current 650,800,900A., welding time 95ms., preheat time 20 ms., preheat current 300A. Analysis of mechanical strength with shear tensile force and microstructure with SEM, micro X-ray diffraction. The results showed that by increasing the welding current, the tensile shear strength increased and then decreased, with a maximum of 954 MPa. Yu Zhang et al[30] worked on ferritic AISI 430 and austenitic AISI 304 stainless steel. Welding parameters welding current, 3,5,7,9kA., welding time 50,100,200,300 ms and electrode pressure 1,2,3,4 kN. The test methods are tensile shear, hardness, macrostructure, and microstructure. The results show that there is a tendency for the interface failure mode to fail to pull out in the following order 304/430 > 304/304 > 430/430.

Liting Shi et al[31] studied the dissimilar connection of Aluminum-Steel material. Welding parameters welding current 24.8,23.3,13.9,11.8 kA., welding time 60,151,540 and 1550ms., electrode pressure 2669,3114,3559,3781N., Hold time 250 ms and preheat stage 10ms. Test method with prediction using formula and experimental test with tensile shear test with failure mode study. The results of the study show that the predicted fracture mode with the failure mode is very suitable. Ladislav Kolarık et al[32] analyzed the connection between low carbon steel and austenitic CrNi stainless steel with welding parameters of 7 and 8 kA. Analysis of the strength of welded joints by light microscopy, surface hardness, and EDX. The size of the weld metal increases with increasing welding current.

Xinjian Yuan et al[33] analyzed the dissimilar joints of DP600 and DC54D steels. Parameters welding current 6,7,89,10,11.,welding current 5,8,11,14,17,20 cycles.,electrode pressure1.8,2.2,2.6,3.0,3.4 kN. Analysis of joints by shear tensile strength, SEM, TEM, EBSD. The results of the analysis showed that the diameter of the nugget increased by increasing the heat input, namely the current 6kA-11kA, welding time 5 and 20 cycles. Xinge Zhang et al[34] researched CR590T/340Y Galvanized Dual Phase Steel. Welding parameters welding current 8.5-12 kA, welding time 20 cycles, electrode pressure 4 kN. Testing with the tensile test, hardness, microstructure with SEM, EDS, and Xray. The results showed that the quality of the welded joint increased with increasing current and there were Zn islands on the weld surface.

M. Pouranvari et al[35] investigated AISI 1008 low carbon steel and DP600 advanced high strength steel. Current welding parameters 8,9,10,11,12.,welding time 15,20,25,30 cycles.,electrode pressure 4,1,5,1,5.7.,holding time 10 cycles.,squeeze time 40 cycles. Tensile test with ASTM E8[36] standard material preparation with ANSI AWS/SAE/D8.9-97 standard[37], failure mode, surface hardness. The results showed that by increasing the welding current and time and decreasing the electrode pressure, a failure mode transition from interfacial to pullout mode occurred. K. Vignesh et al[38] studied the joints of 2205 duplex stainless steel (DSS) and AISI-316L stainless steel sheets. Parameters of welding current 7,8,7,8,9,8,9,7,8 kA.,heating cycle 7,7,8,8,9,9,8,9,8. Tensile test with Finite element (FE) ABAQUS simulation was compared with experimental test results, hardness test in the HAZ region, macrostructure with SEM. The results of the study showed that the tensile strength increased with increasing welding current, as a result of increasing the size of the nugget.

Dr. Sabah Khammass Hussein et al[39] studied the connection of different materials AA 6061-T6 and AISI 1010. Welding parameters selection is the welding currents 11.12.3,13.6 kA., welding time 25.30,35 ms., Electrode force 1.6,2.5,3.5 kN., holding time 30.40, 50. Test method of connection testing Shear tensile test, surface hardness, and microstructure. The results showed that the maximum shear force occurred at a current of 13.6 kA, an electrode force of 1.6 KN, a holding time of 30 cycles, and a welding time of 15 cycles. Sven Roth et al[40] investigated FRP/metal joints. The parameter selection method is the welding current 5,6,7,8,9,10 kA., welding time 50,100,120,140,160,180,200,220,240,260,280,300,320,340 ms. Test method by analyzing the input energy. The results showed that the most optimal is a short welding time and high welding current.

S.M. Manladan et al[41] investigated the joints of AZ31 Mg alloy and 316L austenitic stainless steel (ASS). Parameters welding current 6-18 kA & 5-9 kA., welding time 200 ms & 250 ms., electrode pressure 3.6 kN. Test method with tensile test and metallography. The results showed that with increasing welding current, the REW failure mode occurred from IF to PO. Aravinthan Arumugam and Mohd Amizi Nor[42]. Examine the material dissimilar connection between hot rolled mild steel (SPHC) and cold rolled re-phosphorized steel (SPRC35). Parameter selection are electrode force 2,3,4 kN, welding current 8,9,10 kA and welding time 10,15,20 ms. The welding connection testing method is the tensile shear test and macrostructure testing with an optical microscope. The results showed that the optimal welding point was at an electrode pressure of 3 kN, a welding time of 15 cycles, and a welding current of 9 kA.

Sendong Ren et al[43] investigated the dissimilar joint of the AL5052/CFRP material. The actual condition of welding parameters is welding current 4400, 3600, 4400, 4400, 3200, 3600, 4000, 4400, 4800, 5200A., welding time 0,45 ms., electrode force 2500, 1500 Pa. Test method of shear tensile test with software and tensile test equipment. The highest connection strength is 20 MPa at 4800 A current. Shanqing Hu et al[44] investigated the dissimilar connection between aluminum and steel. Welding schedule are welding current are 11,10 kA., welding time is 250 ms., and electrode pressure is 6 kN. Testing the connection strength by measuring the diameter of the nugget, shear tensile strength with a tensile test, hardness with a hardness test, metallurgical examination with A LEICA digital optical microscope S8 APO, EDS, and SEM. The results showed that the welding parameters produced a strong tensile strength and the weld was able to absorb 36% of energy.

Imad M. Husain et al[45] investigated the connection of copper and carbon steel. Welding conditions current 10000.12000 A., Pressure 25.35 bar., Squeeze time 15.25 cycles.,Welding time 2.8 Cycles. Testing of joints with shear tensile stress and surface contours Shear tensile with software. Maximum shear tensile strength at 1000 A, electrode pressure 35 bar, squeeze time 25 cycles, and welding time 5 cycles. Rohit Verma et al[1] studied the connection of galvanized High Strength Interstitial Free (HIF) steel sheets, and Dual Phase (DP780). Welding parameter selection is welding current 6,6.5,7,7.5,8,8.5,9,9.5,10.,welding time 250,150,200,300.,electrode pressure

2.5,3,3.5. Testing the connection with the tensile shear test, microhardness, and microstructure. The results showed that the increase in welding current and time significantly increased the shear strength of the welded joint.

Sendong Ren[46] investigated the dissimilar joints of Al5052 and CFRP materials. Welding current parameters 2000,3000,3500,4000 A.,welding time 0.45.0.1.0.2.0.3,0.4,0.5.,electrode pressure 2450,1470,1960,2940,3430. Joint analysis with numerical and experimental simulations in the form of mechanical strength and temperature distribution. The results showed that the depth of the liquid zone was correlated with welding current and time. A.K.C. Utomo et al[47] investigated the dissimilar material connection between SUS 304 and low carbon steel SS 400. The method for selecting the welding time parameter was 0.18.0.34s. Analysis method with commercial software ANSYS 12.0. The results showed that welding nuggets would be formed if the welding time was 0.30 seconds with a peak temperature of 14560C.

Subrammanian et al[48] studied the austenitic stainless steel AISI 301 and the ferrous stainless steel AISI 409M. Welding parameters are welding current 7,8,9,10,11,12,13,14 kA.,welding time 15 cycles (1 cycle = 20 milliseconds).,electrode pressure 4 kN, squeeze time 40 cycles, hold time 20 cycles, off time 20, cycle. Testing the connection with shear tensile test, hardness, macrostructure, microstructure. The results of the study show that the increase in welding current is directly proportional to the increase in the diameter of the nugget.
Based on the description of the previous literature review, it is made in the form of a parameter graph that is currently the most studied by researchers, among others, as shown in Figure 2. In Figure 2, it can be seen that for the dissimilar connection the most widely used parameter is the welding current of around 32, then the welding time of about 30, then the electrode force of 24. This means that if you want to research dissimilar materials, you should focus on examining only these three parameters.

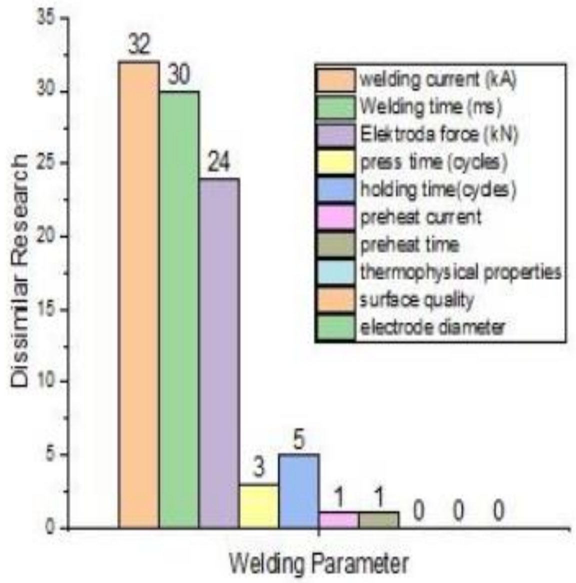
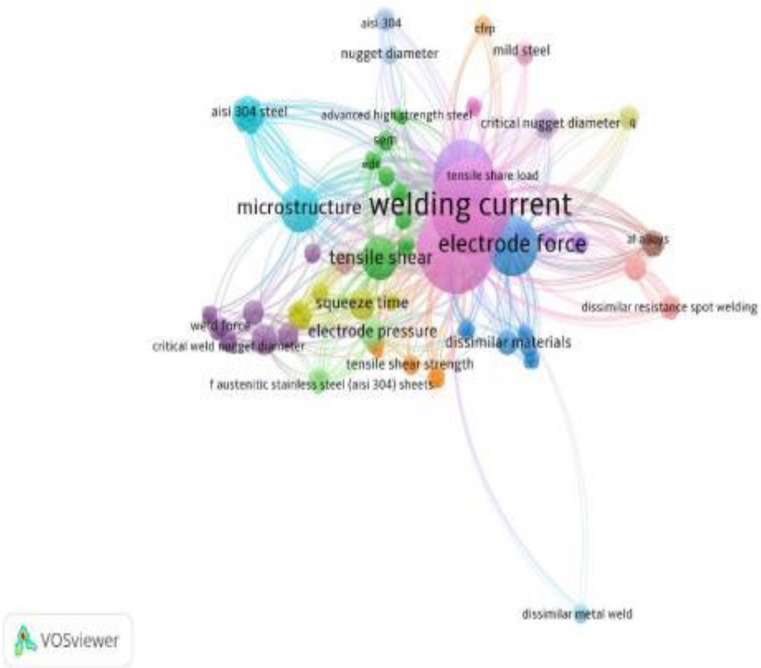


Figure 2 Parameters of resistance spot welding

Bibliometric analysis with VOSviewer[49] is used as the software to visualize the bibliometric network[50], welding parameters, which have been downloaded through Elsevier journal and Springlink journal and then converted into RIS form, then processed in VOSviewer software. It can be seen in figure one bibliometric for dissimilar connection of material resistance spot welding.



Gambar 3. Network Visualization Resistance Spot Welding

Based on software analysis with literature samples from the journal resistance spot welding dissimilar material shown in Figure three, it shows that the most widely used parameters currently in resistance spot welding dissimilar material welding are welding current, then welding time, and electrode force.

CONCLUSION

Based on an analysis of various literature and by using VOSviewer software analysis, for dissimilar resistance spot welding material joints with a focus on parameter selection including welding current, welding time, electrode force, electrode holding time density, preheat current, preheat time, thermophysical properties, electrode diameter, and electrode shape it can be concluded that the most influential parameter is the welding current. where the current affects the heat input which makes the diameter of the welding nugget bigger and directly proportional to the strength of the welded joint.

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

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***Abstract*—Resistance spot welding is widely used in the automobile, ship, and food industries. The durability and safety of the product being produced from these different industries depend on the spot welding joint's connection quality, which makes it very important. However, there are a lot of poor quality resistance spot welding connections and this is caused by several factors, namely: material preparation, welding time, welding current, electrode pressure applied during welding, and post-welding treatment. This research was conducted to analyze how changing the joint surface's roughness before welding and current parameters during welding could improve the quality of resistance spot welding joints. The experiments were conducted using a stainless steel plate material 304 with a size of 175x25 mm. Furthermore, mechanical testing was carried out the tensile shear and macrostructure using the Gwyddion software. The results showed that the parameters of the welding current, significantly affect the width of the welding nuggets and the quality of the spot welding resistance joint is improved by even the slightest roughness variation on the joint surface.**

***Index Terms*—resistance spot welding, welding time, electrode pressure, nugget, surface roughness**

I. Introduction

The quality of AISI 304 stainless steel joints is very important. Furthermore, it is currently being used by many industries, among which are: the marine [1], chemical, aeronautics, and naval industries [2], [3]. Unfortunately, the AISI 304 stainless steel is weaker at the welded joint and this is caused by some occasional flaws which tend to reduce the quality of the weld joint [4].

Therefore, the resistance spot welding (RSW) parameters are processes that must be considered to ensure a stronger connection between two high-quality components. [5] In general, numerous factors including thenugget size [6], [8], material grain size [9], surface roughness [10][11], tensile shear strength [12], hardness value [13], and failure type [14] can be used to determine the quality of welding joints. Accordingly, the quality of the AISI 304 stainless steel joint can be mechanically improved with variations in surface roughness prior to welding. This is also possible with the application of the right amount of current. According to Kumar et al [5] there is a correlation between the tensile shear and the nugget diameter. Luo et al [15] also discovered nanoparticles with an average of 20 μm on the surface of the AISI 304 steel with the use of photographs, which had an impact on the mechanical properties of the joint.

The following research has been conducted by some researchers to improve the quality of resistance spot welding joints,: : surface fiber in welded friction[16], geometry [17], sealing [18], resistance spot welding parameter with a focus on electrode force [19][20], resistance spot welding with focus in parameter current [21], the holding time varies[22], and PWHT on the hydrogen [23].

Furthermore, surface roughness has been the subject of numerous investigations. Jhe-Yu Lin et al [24] used ultrasonic welding to join Ni and steel while also examining how roughness affected the evolution of their bonding strength. Their findings showed that the binding strength evolves quickly when the surface is smooth and that the formation of the contact plane region affects the strength of the welded joint. In another study, Hyeongggeun Jo et al [25] examined the effects of the surface roughness treatment of electrodes resistance spot welding on the strength of welded joints. The procedure involved the use of sandpaper to increase surface roughness, followed by measurements of the nuggets' diameter, tensile strength, and welded joint hardness. It was observed that roughness has an impact on the strength of welded joints. Furthermore, another research

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conducted by Michaela et al [26] examined the impact of surface roughness on the Laser Beam Welding of Aluminium Alloys. They examined the effects of different surface roughness which was monitored in the range Ra 0.8 to Ra 15. The research results also showed that welded joints are impacted by surface roughness. Mechanical testing and macrostructures are methods used to test the strength of welded joints and several studies have been conducted in this regard. They include M. Sabzi et al's [27] study, which examined the mechanical properties of AISI 316L-AISI 310S stainless steels with mechanical tests, specifically the tensile shear, Charpy impact, and Vickers micro-hardness tests. In a different study, M. Sabzi et al [28] investigated the relationship between the AISI 316L and the AISI 310S stainless steels using mechanical testing, among others (tensile, impact, and Vickers micro-hardness tests). Following this, R. Sokkalingam et al [29] explored the joints of Dissimilar welding of high-entropy alloy to Inconel 718 super-alloy using macrostructures testing. Furthermore, Jilin Xie et al [30] tested the different cross-sectional macrostructures of the TiNi SMA and Ti6Al4V dissimilar. Lastly, Saurabh Akulwar et al [31] explored the resistance spot welding behavior of automotive steels by testing macro structures in a fusion zone, heat-affected zone (HAZ), and the base metal.

Prior to this time, no in-depth analysis has been carried out to examine how the correlation of material preparation and the selection of suitable currents can improve the quality of welded joints. Therefore, The goal of this investigation is to determine whether there is a relationship between the roughness variation treatment, preparation, and welding current selection for AISI 304 stainless steel material to improve the quality of the joint. This is an important research since the preparation of materials with variations in roughness will make the adhesion between the two specimens better, thus having an impact on the quality of welded joints.

II. Research Methods

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

A. Material Preparation

The Foundry Master Oxford instruments were used to examine the material composition of AISI 304. These instruments are high performance metal analyzers with a small tread observation method.

TABLE I. Summarization of the Components of AISI 304

Composition	C	Si	Mn	Cr	S	P	Ni	Fe	Mo
wt%	0.0531	0.533	1.05	19.0	< 0.0005	0.0205	7.84	71.0	0.0010

The AISI 304 stainless steel plate, was cut using a sample metallographic AWS D8.9-2002 Sq-100 cutting machine, with a standard size of 105x45x1 mm as shown in Fig. 1. When the metallographic cutting machine was working, a cooling stream was used to ensure that the cutting did not affect the properties of the material.

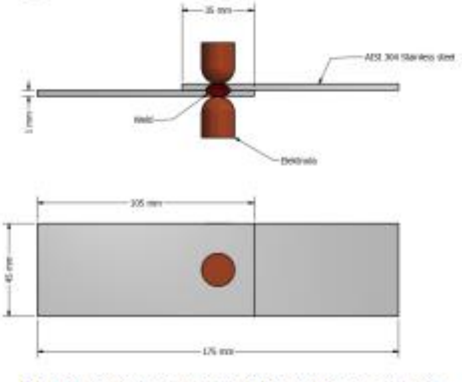


Figure 1. A Schematic diagram of the test objects used in the experiments

B. Treatment Before Welding

Prior to welding the surface side, was treated by sanding with a modern sandpaper machine M2500-B. This was conducted by installing sandpaper and sanding each specimen's surface for three minutes. Furthermore, the surface roughness machine and the following variations were applied for the connecting surface's roughness: (0.34, 0.33, 0.24, and 0.20 μm). Fig. 2 is a photograph of the equipment used.

Figure 2. Roughness test process with surftest SJ 310 Mitutoyo

C. Treatment During Welding

Figure 3. Resistance spot welding machine

The welding process was carried out using a pressurized air electrode suppression system that had a pressure adjustable mechanism. Also, analog settings were employed in thecurrent setting system and the system's welding time is adjusted using digital parameters as shown in Fig. 3

Following this, the welding parameter optimization settings were based on the standards of AWS C1.1-MC.1:2012 The parameter settings for the different rough specimen surfaces observed are as follows: for base metals with a roughness of 0.34 µm, the setting parameters were, an electrode pressure of 30 Psi, welding current of 5 kA, and welding time of 5 seconds , and this is the same for specimens with a surface roughness of 0.33 µm. The electrode pressure, welding current, and welding time were all optimized for surface roughness of 0.24 µm, at 40 Psi, 6 kW, and 6 seconds. , respectively. Furthermore, specimens with a surface roughness of 0.20 µm, have the parameters; 50 psi electrode pressure, 7 kW welding current, and 7 seconds welding time. The total number of specimens used was 36, with Each experiment consisting of 3 specimens. and their average values were determined to provide more accurate findings. Details of the welding settings and roughness conditions are shown in Table I.

TABLE I. WELDING PARAMETERS AND CONDITIONS

Experiment	Welding Parameters Process			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

D. Connection Testing

The quality of the welded sample was tested using the tensile shear method [32] as shown in Fig. 4.

Figure 4. Tensile test machine

Sample quality for electrode-subjected surface contours was tested using macro photos. The surface contours were then analyzed by Gwydion software.

III. RESULT AND DISCUSSION

Tensile strength [33][32], macrostructure [34], and surface conditions [35]in the region of electrode pressure were parameters used by the guidance software to examine the weld quality.

A. Connection Quality Testing with Tensile Shear Test

A total of 36 specimens were examined in this study, with each experiment consisting of 3 specimens. To make the displayed data more accurate, each data point was an averaged value from each experiment. Following this, specimens with shear tensile strength and contouring of the connecting surface subjected to the electrodes are as follows:

a. The relationship between a surface's roughness and the maximum voltage points using the following welding parameter settings: 30 Psi electrode pressure, 5 kW Current, and 5 seconds, welding time, is shown in Fig. 5.

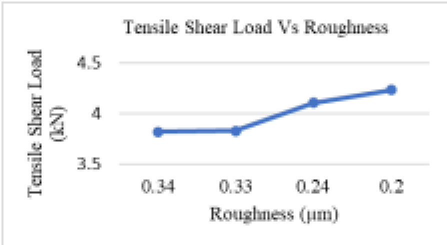


Figure 5. Welding parameters at 5 kA

Fig. 5 shows the tensile strength of base metal with a surface roughness of 0.34 µm using the following welding parameters: 30 Psi electrode pressure, 5 kW current, and 5 seconds welding time. the result showed that the tensile strength increases directly in proportion to how smooth the surface is. Likewise, a base metal having a surface roughness of 0.2 µm, had a tensile strength of 4.2±0.4 kN which also proves the relationship between the display smoothness and the shear tensile strength value. According to S. Akulwar et al [30], the smoother the connection surface, the better the electrical resistance and the more the heat input to the welding area , thus, improving the quality of the weld.

b. The relationship between a surface's roughness and maximum voltage points using the following welding parameter settings namely: 40 Psi electrode pressure, 6 kW current, and 6 seconds of welding time is illustrated in Fig. 6

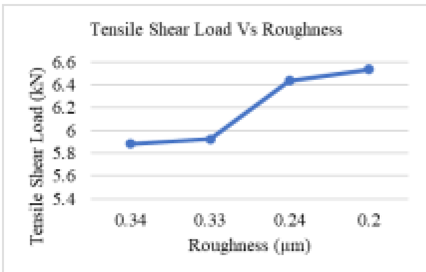


Figure 6. Current welding parameters 6 kA

Fig. 6 shows the relationship between the tensile strength and surface roughness of 0.33 µm for the welding parameter sets of 40 Psi electrode pressure, 6 kW current, and 6 seconds of welding time. There is a directly proportional relationship between the smoothness of a surface and the increases in the shear tensile strength. In addition, the highest tensile strength measured is 6.5±0.3 kN, exceeding the most optimal research findings (3.8 kN), which was obtained by Manoj Raut [36] . This is because Manoj's research focused only on optimization of parameters, whereas in this study, the optimization of parameters, as well as the preparation treatment welding with varying surface roughness Is the main point of attention.

c. The relationship between a surface's roughness and the maximum voltage point using the following welding parameter settings, namely: 50 Psi electrode pressure, 7 kW Current, and 7 seconds welding time, is illustrated in Fig. 7.

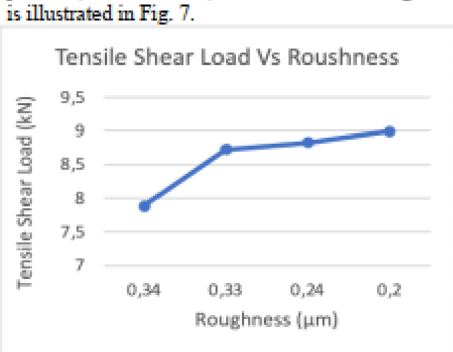


Figure 7. Welding parameters current 7 kA

Fig. 7 shows that there is a relationship between the tensile strength and the surface roughness of Ra 0.24 µm at the setting of the electrode pressure welding parameter of 50 Psi, Current 7 kW, and time 7 seconds. The results showed that an increase in current is directly proportional to the sheer tensile strength. This observation is valid because, an increase in current results to an increased heat input to the area being welded. This has an impact on the increase in tensile strength since the increase in heat input facilitates the melting process of the mild steel on the surface of the specimens being welded. Fig. 7 also shows the relationship between the surface smoothness and the sheer tensile strength. Furthermore, using the same parameter settings as those reported by Tanmoy [20], the highest tensile strength obtained was 9±0.2 kN, which is 2.4 kN greater than the result encountered by Manoj Raut [36].

As observed in Fig. 1, 2, and 3, the roughness treatment has a significant impact on the tensile strength of welding shear; the smoother the surface, the higher the value of the shear tensile strength. This occurs because the contact area that is covered by the heat input is larger with smoother surfaces [24].

B. Connection Quality Testing with Macrostructures

Result of the photographs taken using macro cameras and analyzed using Gwydion software are shown in Table II

TABLE II. PHOTO MACRO WITH VARIATIONS IN ROUGHNESS

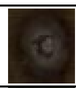
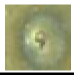
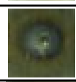
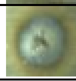
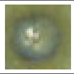
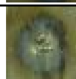
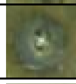
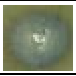
Level of Roughness (µm)	Current (kA)	Time (Second)	Pressure (Psi)	Photo
0.34	5	5	30	
	6	6	40	
	7	7	50	
0.33	5	5	30	
	6	6	40	
	7	7	50	
0.24	5	5	30	
	6	6	40	
	7	7	50	
0.20	5	5	30	
	6	6	40	
	7	7	50	

Table III shows the results of the photographs taken using macro cameras, and analyzed using Gwydion software to determine the contours of the surface subjected to electrodes. It was obtained that the surface subjected to the electrode becomes smoother using a connection surface with a roughness of 0.20 µm, a current of 7 kA, 7 seconds welding time, and 50 psi electrode pressure. This implies that the smoothness of the connection surface determines the quality of the surface contours exposed to the electrodes. Using Gwydion software, the detailed results are displayed as a three dimensional contour (Fig. 7).

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C. Quality Testing with Gwydion Software Analysis

Using some high-resolution digital, macro pictures, the analysis done with the Gwydion software, revealed some of the electrode affected areas.

a. Fig. 8 depicts the surface contours of the area subjected to electrode pressure, at a roughness of 0.34 µm

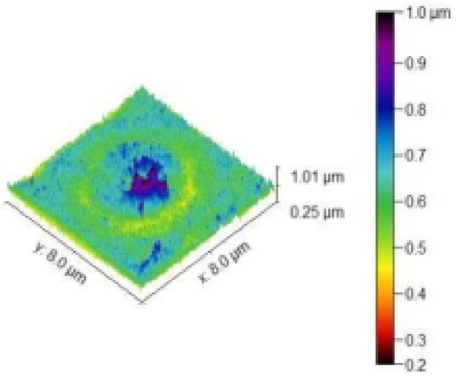

Figure 8. Surface contour of the area surface subjected to the electrode with a surface roughness of Ra 0.34 µm

Fig. 8. shows the contour of the area surface subjected to the electrode with a surface roughness Ra 0.34 µm, electrode pressure 30 Psi, current 5 kW, and time 5 seconds welding time. A macro photo was taken of the connecting area that was exposed to the electrodes, and the image was then further examined using the Gwydion software. The surface of the rough area is in the center subjected to electrode pressure with a roughness value of 1.01 µm. Furthemore, the specimen showed the lowest shear tensile strength of 4.2 kN. From these two phenomena, it is clear that the roughest surface is that of the area where the electrode will be placed, which has the lowest tensile strength at the time of preparation.

b. Fig. 9 shows the surface contours of the area subjected to electrode pressure, with a roughness of Ra 0.33 µm

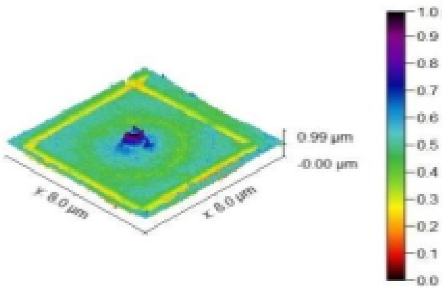

Figure 9. Surface contour Ra 0.33 µm of the area undergoing electrodes

Fig. 9 shows the surface contour of the electrode undergoing area with a surface roughness of 0.33 µm, an electrode pressure of 30 Psi, a current of 5 kA, and time 5 seconds. Meanwhile, the roughest area is on the edge of the area to which the electrode is subjected, with a roughness value of 0.99 µm.

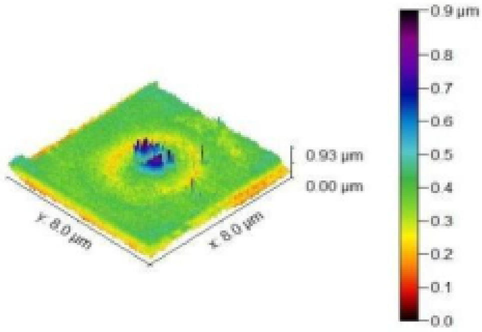

Figure 10. Depicts the surface contour of the area subjected to electrode pressure, at a roughness of Ra 0.24 µm

Fig. 10. Surface contour of the area undergoing electrodes surface subjected to the electrode with a surface roughness of Ra 0.24 µm

Fig. 10 shows that the contour of the area surface subjected to the electrode with a surface roughness of Ra 0.24 µm, pressure 40 Psi, the current of 6 kA, and t time 6 seconds, with the roughest area being on the edge subjected to the electrode, which is 0.93 µm.

c. Fig. 11 shows the surface contour of the area subjected to electrode pressure, with a roughness of Ra 0.20 um

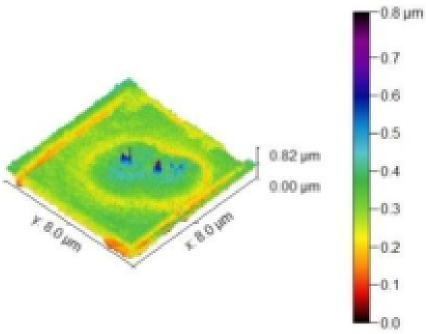

Figure 11. Surface contour of the area subjected to electrodes with a surface roughness of Ra 0.20 µm

Fig. 11, shows that the surface contour of the area subjected to electrodes with a surface roughness of Ra 0.20 µm, electrode pressure 50 Psi, current 7 kA, and time 7 seconds. Also the roughest area is on the edge that is subjected to electrodes, which is 0.82 µm.

Figs. 8,9,10, and 11 show that in terms of roughness, the contours of the surface are subjected to electrodes. The smoother the surface of the joint before welding, the lower the roughness in the area subjected to the electrode. This is excellent because it will cut down the cost of putty and paint during projects like finishing an automobile's body. However, this welding process still needs to be tested with other materials, especially those that differ from the surface. It is, therefore, essential to find an ideal setting point to get better surface contours.

IV. CONCLUSION

The results obtained from testing the tensile strength of the shear, the macrostructure, and surface roughness of the area subjected to electrodes using the Gwydion software, varied based on the optimization of the welding parameters and the surface treatment of the AISI 304 stainless steel joint. Furthermore, the results showed that the higher the level of the material's connection surface smoothness, the stronger the weld. Also the higher the welding current, the higher the tensile strength of the welding joint. and the higher the smoothness degree of the joint's surface, the more delicately exposed the surface area becomes to the electrode. Finally, by addressing joint's surface area during material preparation, resistance spot welding results in a stronger connection. However, this study is still limited to AISI 304 stainless steel material alone, so it is recommended to test on other materials, especially those that are dissimilar.

AUTHOR CONTRIBUTIONS

During the process of data collection, the authors were assisted by students, especially in the specimen welding process, and BLKI Makassar which provided the labor that aided in the tensile test process, as well as in the collection of the test results.

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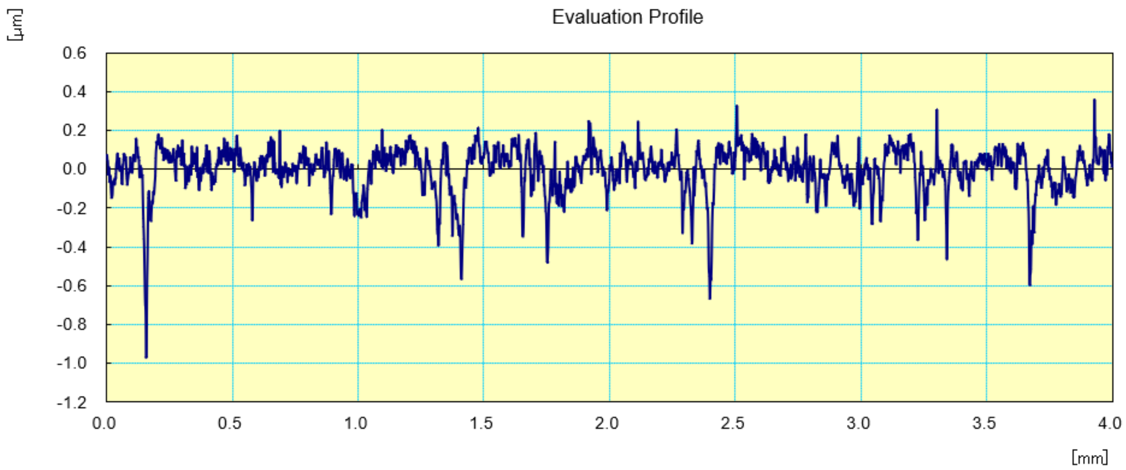
3.7.2 Lampiran data pengujian kekasaran

Ra 0. 20 µm	CUT 0. 8mm	0	99	0. 0005	7. 54E-02
Rq 0. 117 µm	N 5	0. 00E+00	98	0. 001	6. 65E-02
Rz 0. 955 µm	CUV R	0. 00E+00	97	0. 0015	5. 63E-02
	FIL GAUSS	0. 00E+00	96	0. 002	4. 88E-02
	STD ISO 1997	0. 00E+00	95	0. 0025	4. 72E-02
	LS 2. 5µm	0	94	0. 003	4. 64E-02
	STP 0. 5	0	93	0. 0035	4. 43E-02
	UNT 1	0	92	0. 004	3. 41E-02
	LNG E	0	91	0. 0045	1. 59E-02
		0	90	0. 005	-6. 50E-03
		0	89	0. 0055	-2. 41E-02
		0	88	0. 006	-2. 64E-02
		0	87	0. 0065	-2. 24E-02
		0	86	0. 007	-1. 15E-02
		0	85	0. 0075	5. 00E-04
		0	84	0. 008	9. 70E-03
		0	83	0. 0085	9. 50E-03
		0	82	0. 009	-8. 00E-04
		0	81	0. 0095	-1. 81E-02
		0	80	0. 01	-3. 49E-02
		0	79	0. 0105	-4. 89E-02

CERTIFICATE OF INSPECTION



Ra 0. 240 µm	CUT 0. 8mm	0	99	0. 0005	−5. 44E−02
Rq 0. 089 µm	N 5	0. 00E+00	98	0. 001	−6. 32E−02
Rz 0. 951 µm	CUV R	0. 00E+00	97	0. 0015	−6. 46E−02
	FIL GAUSS	0. 00E+00	96	0. 002	−5. 90E−02
	STD ISO 1997	0. 00E+00	95	0. 0025	−4. 57E−02
	LS 2. 5µm	0	94	0. 003	−2. 89E−02
	STP 0. 5	0	93	0. 0035	−2. 08E−02
	UNT 1	0	92	0. 004	−1. 79E−02
	LNG E	0	91	0. 0045	−1. 94E−02
		0	90	0. 005	−2. 60E−02
		0	89	0. 0055	−3. 23E−02
		0	88	0. 006	−3. 55E−02
		0	87	0. 0065	−3. 22E−02
		0	86	0. 007	−2. 21E−02
		0	85	0. 0075	−1. 80E−03
		0	84	0. 008	2. 52E−02
		0	83	0. 0085	3. 91E−02
		0	82	0. 009	3. 18E−02
		0	81	0. 0095	4. 80E−03
		0	80	0. 01	−2. 98E−02
		0	79	0. 0105	−5. 85E−02

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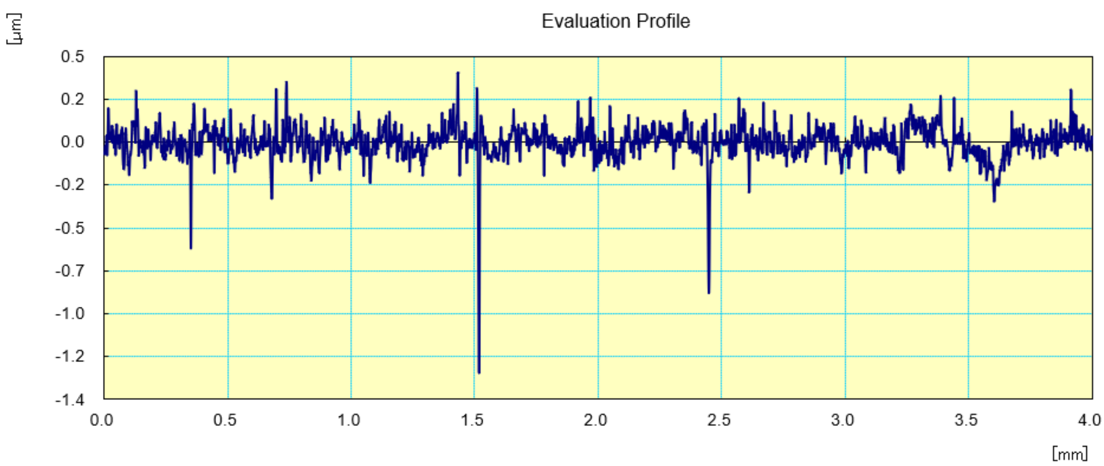
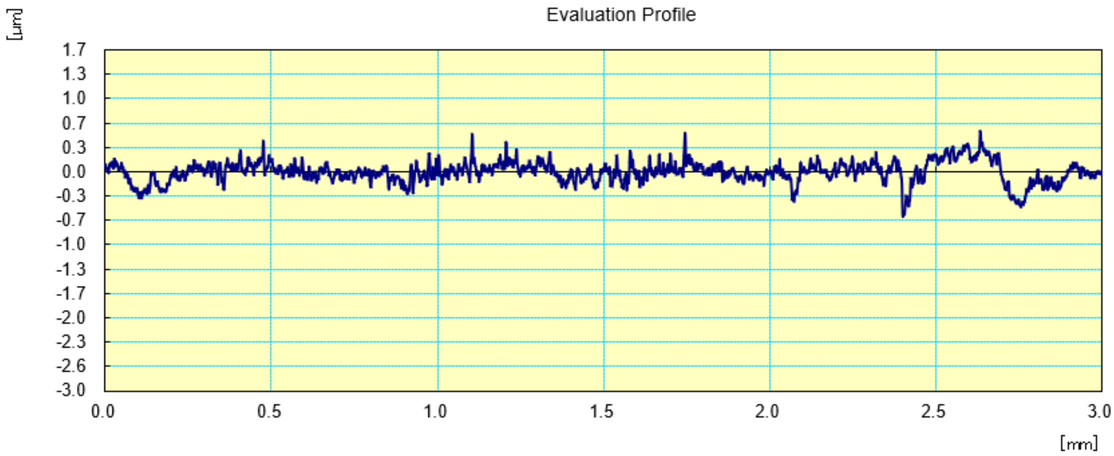
CERTIFICATE OF INSPECTION



Ra 0. 33 μm		CUT 0. 8mm	0	99	0. 0005	1. 04E-01
Rq 0. 270 μm		N 5	0. 00E+00	98	0. 001	9. 89E-02
Rz 1. 660 μm		CUV R	0. 00E+00	97	0. 0015	8. 60E-02
		FIL GAUSS	0. 00E+00	96	0. 002	7. 08E-02
		STD ISO 1997	0. 00E+00	95	0. 0025	5. 65E-02
		LS 2. 5μm	0	94	0. 003	5. 06E-02
		STP 0. 5	0	93	0. 0035	4. 94E-02
		UNT 1	0	92	0. 004	5. 28E-02
		LNG E	0	91	0. 0045	5. 40E-02
			0	90	0. 005	5. 03E-02
			0	89	0. 0055	4. 35E-02
			0	88	0. 006	3. 65E-02
			0	87	0. 0065	3. 43E-02
			0	86	0. 007	3. 65E-02
			0	85	0. 0075	3. 39E-02
			0	84	0. 008	2. 30E-02
			0	83	0. 0085	1. 04E-02

CERTIFICATE OF INSPECTION



Ra 0. 34 µm	CUT 0. 8mm	0	99	0. 0005	1. 84E-01
Rq 0. 406 µm	N 5	1. 25E-01	98	0. 001	1. 79E-01
Rz 1. 581 µm	CUV R	2. 25E-01	97	0. 0015	1. 77E-01
	FIL GAUSS	3. 00E-01	96	0. 002	1. 72E-01
Ra	STD ISO 1997	4. 50E-01	95	0. 0025	1. 70E-01
0. 201	LS 2. 5µm	0. 525	94	0. 003	1. 66E-01
0. 303	STP 0. 5	0. 575	93	0. 0035	1. 59E-01
0. 3525	UNT 1	0. 7125	92	0. 004	1. 52E-01
	LNG E	0. 875	91	0. 0045	1. 47E-01
		1. 15	90	0. 005	1. 49E-01
		1. 3875	89	0. 0055	1. 54E-01
		1. 5875	88	0. 006	1. 58E-01
		1. 725	87	0. 0065	1. 61E-01
		1. 825	86	0. 007	1. 64E-01
		1. 9375	85	0. 0075	1. 69E-01
		2. 125	84	0. 008	1. 71E-01
		2. 25	83	0. 0085	1. 73E-01
		2. 45	82	0. 009	1. 76E-01
		2. 6375	81	0. 0095	1. 85E-01
		2. 7	80	0. 01	1. 92E-01
		2. 85	79	0. 0105	2. 02E-01
		3. 0375	78	0. 011	2. 07E-01

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16- Feb -2022

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