



Tensile Strength Analysis of Resistance Spot Welding

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ABSTRACT

Spot welding is an electrical resistance welding method in which two or more metal sheets are clamped between two electrodes, then a low-voltage electric current is flowed between the electrodes, the metal in contact becomes hot and the temperature rises to the welding temperature, as soon as the welding temperature is reached, the pressure between the electrodes forces the metals together and a welded joint is formed. Tensile testing is to determine the strength of the point weld joint, also to get the stress and strain, in this study using a galvanized mild steel plate with a thickness of 0.2 mm with time variations of 4 seconds, 6 seconds, 8 seconds. The results obtained after a tensile test for 4 seconds obtained a maximum load of 23.5 kg/, and the lowest was 15.7 kg, in 6 seconds the maximum load was 78.8 kg, the lowest was 47.2 kg, in 8 seconds the load was obtained. maximum 87.1 kg, the lowest 43.3 kg. The highest stress from the three times is at 8 seconds at 7.705 kg/mm², the lowest at 4 seconds is at 1.388 kg/mm², while the highest strain from the three times is at 8 seconds at 2.434, the lowest is at 4 seconds at 0.034.

Keywords: Spot Welding, Time Variation, Tensile Strength

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1. Introduction

Welding is a technique used to join two or more metal materials by utilizing heat as the energy source. Along with technological advancements in the field of welding, manufacturing companies are required to continuously improve the quality of their products in order to remain competitive. Currently, there are various welding methods whose applications are adjusted according to the type of metal being joined, one of which is the spot welding method. The Resistance Spot Welding (RSW) process has developed in line with the increasing availability of more economical electrical energy. Welding technology is not applied to the manufacture of only a single type of product; therefore, variations in welding time are used as a parameter to evaluate the tensile strength of welded joints. The material used in this study is galvanized steel

plate, with the aim of determining the effect of different welding times on the joint quality in the spot welding process.

Hardness testing was conducted on bent specimens using deflection variations of 6 mm, 12 mm, and 18 mm. To determine the wear value obtained from wear testing on bent specimens using deflection variations of 6 mm, 12 mm, and 18 mm.

The benefits of this research are as follows:

- For the researcher, to determine grain size and to identify the results of microstructure testing on square hollow steel profile specimens with deflections of 6 mm, 12 mm, and 18 mm.
- For future research, the hardness test results can be further developed by varying the deflection in order

to determine the hardness limits of square hollow steel profiles.

- Future studies can continue this research to determine the magnitude of strain and stress occurring in square hollow steel profiles after bending using deflections of 6 mm, 12 mm, and 18 mm

1.1 Basic Theory of Spot Welding

Spot welding is a process of joining two or more metal sheets by applying pressure while simultaneously passing a high electric current for a short period of time at a specific point. This method is classified as a type of electrical resistance welding, in which the metal sheets are clamped between two electrodes. A low-voltage electric current is then conducted through the electrodes, causing the contacting metal surfaces to heat up until they reach the welding temperature. Once the welding temperature is achieved, the pressure applied by the electrodes causes the metals to fuse, forming a strong welded joint.

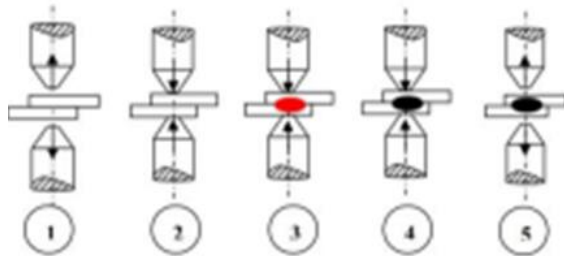


Figure 1 Spot Welding Process

1.2 Spot Welding Parameters

Spot welding parameters are a set of variables that influence the process conditions and the quality of the welded joint in spot welding. In practical applications, the number of parameters affecting the spot welding process is very large; some researchers even suggest that more than one hundred parameters can influence welding results. Therefore, to achieve a structured understanding, this section discusses several main parameters that have the most significant impact on the spot welding process.

1.2.1 Weld Current

Weld current is the magnitude of electrical current supplied during the welding process to generate sufficient heat for the metal to melt and fuse.

In the context of spot welding, weld current is the most critical factor.

Functions of weld current:

- Generates heat through electrical resistance (I^2R)
- Determines the size of the weld nugget (spot weld)
- Influences the strength of the welded joint

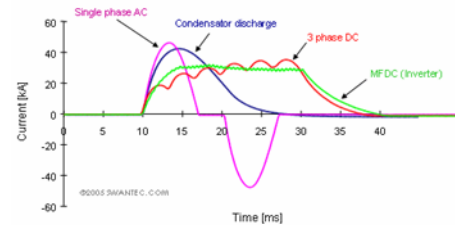


Figure 2 The magnitude of the weld current for a specific welding machine

1.2.2 Squeeze Time

Squeeze time is the time interval during which the electrodes of a spot welding machine apply pressure and clamp the workpieces before the welding current is supplied. During this stage, no electric current flows; only the electrode force is applied to ensure proper contact between the workpieces.

1.2.3 Welding Force

Welding force is the magnitude of pressure applied by the electrodes to the workpieces during the welding process, particularly in spot welding or resistance welding. This force is applied before, during, and after the welding current flows.

Main functions of welding force:

- Maintaining good electrical contact: Without sufficient pressure, the current cannot flow uniformly.
- Controlling welding heat: Pressure affects electrical resistance; higher force reduces resistance, resulting in lower heat generation.
- Preventing expulsion (spatter): Adequate pressure restrains molten metal from being expelled from the weld zone.
- Forming a uniform weld nugget

A sound weld nugget requires appropriate and consistent pressure. Welding force is a key parameter in spot welding that determines contact stability, heat distribution, and joint strength. Proper welding force produces strong, uniform welds with minimal defects

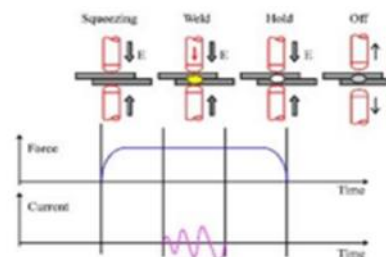


Figure 3 Relationship between Force and Time

1.2.4. Weld Time

Weld time is the duration for which the welding current is passed through the workpieces during the welding process, particularly in spot welding (resistance welding). During this phase, heat is generated, causing the metal to melt and fuse, forming a weld nugget (spot weld).

Weld time determines how long heat is applied at the weld location. When electric current flows through two sheets pressed by the electrodes, heat is generated due to electrical resistance. If the duration is appropriate, the metal melts sufficiently and forms a strong welded joint.

1.2.5 Hold Time

Hold time in spot welding is the period after the welding current has been switched off while the electrodes continue to apply pressure to the workpieces. During this stage, no electric current flows, but electrode pressure is maintained.

The function of hold time is to support and stabilize the weld nugget, which is still hot and in a molten or semi-molten state, allowing it to cool and solidify properly. If the electrodes are released too early, the nugget may crack, become porous, or result in a weak joint.

1.2.6 Contact Resistance

Contact resistance in spot welding is the electrical resistance that occurs at the interfaces between: the electrode and the sheet surface, and The interfaces between the two metal sheets being welded.

This resistance converts electrical energy into heat, enabling metal melting at the weld spot.

In practice, metal surfaces are never perfectly smooth. When two sheets are pressed together, contact occurs only at microscopic points. This limited contact area creates resistance to the flow of electric current, resulting in localized heat generation at the weld zone.

1.2.7 Electrode Contact Surface

The electrode contact surface in spot welding is the tip of the electrode that comes into direct contact with the surface of the metal sheet during the welding process. This area serves as the entry path for electric current and also acts as the medium for transmitting pressure to the workpiece.

The electrode contact surface is a key element that determines the distribution of current and pressure in spot welding. Its condition, shape, and size must be maintained to ensure that heat is focused at the interface between the sheets, resulting in a strong, uniform, and consistent weld nugget.

1.3 Spot Welding

The spot welding process involves joining sheets together using two electrodes made of copper alloy, which can conduct high current in a short period of time. As electric current flows between the two electrodes, it

passes through the metal at the contact area, generating heat that melts the metal in that region to form a joint. Although electrical resistance also exists at the contact point between the electrodes and the sheets, the melting occurs primarily at the interface between the sheets, where the resistance is higher.

The main function of the electrode pressure in this process is to press the electrodes against the workpieces, forcing the workpieces to make intimate contact with each other. This allows the electric current to flow through the contact area. When the bonding temperature is reached, the contact point is pressed together to form the weld.

Spot welding is a type of resistance welding in which two or more sheets are placed in contact, and a high current is passed through copper electrodes. The area between the metal sheets under the electrodes becomes heated due to electrical resistance until the welding temperature is reached, causing the two sheets to fuse in that area (Nofriady, 2013). According to Amstead (1995), the area under the electrodes is expected to generate heat due to electrical resistance; however, the sheets do not melt at the electrode contact surfaces because the surface resistance is lower than the resistance between the two sheets.

In spot welding, the process is divided into four phases: squeeze time, weld time, hold time, and off time. Squeeze time is the period between electrode contact and the start of current flow. Weld time is the duration during which the electric current flows. Hold time is the period during which pressure is maintained while the current is no longer flowing. Off time is the period when the electrodes are separated from the workpieces, during which no current or voltage is applied (Purwaningrum, 2014).

The formula for spot welding is as follows:

$$H=I^2 R t$$

Where:

H = Heat generated (joules)

I = Welding current (amperes)

R = Resistance (ohms)

t = Welding time (seconds)

1.4 Working Principle of Spot Welding Machine

In spot welding, the welding transformer converts an input voltage of 110 or 220 volts into a much higher current sufficient to generate the desired heat. The sheets to be joined are placed together at the joint and clamped between a pair of copper alloy electrodes. A high current is then passed through the electrodes for a short period, causing electrical resistance in the metal at the contact area to generate heat at that location. This heat melts the metal momentarily and forms the weld joint.

Heat is also generated at the contact points between the electrodes and the sheets; however, since the electrode

tips are cooled with water, they do not melt the metal. If the power supply fails, the molten metal cools and solidifies under the pressure of the electrodes, preventing an arc from forming between the electrodes and the joint.

Spot welding begins when the electrodes are pressed against the sheets, during which no current flows. This processing period is known as squeeze time. After the current is supplied to the electrodes, heat is generated in the sheets at the electrode contact area, forming the weld joint. This process time is referred to as weld time.

The transformer consists of separate windings, namely the primary and secondary coils. When an AC current flows through the primary coil, it generates a magnetic field or magnetic flux around it. In this design, the transformer functions as a spot welding machine by replacing the secondary winding with welding cables (Ilham, 2017).

1.5 Basic Principles of Spot Welding

Spot welding is a type of resistance welding that falls under the category of pressure welding. The basic process involves welding by applying pressure to the stacked base metal sheets held between two electrodes. A large amount of electric current is used, and the heat generated (Joule heat) by the current in the contact area causes the joint area to melt. Pressure is required to fuse the molten metals together.

The execution of spot welding depends on four main factors, as stated by Hartono and Okomura (2000):

- Welding Current

The welding current must be precisely controlled and not excessive. The current value should be adjusted according to the type and thickness of the metal sheets to be joined, because improper current can affect the quality of the weld.

- Effect of Pressure in Spot Welding

The pressure applied at the weld area must be carefully controlled. The purpose of applying pressure is to ensure that the metal sheets being welded are in full contact with each other, so that electrical resistance and conductivity during the welding process remain stable

- Squeeze Time

Squeeze time is the initial stage of the welding process, during which the electrodes make contact with the metal and apply pressure before the electric current is supplied. After the squeezing stage is completed, a low-voltage current is applied, causing the contacting base metal surfaces to heat up until the welding temperature is reached. Once the metal melts and fuses, the current flow is stopped while the pressure is still maintained. This stage is known as hold time.

- Electrode Tip Surface

The diameter of the electrode tip affects the strength of the spot weld joint. If the electrode tip diameter is too small, the resulting weld joint tends to have lower strength

1.6 Effect of Squeeze Time on Spot Weld Joints

Squeeze time is the period during which the metal is held between two electrodes before the electric current is applied. This squeezing time is necessary to delay the current flow until the electrode pressure reaches the desired level. The duration of the squeeze stage determines the welding outcome and the required joint strength. Spot welding involves joining plates by melting a specific area or multiple areas through the heat generated by electric current flowing between two electrodes (Handra, 2014).

The length of the squeeze time affects the resulting material strength. Therefore, spot welding tests need to be conducted to investigate the weld strength for different squeeze time durations. Variations in squeeze time are applied, and the strength of the resulting weld nugget is evaluated.

Squeeze time, also known as the pressing time, is the period during which the welding electrodes press the sheets without current flow. The welding process then continues with weld time (heat time), during which the current is supplied to form the weld joint. After the current is stopped, the pressure is maintained while the metal is allowed to cool until the bond becomes strong, and the pressure is finally released

Spot welding is a resistance welding method performed by clamping two metal sheets using metallic electrodes. The welding process begins when the electrodes contact the metal surfaces and apply pressure before the electric current is supplied. This initial period is known as squeeze time. Subsequently, a low-voltage current is passed through the electrodes, causing the contacting metal areas to heat up until the welding temperature is reached. Once this temperature is achieved, the electrode pressure causes the two metals to fuse together and form a welded joint.

The quality and characteristics of the spot weld joint are influenced by various parameters, including welding duration, the magnitude of current and voltage used, and the pressure applied during the welding process.

1.7 Working Principle of a Spot Welding Machine

The working principle of a spot welding machine begins with a transformer that reduces the alternating current voltage from a power source of 110 or 220 volts to approximately 4–12 volts, while increasing the current to a high value capable of generating the heat required in the welding process. The metal sheets to be joined are then clamped at the joint area using a pair of copper alloy electrodes. A

high current is subsequently applied for a short period through these electrodes, causing electrical resistance at the clamped spot to generate heat. This heat melts the metal at the joint area, allowing the sheets to fuse together.

Temperature also rises at the contact area between the electrodes and the sheets; however, the electrodes do not melt because their tips are cooled by water flow. After the current is stopped, the molten metal cools and solidifies, forming the weld joint, while the electrode pressure is maintained to prevent an electrical arc between the electrodes and the joint.

The spot welding cycle starts when the electrodes press the sheets without current, which is known as squeeze time. The next stage is the flow of current through the electrodes, generating heat in the joint area and forming the weld, which is referred to as weld time (heat time). The transformer itself consists of insulated primary and secondary coils. When the primary coil is energized with alternating current, a magnetic field is generated around it. In this design, the transformer is utilized as a spot welding machine by modifying the secondary coil using NYAF cables.

1.8 Basic Principles of Spot Welding

Spot welding is a type of resistance welding that belongs to the pressure welding group. Its main principle is joining metals by applying pressure to the base metal sheets held between two electrodes. A large electric current is used, so the heat generated due to electrical resistance is concentrated at the joint area, causing the metal in that region to melt. To ensure the metals melt together and fuse properly, pressure is required to hold and compress the metal during the welding process.

In general, the spot welding process consists of three main stages: squeezing, current flow, and holding. In the initial stage, the electrodes apply pressure to the metal surfaces so that the two sheets make contact when the electric current begins to flow. Next, a high current flows through the electrode tips and penetrates the base metal sheets, producing Joule heat in the joint area where resistance is highest. As a result, the temperature in that area rises rapidly. With continued current flow, the base metal at the joint area melts and fuses together, while pressure is maintained through the electrodes. After the current is stopped, the joint area gradually cools and forms a weld nugget. The pressure that remains is intended to compact the nugget, improving the weld quality and mechanical strength.

In practice, each process stage must be performed carefully and correctly because small errors can easily occur due to negligence. The characteristics of spot welding can be explained as follows:

- Since the welding time is relatively short and the heat is concentrated in a specific area, the likelihood of distortion defects is very small.

- Spot welding is highly suitable for joining thin sheets with thicknesses of approximately 0.7 to 1.4 mm (0.028–0.055 inches).
- This welding process does not require high levels of skill or experience from the operator.
- The high current requirement makes spot welding equipment generally large and heavy.
- The quality and integrity of the weld joint are difficult to assess solely from the surface appearance, because the melting occurs at the contact area between the base metal sheets

2. Methodology of Research

2.1 Research Flowchart

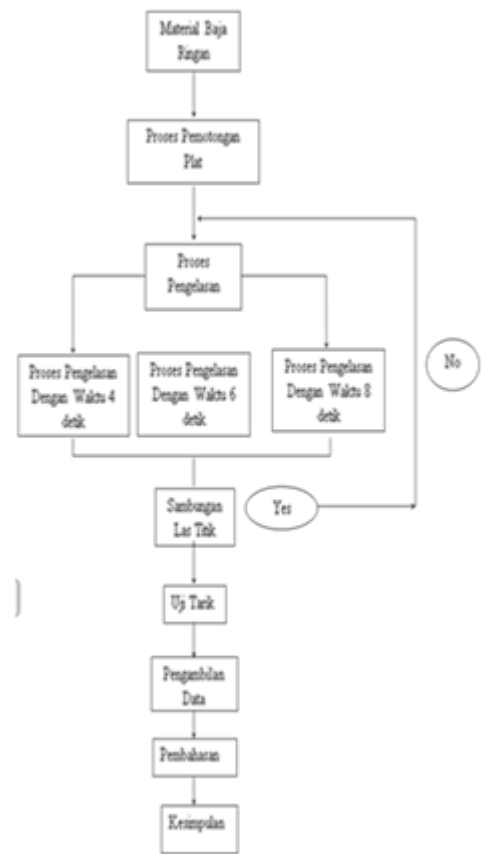


Figure 4 Research Flowchart

2.2 Research Time and Location

The testing process was carried out at the Materials Laboratory, Department of Mechanical Engineering, Universitas Merdeka Malang. The tests were conducted from June to July 2022.

2.3 Research Variables

- Independent Variable
The independent variable used is the spot welding time, which is varied at 4 seconds, 6 seconds, and 8 seconds.
- Dependent Variable
The dependent variable used is the tensile strength of galvanized lightweight steel after spot welding with three different welding time variations

2.4 Research Equipment

- Spot Welding Machine: The spot welding machine is used to weld galvanized lightweight steel plates.

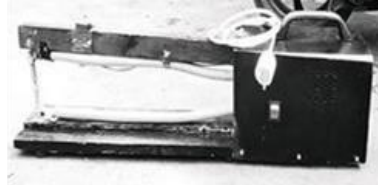


Figure 5 Spot Welding Machine

- Tensile Testing Machine : The tensile testing machine is used to pull the spot-welded specimens to determine their tensile strength.

Figure 6 Tensile Testing Machine



2.5 Research Materials

The specimens used were galvanized lightweight steel with a thickness of 0.2 mm

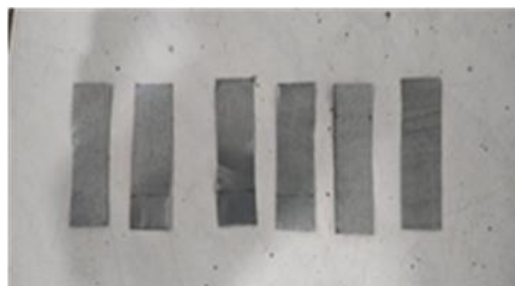


Figure 7 Research Material

3. Result and Discussion



Figure 7 Welding Result at 4 Seconds

Table 4.1 Welding Results for 4-Second Weld Time

Waktu pengelasan (detik)	Panjang awal (mm)	Panjang akhir (mm)	Tebal awal (mm)	Tebal Akhir (mm)	Lebar Awal (mm)	Lebar Akhir (mm)	Diameter awal (mm)	Beban maksimum (kg)
4 A	117	121	0,4	0,2	20	20	1,5	17,1
4 B	117	120	0,4	0,2	20	20	1,5	15,7
4 C	117	123	0,4	0,2	20	20	1,5	23,5



Figure 8 Spot Welding Result with 6-Second Weld Time

Table 4.2 Spot Welding Results at 6 Seconds

Waktu pengelasan (detik)	Panjang awal (mm)	Panjang akhir (mm)	Tebal awal (mm)	Tebal Akhir (mm)	Lebar Awal (mm)	Lebar Akhir (mm)	Diameter awal (mm)	Beban maksimum (kg)
6 A	117	128	0,4	0,2	20	20	1,5	47,2
6 B	117	123	0,4	0,2	20	20	1,5	78,8
6 C	117	124	0,4	0,2	20	20	1,5	57,6



Figure 9 Spot Welding Result with 8-Second Weld Time

Table 4.3 Welding Results for 8-Second Weld Time

Waktu pengelasan (detik)	Panjang awal (mm)	Panjang akhir (mm)	Tebal awal (mm)	Tebal Akhir (mm)	Lebar Awal (mm)	Lebar Akhir (mm)	Diameter awal (mm)	Beban maksimum (kg)
8 A	117	135	0,4	0,2	2	2	1,5	87,1
8 B	117	13	0,4	0,2	2	2	1,5	68,3
8 C	117	145	0,4	0,2	2	2	1,5	43,3

Tensile Test Specimens

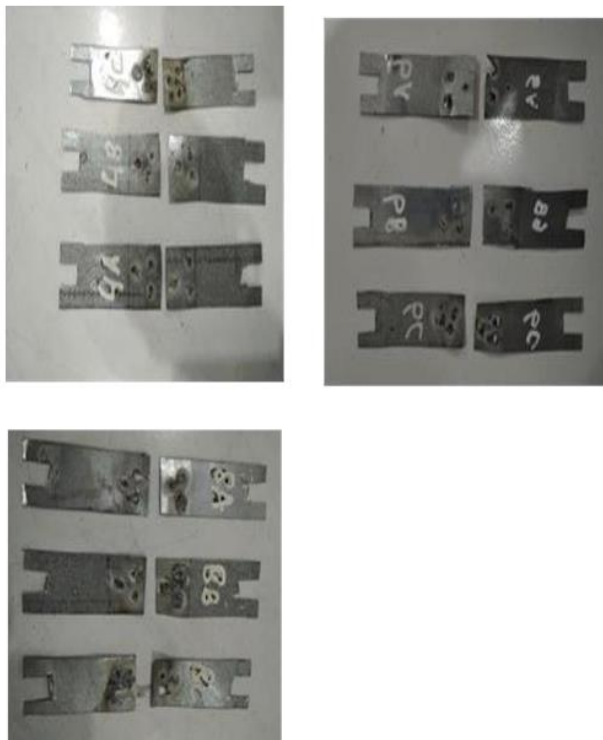


Figure 10 Tensile Test Specimens

Tensile Strength Calculation

1. Cross-Sectional Area Calculation

Cross-sectional area for one spot:

$$A_o = 3.768 \text{ mm}^2$$

Cross-sectional area for three spots:

$$A_o = 3 \times 3.768 = 11.304 \text{ mm}^2$$

2. Stress

Notation:

$$\sigma = \text{Stress (kg/mm}^2\text{)}$$

$$F = \text{Applied load (kg)}$$

$$A_o = \text{Cross-sectional area (mm}^2\text{)}$$

3. Strain

Notation:

$$\varepsilon = \text{Strain}$$

$$L_o = \text{Initial length (mm)}$$

$$\Delta L = \text{Change in length (mm)}$$

Table 4.4 Tensile Stress and Strain Calculation Results

Waktu Pengelasan (detik)	Luas Penampang awal (A _o)	Pertambahan Panjang (ΔL)	Tegangan (kg/mm ²)	Regangan (%)	Tegangan Rata-rata (kg/mm ²)
4 A	11,304	4	1,512	0,034	1,662
4 B	11,304	3	1,388	0,526	
4 C	11,304	6	2,078	0,521	
6 A	11,304	11	4,175	0,940	5,395
6 B	11,304	6	6,917	0,512	
6 C	11,304	7	5,095	0,598	
8 A	11,304	18	7,705	1,596	7,525
8 B	11,304	13	6,042	1,130	
8 C	11,304	28	3,380	2,434	

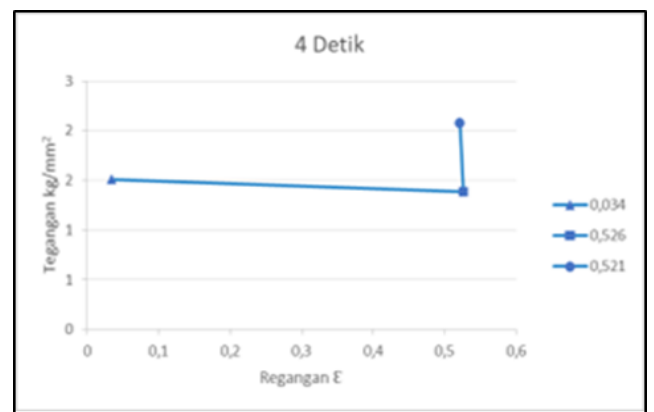


Figure 11. Tensile Test Graph for 4-Second Weld Time

Based on the graph above for a welding time of 4 seconds, the stress values obtained for the first 4-second test were 1.512 kg/mm², strain 0.034%, and load 17.1 kg. In the second 4-second test, the values decreased, yielding a stress of 1.388 kg/mm², strain of 0.526%, and load of 15.7 kg. In the third 4-second test, the values increased, with stress reaching 2.078 kg/mm², strain 0.521%, and load 23.5 kg.

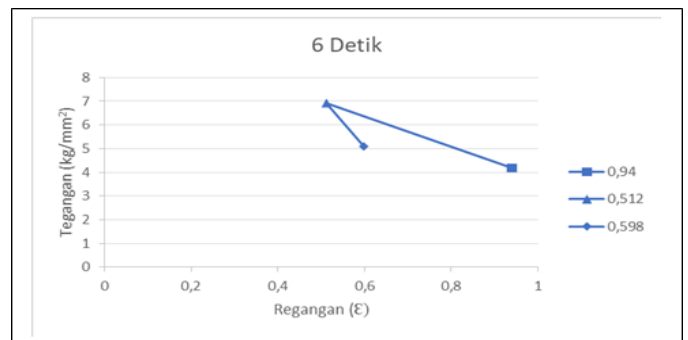


Figure 12 Tensile Test Graph for 6-Second Weld Time

Based on the graph above, it can be observed that in the first 6-second test, the stress value obtained was 4.175 kg/mm², strain 0.940%, and load 47.2 kg. In the second 6-

second test, the values increased, resulting in a stress of 6.917 kg/mm², strain of 0.512%, and load of 78.8 kg. In the third 6-second test, the values decreased, with a stress of 5.095 kg/mm², strain 0.598%, and load 57.6 kg

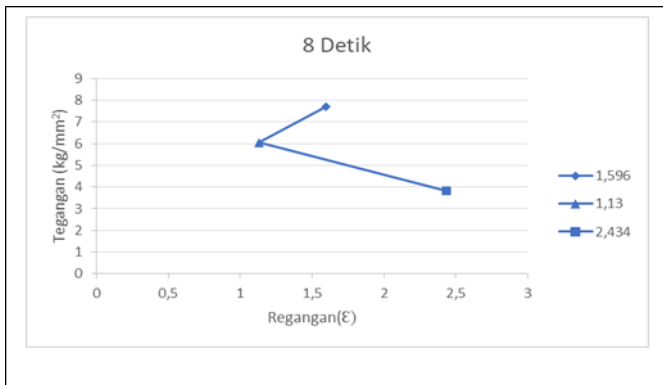


Figure 13 Tensile Test Graph for 8-Second Weld Time

Based on the graph above, the results for the first 8-second test show a stress value of 7.705 kg/mm², strain of 1.596%, and load of 87.1 kg. In the second 8-second test, the values decreased, with a stress of 6.042 kg/mm², strain of 1.130%, and load of 147.8 kg. In the third 8-second test, the values also decreased, yielding a stress of 3.830 kg/mm², strain of 2.434%, and load of 43.3 kg

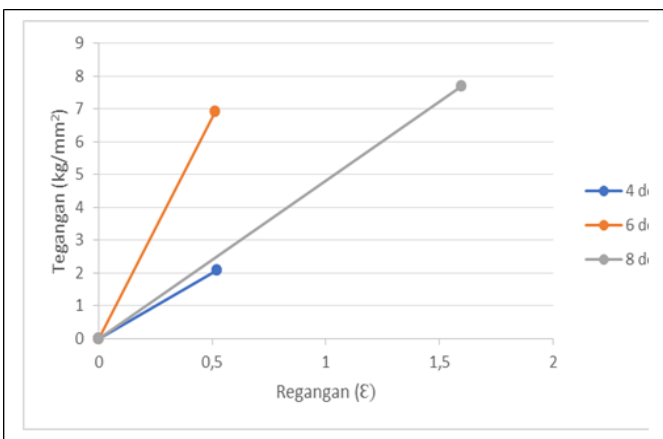


Figure 14 Comparative Graph of Tensile Test Results for 4, 6, and 8 Seconds

4. Conclusions

From the tensile test results with welding time variations of 4 seconds, 6 seconds, and 8 seconds, the following conclusion can be drawn: an 8-second welding time is the most optimal for spot welding, producing an average tensile stress of 7.525 kg/mm². This is higher compared to the 4-second welding time, which produced an average tensile stress of 1.662 kg/mm², and the 6-second welding time, which produced an average tensile stress of 5.395 kg/mm².

Reference

- [1] A. Amin and S. Anwar, "Pengaruh Variasi Arus Listrik Terhadap Kekuatan Tarik Geser Las Titik Beda Material Stainless Steel Dan Aluminium," *Al Ulum Jurnal Sains dan Teknologi*, vol. 5, no. 2, p. 44, 2020, doi: 10.31602/ajst.v5i2.2800.
- [2] E. Nugroho, U. S. Dharma, and S. Kurniawan, "Analisis Pengaruh Ketebalan Plat Baja Karbon Rendah Dan Lama Penekanan Pada Pengelasan Titik (Spot Welding) Terhadap Nilai Kekuatan Tarik," *Turbo: Jurnal Program Studi Teknik Mesin*, vol. 7, no. 1, 2018, doi: 10.24127/trb.v7i1.739.
- [3] M. Sahrevy, "Analisa Pengaruh Kuat Arus Dan Waktu Las Pada Proses Las Titik (Resistensi Spot Welding) Terhadap Kekuatan Tarik Pada Hasil Sambungan Las Pelat SS 400," [Nama Jurnal tidak tercantum], vol. 5, no. 2, pp. 114–119, 2021.
- [4] A. Ahmadil, *Pengaruh Variasi Arus Listrik Terhadap Kekuatan Tarik dan Struktur Mikro Sambungan Las Titik (Spot Welding) Logam Dissimilar Stainless Steel dan Baja Rendah*, 2017.
- [5] F. A. Harnudin, "Penelitian Pengaruh Ketebalan Plat dan Jumlah Las Titik Terhadap Kekuatan Tarik Las Titik (Spot Welding) Pada Baja St.37," Tugas Akhir S-1, Teknik Mesin, Universitas Muhammadiyah Surakarta, Surakarta, 2007.
- [6] R. Raldi, "Analisa Kekuatan Tarik Hasil Las Titik (Spot Welding) Pada Baja Karbon Rendah," 2009.
- [7] A. Anrial and H. Hendri, "Analisa Kekuatan Tarik Hasil Spot Welding Baja Karbon Rendah," *Jurnal Teknik Mesin*, vol. 1, no. 2, 2012.
- [8] E. Nugroho, U. S. Dharma, and S. Kurniawan, "Analisa Pengaruh Ketebalan Plat Baja Karbon Rendah dan Lama Penekanan Pada Pengelasan Titik (Spot Welding) Terhadap Nilai Kekuatan Tarik," *Jurnal Teknik Mesin UMM*, vol. 7, no. 1, 2018.
- [9] M. Alenius et al., "Exploring the Mechanical Properties of Spot Welded Dissimilar Joints for Stainless and Galvanized Steels," *Welding Journal*, Dec. 2006, pp. 305–313.
- [10] M. Anis et al., "Studi Lapisan Intermetalik Cu3Sn Pada Ujung Elektroda Dalam Pengelasan Titik Baja Galvanis," *Makara of Technology Series*, vol. 13, no. 2, pp. 91–95, 2009.