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An Analysis of Tensile Strength and Performance of Resistance Spot Welding Parameters for HSLA 355 Stainless Steel

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Abstract

Resistance Spot Welding (RSW) is a technique used in a variety of industries, including manufacturing, aerospace, and automotive. To better understand how RSW process factors affect the performance of High-Strength Low-Alloy (HSLA) 355 stainless steel sheet joints, this study was conducted. Because of its remarkable mechanical qualities and exceptional corrosion resistance, HSLA 355 stainless steel is a popular choice for applications needing high performance and dependability. The impact of crucial spot welding (RSW) process variables, including electrode force, welding current, and welding time, on joint formation is examined in the first study. The significance of welding current in regulating the size of the weld spot and joint strength is highlighted in particular. Understanding the performance of welded joints requires an evaluation of mechanical properties. The purpose of this study was to assess the fatigue resistance, shear strength, and tensile strength of surface welded joints. By examining the effects of various mechanical properties of composite materials on joint performance, this study sought to better understand the ideal circumstances needed to create strong and long-lasting welds. Additionally, the association between the joint area's grain structure and the weld parameters was discovered using microstructural research. Predicting and managing the characteristics of weld materials requires an understanding of these microstructural changes.

Major Findings: *The major findings of this study may contribute to improved welded component durability and dependability in high-risk settings. This study offers significant insights into current attempts to enhance the quality and performance of RSW in HSLA 355 stainless steel applications by illustrating the relationship between qualities employing welding and joining.*

Keywords: *HSLA 355 Stainless Steel, Mechanical Performance, Optimization, Process Parameters, Resistance Spot Welding*

1.0 Introduction

Almost all metals can be joined using the resistance spot welding technique, which is regarded as one of the first electric welding techniques still in use today[1,2]. A popular technique for joining metal components in a variety of sectors is resistance spot welding[3,4]. It has become well-known for its effectiveness and superb craftsmanship in creating long-lasting goods[5,6]. However, weld seam correction has become essential as the industry evolves and demands more performance and dependability from welded connections[7,8]. By analysing the parametric aspects of RSW to manage its impacts and work based on participatory procedures, recent research has not only addressed the

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necessity of the requirement but also attempted to improve it[9,10]. More research on RSW is required, according to recent findings[11,12]. To enhance the qualities of welded connections, authors underlined the necessity of optimising the surface spot welding process of high-strength materials[13,14]. Authors have stressed how crucial it is to research the welding parameters and how they affect joint strength, particularly when working with different materials[15,16]. Understanding the intricacies involved in the failure mechanisms is also essential[17,18]. The formation of internal fissures caused by liquid metal embrittlement during tensile shear testing of welded surfaces was ascertained by the author using 3D characterisation[19,20]. The aforementioned research highlights how crucial it is to comprehend the different components of failure[21,22]. Changing microstructural characteristics is crucial to getting good spot welding results[23,24]. Investigated the connection between fatigue life and microhardness in spot welding[25,26]. To optimise the spot welding process, the authors stressed the significance of taking microstructural characteristics into account[27,28]. Furthermore, research on how temperature affects the electrical characteristics of duplex stainless steel's electrical and electronic components has shown how crucial it is to modify heating to get the required weld qualities[29,30]. When combined, the aforementioned findings demonstrate how urgently spot welding procedures need to be further examined and improved[31,32].

2.0 Literature Summary

These studies address a wide range of subjects, such as new welding techniques, material combinations, and modifications to enhance performance, mechanical qualities, and integration for particular applications[33,34]. Because of its excellent performance and robust integrity, resistance spot welding is a significant joining technology that is utilized in many different industries[35,36]. Despite its significance, the RSW sector urgently needs more research and development because of some significant problems that have surfaced from recent studies[37,38]. Additionally, research has shown how crucial it is to comprehend the metallurgical characteristics and corrosion behavior of welding consumables to enhance our comprehension of the functionality and longevity of RSW surfaces[39,40]. These results open up new avenues for investigation in this field[41,42]. In conclusion, new research has highlighted the necessity of a thorough assessment of the RSW procedure[43,44].

3.0 Objectives of the Research Work

To perform metallurgical testing, analyse the impacts of heat treatment, and adjust the welding conditions.

To enhance the mechanical characteristics and lifespan of spot-welded junctions between disparate materials is the goal of these studies.

4.0 Methodology and Experimental Setup

The details of the experimental setup are provided in subsequent points.

4.1 Experimental Setup and Machine Specifications

The RSW experimental setup, manufactured by Kirti Pressings Pvt. Ltd. and is available with Janak Industries, Ambad, Nashik, as shown in Figures 1 and 2. This advanced system allowed for accurate control of process parameters[45,46]. Table 1 illustrates data of machine specifications. The Figure 1 represents experimental setup of RSW.

The Figure 2 depicts the welding parameters of control panel. In the manufacturing and automotive

Table 1. Machine specifications[3]

Sr. No	Machine Specification	Unit	SS125l
1	Rated power	kVA	125
2	Welding current max	kA	24
3	Control type	-	AK-54V
4	Welding time setting least count	Ms	10
5	Arm gap max	Mm	300
6	Electrode force min-max	Kg-f	150 to 984
7	Free air consumption @ 1 bar for 100 spots	Liters	314
8	Cooling water pressure	Kg/cm^2	2
9	Cooling water flow rate	L/min	6
10	Dimensions	Mm	1050 x 410
11	Height	Mm	1780
12	Weight	Kg	680

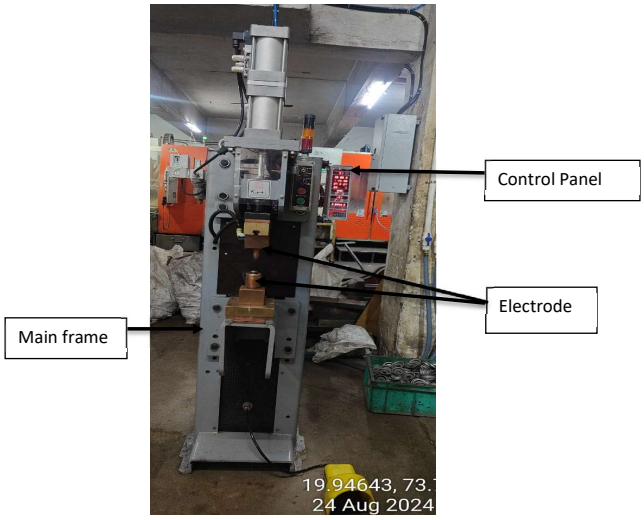


Figure 1. RSW experimental setup[5]



Figure 2. Welding parameters of control panel[7].

sectors, RSW is a common technique that joins metal sheets by passing electrical current and pressure through electrodes[47,48]. Several crucial process variables, including welding current, electrode force, and weld time, affect the weld's quality and strength[49,50]. RSW is a productive and successful technique for mass production in metalworking applications since accurate control and optimisation of these parameters are necessary to provide dependable and consistent welds[51,52].

1. Welding Current:
   The amount of current that passes through the welding electrodes to the workpieces[53,54]. Higher current leads to more heat generation, which is essential for melting the metal and forming the weld nugget[55,56]. Typically measured in kiloamperes (kA).
2. Electrode Force:
   The pressure applied by the electrodes on the workpieces during welding. It affects the heat generation and the mechanical strength of the weld. Too little force can lead to expulsion, while too much force can lead to insufficient nugget formation.
3. Weld Time:
   The duration for which the welding current is applied. Longer weld times allow for more heat generation and deeper penetration, but can also lead to excessive heat and weakening of the material.
1. Squeeze Time:
   The time allowed for the electrodes to apply pressure on the workpieces before the current is initiated. This ensures proper contact between the materials.
2. Hold Time:
   The time for which the pressure is maintained after the current is turned off. This allows the molten material to solidify under pressure, ensuring a strong weld.
3. Electrode Geometry:
   The shape and size of the electrodes can influence the current density and the heat distribution. Common geometries include flat and dome-shaped electrodes.
4. Material Properties:
   The type of materials being welded, including their thickness and surface condition, can impact the welding parameters. Different materials require different settings for optimal welding.
5. Shunting:
   In multi-spot-welding scenarios, the presence of neighbouring welds can influence current flow, which may need to be compensated for by adjusting parameters.
6. Cooling Rate:
   The rate at which the weld cools down affects the microstructure and the mechanical properties of the weld joint.

7. Electrode Wear:
   Over time, electrode tips wear out, affecting the quality of the weld. Regular maintenance and replacement of electrodes are essential.

Fine-tuning these parameters is crucial to achieving the desired weld quality, and optimisation often involves experimental trials and analysis, such as DOE (Design of Experiments) or other optimisation techniques[57,58].

The finalised maximum and minimum parameter ranges are outlined below, representing the optimal limits determined through the experimentation process[59-61]. The ranges of significant processing parameters are shown in Table 2.

Table 2. Ranges of significant processing parameters[9]

Parameter	Min	Max
Welding Current	8.5	10
Squeeze Time	30	50
Hold Time	18	50
Weld Time	20	35
Welding Pressure	3.5	4.5

Figure 3, 4 and 5 shows the specimens prepared before the Spot Weld of the above combination and marked with numbers. These specimens are prepared in the Janak Industry, Ambad MIDC, Nashik.



Figure 3. Sample preparation[11].



Figure 4. Welded sample preparation[13].

4.2 Resistance Spot Welded Fractography

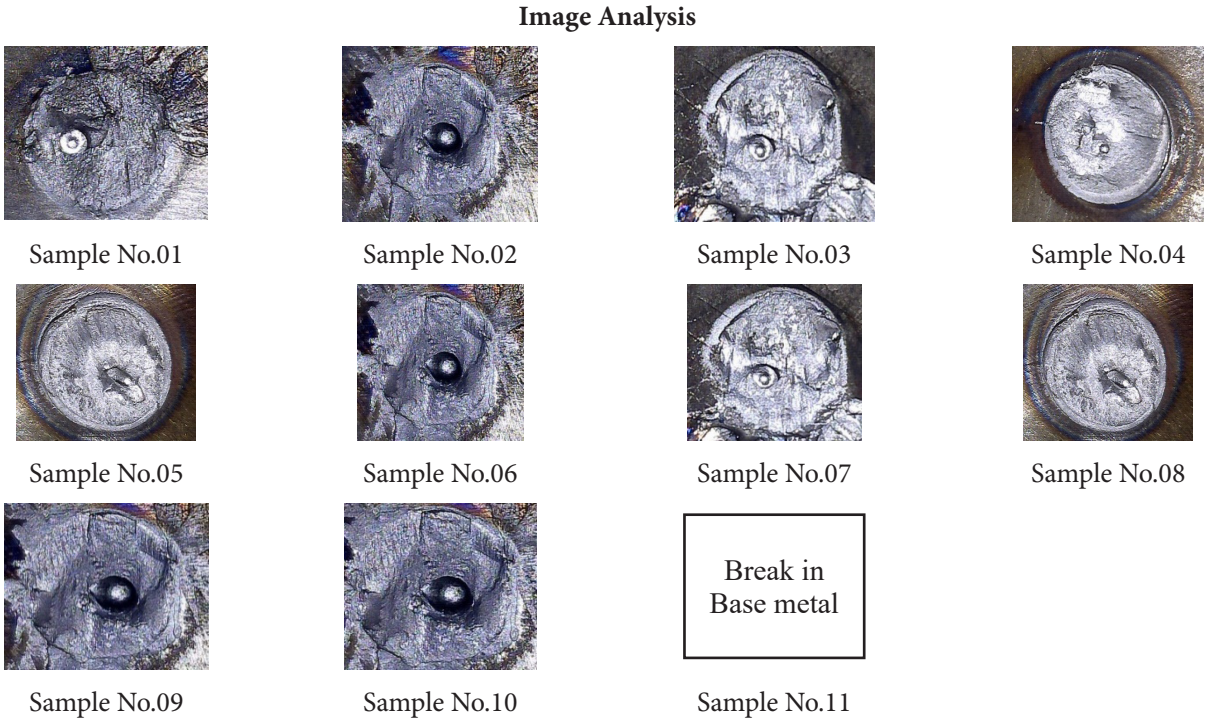


Figure 5. Image analysis for tensile strength[15].

5.0 Results and Discussion

Figure 6 shows the relationship between Squeeze time and tensile strength. In this figure, the highest tensile strength was observed in the 11th test with a Squeeze Time of 47 cycles.

Figure 7 shows the Welding current vs. tensile strength. In this graph maximum tensile strength was observed in the 11 experiment by using 10KA welding current.

Figure 8 shows the hold time vs. tensile strength. In this graph maximum tensile strength was observed in the 11th experiment by using 48 48-cycle hold time.

Figure 9 shows the Weld time vs. tensile strength. In this graph maximum tensile strength was observed in the 11th experiment by using 35 cycles of Weld time.

Figure 10 shows the hold time, weld time, welding current, squeeze time, and pressure vs tensile strength. In this graph maximum tensile strength was observed in the 11th experiment by using above above-specified parameter.

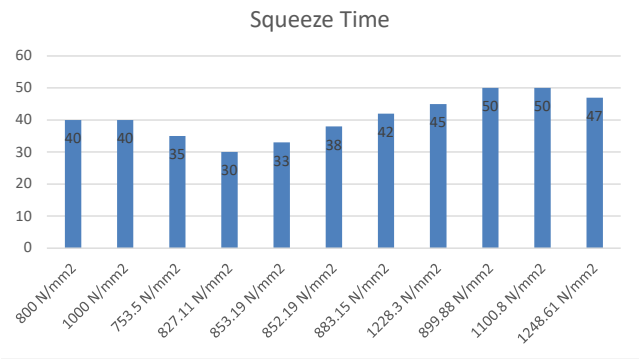


Figure 6. Squeeze time VS tensile strength.

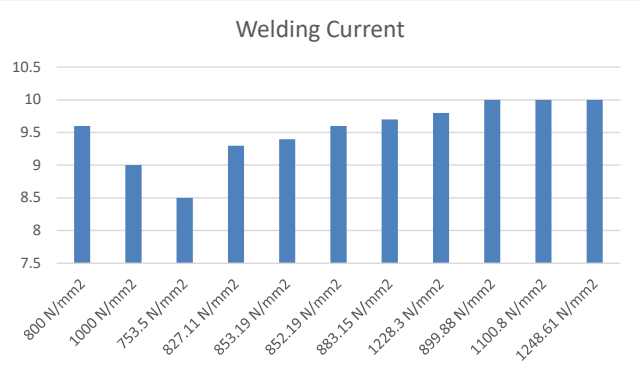


Figure 7. Welding current VS tensile strength[19]

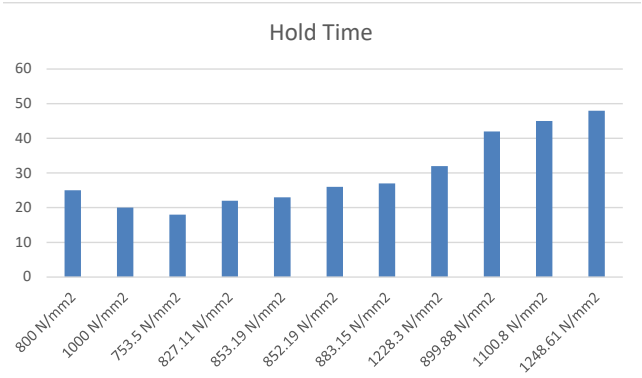


Figure 8. Hold time VS tensile strength.

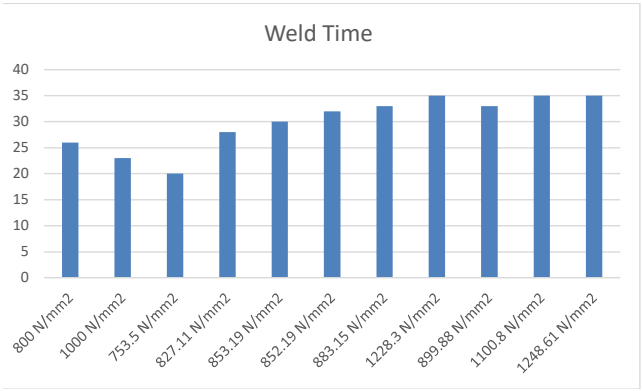


Figure 9. Weld time VS tensile strength.

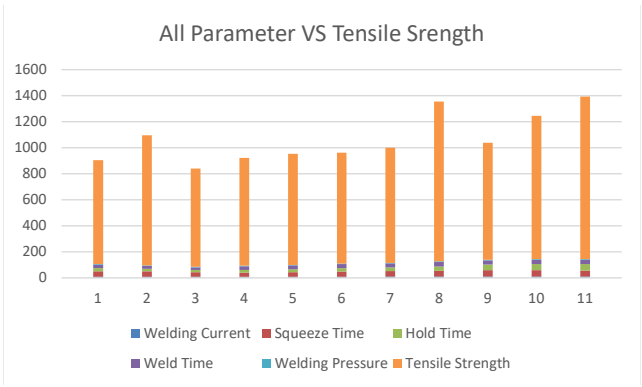


Figure 10. Hold time, weld time, welding current, squeeze time, pressure vs tensile strength.

6.0 Conclusion

In conclusion, it is crucial to take into account how RSW process factors affect joint performance and productivity to guarantee the dependability and quality of welded connections. Numerous studies and tests

have demonstrated that the choice and optimisation of RSW process parameters can have a substantial impact on several joint quality factors, such as weld core size, mechanical characteristics and overall productivity. The heat input, thermal cycle and pressure exerted during the welding process are all directly impacted by process variables such as welding current, welding time, electrode force, and electrode material. The creation of the weld core, which is crucial in defining the joint's strength and integrity, can be controlled with careful manipulation of these parameters. Furthermore, difficulties like weld flaws like porosity, fractures, and lack of penetration can be decreased with the right process parameter selection.

Joint performance is also enhanced by optimising RSW process parameters. The joint shows enhanced mechanical qualities, such as tensile strength, fatigue strength, and corrosion resistance, by attaining the required weld quality and integrity. These characteristics are crucial for guaranteeing the endurance and structural soundness of welded components in a variety of sectors, including construction, automotive, and aerospace. In conclusion, creating welded joints of superior quality and dependability requires an awareness of and ability to regulate the impacts of RSW process parameters on joint characteristics and performance. Joint strength, mechanical characteristics, and overall performance will all be enhanced by careful parameter selection and optimisation. Additionally, this will increase cost-effectiveness and process efficiency. Resistance spot welding technology will advance with more research and development in this field, which will eventually help a variety of sectors that require welded components.

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