

Simplified Methodology Research for Parameter Setting of Resistance Spot Welding

Xuefeng Wang

McMaster University, Hamilton, Ontario, Canada

Abstract

The research is explored an efficient methodology in parameter setting for RSW (resistance spot welding). The methodology mainly focusses on weld cycles and weld current, which has included a process for parameter selection, performance evaluation, and failure mode analysis. Effects on welding resistance caused by various technical parameters. Relationship between weld cycles, weld current and the mechanical performance will be established by simplified model. Also, the parameter setting of welding operation, inspection methods, failure modes and control system will be discussed in the following content. This methodology will lead to higher efficiency and optimized quality during for manufacture parameter determination in sample A round before massive production. A proper resistance spot welding will be more economical engineering method for joints in the industry.

Keywords

Resistance Spot Welding; Parameter Setting; New Engineering Method.

1. Introduction

1.1. Background

Spot welding process are usually applied in assembly of sheet metals. Force on the electrode will act as clamping force to held workpieces together. Electric current will flow sthrough work pieses, the low-voltage and high-amprage current will form a short time pulesse to heat work piece on a certain point. Which is nugget, a fused nugget will cool down and solidifie in shot time to connect separated work pieces.

The electrode face size primarily lead to welds with varying sizes and shapes. Ideally, the nuggut will formed into a oval shape on section view of faying surfaces. The space must be applied between adjacent welding spots to avoid shunting to exceeds acceptable range.

Different engineering setting durring the process will lead to different performance. But the parameters are able to be controlled by computer PLC programming. A resistance spot welding in proper PLC setting with controlling in current; time; electrode clamping force will be a more economical engineering method for joints in the industry. Especially for the stamping parts in automobile BIW production process, the resistance spot welding would be able to offer advantages in production pace, yield rate, and sustainability.

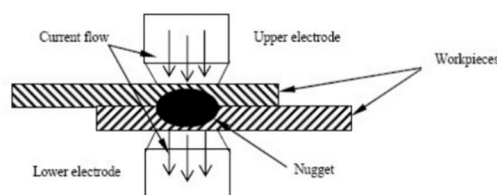


Figure 1. Spot Welding

The current evaluation for RSW is complicated model consisted by multiple parameters and steps, which is accurate in academic purpose but lack of efficiency to make rapid uncertainty decision during the testing.

1.2. Principles

The resistance spot welding involves with two significant parameters, magnitude in current and length of time. Electrodes and workpieces will form into a closed circuit. The heat accumulated in weld cycle to cause incipient fusion in workpieces. The confined volume of metal in fusion will form a agglomeration with temperature falling. The heat required to cause incipient fusion is produced by resistance of workpieces offered to the current flow through. The rate of heat accumulaton depends on the flow magnitude of current. Other electical factors, for example the voltage, frequency, etc will be regard as uniformity in this research.

The heat can be expressed by Ohm’s law and energy equation respect to current and volatge.

$$I = \frac{U}{R}, U = IR$$

$$P = \frac{E}{t}, E = Pt$$

$$P = UI$$

$$E = UIt$$

$$E = I^2Rt$$

Where I is current in Amps, U is volatge drop caused by current flow through workpiece in Volts, R is sum resistance of the workpiece in Ohms, E is the heat energy during the process in Jouls, t is time that current flow through the work piece.

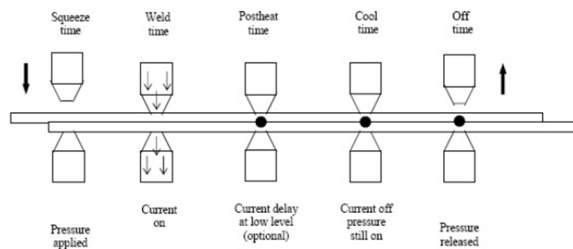


Figure 2. Weld Cycle

1.3. Apparentus



Figure 3. Experiment Apparatus

- A. Welding control unit
- B. Spot welder
- C. Tensile test machine – Instron 4400R
- D. Computer for control and data collection

2. Result

There are three failure modes appear in the tensile test result. Ductile shear fracture, tearing fracture, and brittle fracture. We regard the blank sample as the base line for the further analysis.

The failure mode for clean specimen is typically ductile and shear fracture (Figure 3). The necking is happening when tensile strength passed ultimate strength, significant deformation is observed before fracture. The result from tensile test has a fracture surface formed in approximately 45° after necking. Micromechanically, slip happening at the grain boundary. The critical resolved shear stress is on the slip plane. Under the condition of uniaxial loading, the maximum shear stress appear on the 45 degrees respect to ground axis based on the equation of $\tau = \frac{P}{2} \sin (2\theta)$. Which will be maximized at the $2\theta = \frac{\pi}{2}$.

Single weld specimens in test condition of (1 cycle 85% current) and (15 cyclesC 45% current); dual weld specimens in (1 cycle 85% current) and (7 cycles 45% current) have brittle fracture in tensile test. Fracture for four of them are all in the weld spot.

Single weld specimen in test condition of (15cycles 55%current), (6cycles 85current) and (11cycles 85%current) have 2-step failure in the tensile test. The resistance occurs after first brittle failure initiated; stress did not drop to 0 linearly beyond fracture strength. The combination of tearing failure and ductile failure are co-existing on the tested specimens.

Ductile failure is happened on the blank base material for the rest of the weld samples.

The fracture location is varying by different parameter setting. The brittle failure is happening at the weld joint. The ductile shear failure is happening at the base material. The 2-step failure is essentially a process of fracture propagation. Tearing initially happened on the edge of the weld joint.

3. Discussion

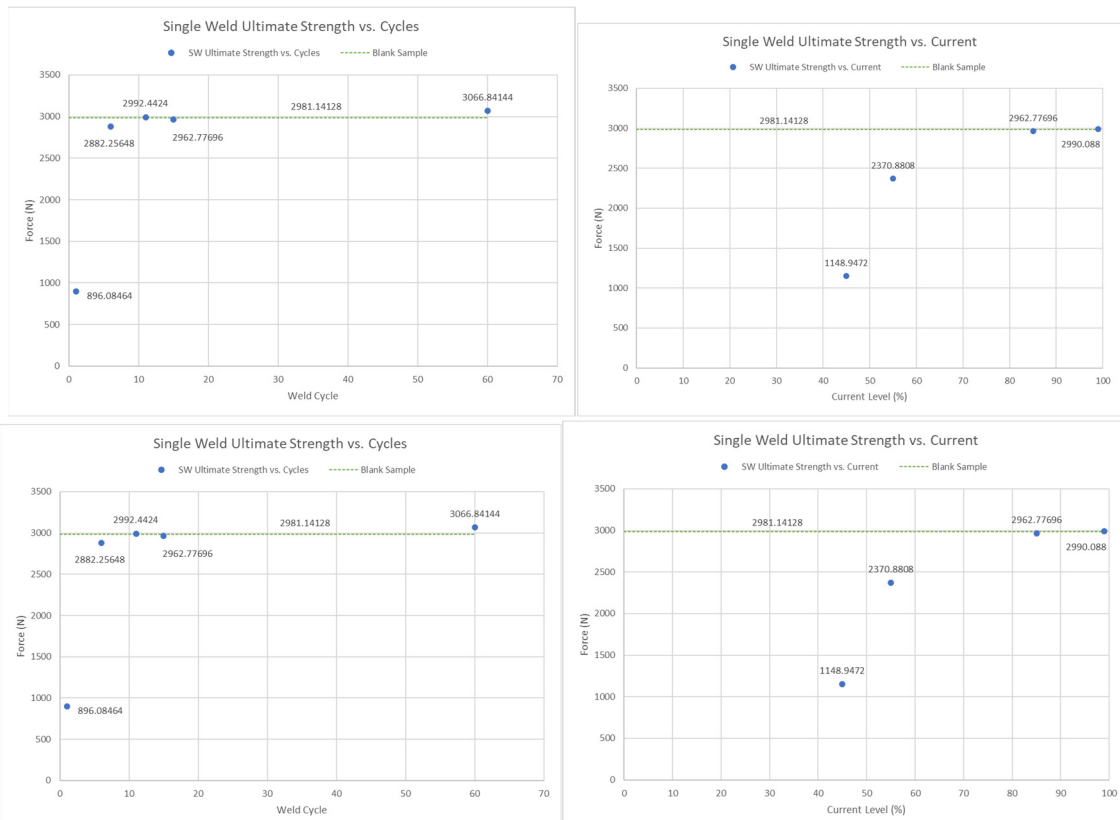


Figure 4. Ultimate Strength vs. Weld cycles and Weld current for single weld

With the increase the of weld cycles, the ultimate strength will increase to the level match with base material. The augment of current percentage will also increase ultimate strength for weld specimen to match with base material. The overall trend of relationship between cycles and current percentage are in logarithmic model. The high weld cycles are excessive for influence to ultimate strength in the welding process with correct current setting. The current influenced welding result in a controllable range, the current lower than 45% is insufficient to be workable even with high weld cycles. The current percentage offers a more accurate adjustable scale than weld cycles.

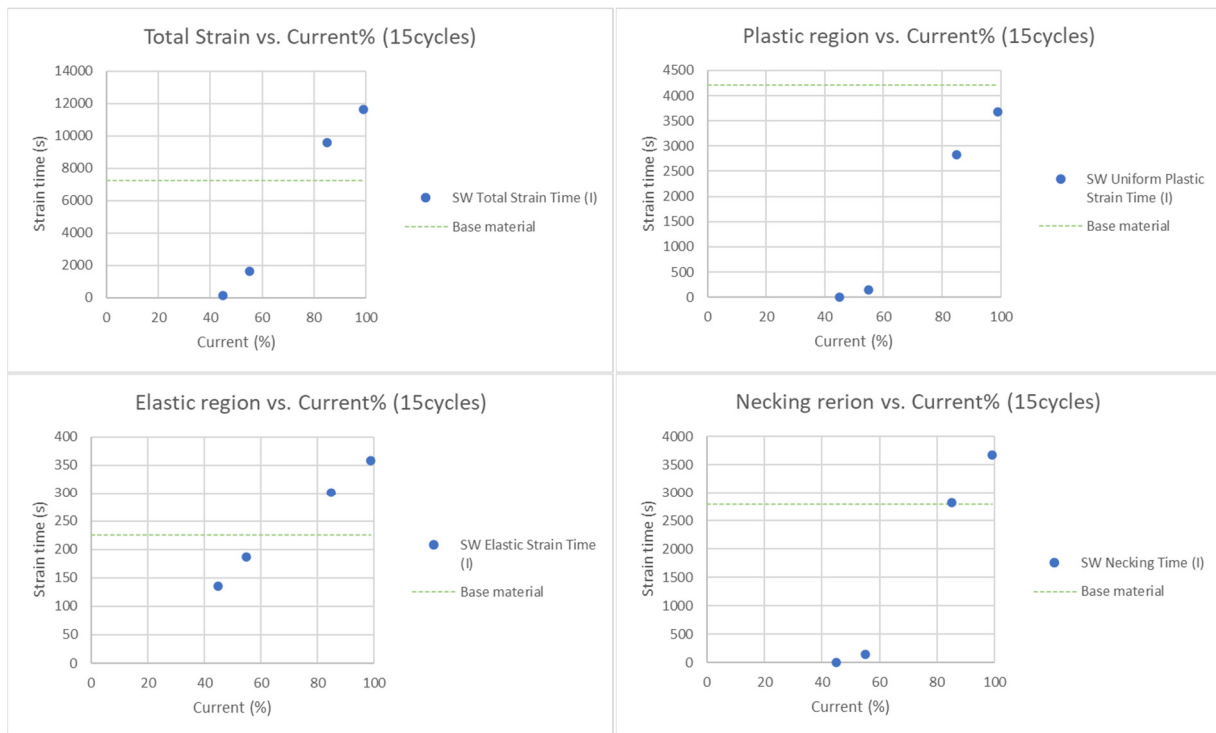


Figure 5. Strain respect to Current percentage in sections at 15cycles

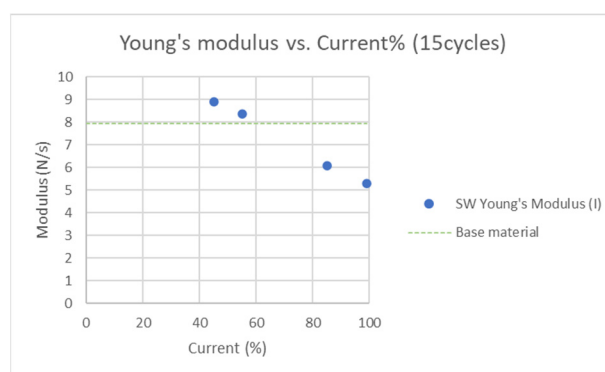


Figure 6. Modulus respect to Current percentage at 15cycles

Figure 5 above which illustrated the effect of current percentage to the tensile test in each period. We selected the 15 weld cycles as controlled variable to discuss the effect from current percentage. From data obtained, the strain time length is greater with increasing of current percentage. Increasing current percentage will lead to positive change in elastic region, uniform plastic region, and non-uniform plastic region (necking). Which indicate that, increasing current percentage will lead to higher ductility of the specimen. The increasing current

percentage will lead to lower modulus based on Figure 6, which restate positive correlation between current percentage and ductility.

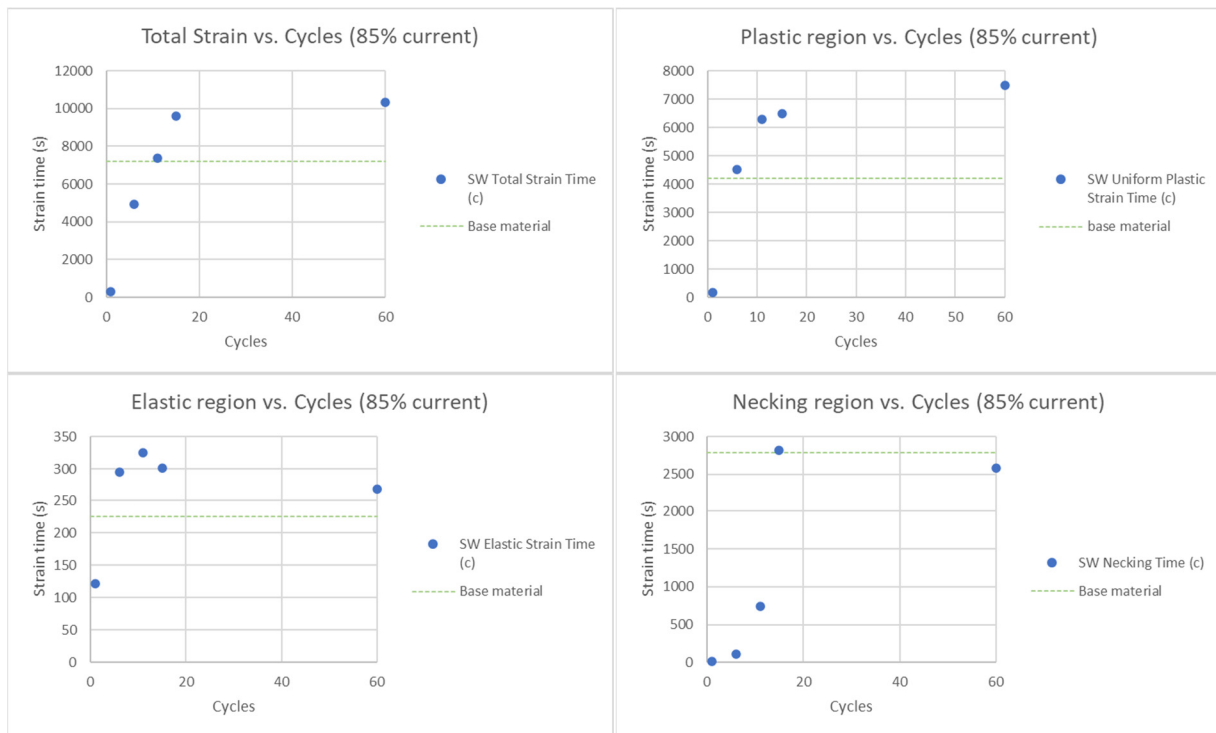


Figure 7. Strain respect to weld cycles in sections at 85%current

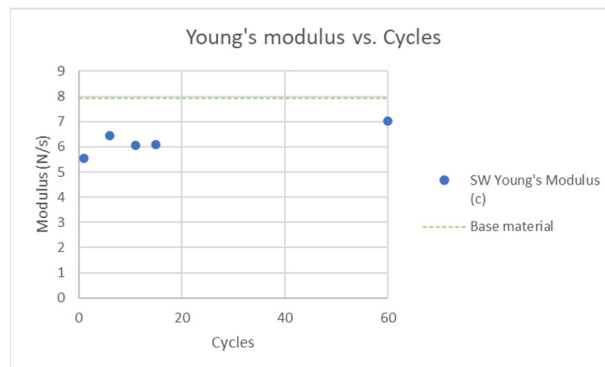


Figure 8. Modulus respect to weld cycles at 85%current

The result of effect from weld cycles in tensile test is discussed with controlled variable of 85% weld current. In the overall process, more weld cycles will lead to higher strain time length. In the different sub region in tensile test, the positive correlation between weld cycles and strain time length is conditional. In the uniform plastic region, more weld cycles will have positive influence on strain time length in logarithmic model. However, the influence caused by weld cycles on elastic region and non-uniform plastic region (necking region) have a peak value. More weld cycles add on to the process will lead to more strain time length before the peak value appear. After peak value, weld cycles increment will not lead to longer strain time length, instead it will have negative affect.

The brittle failures are seen at the weld nugget. The 2step-failure are seen at the edge between the weld zone and heat affected zone. The typical ductile shear failures are happened on the unwelded blank. The weld zone size for brittle failure is smaller than the specimens coming with ductile failure. Phenomenon indicates that the brittle failure is caused by insufficient heat

energy to form an acceptable weld nugget. To improve weld process with brittle failure, more heat energy should be applied to weld zone, either could be increase weld cycles or could be larger weld current. The 2-step failure are happened at the edge of the weld zone. The micro crack is initially generated in weld zone edge, this is because the heat energy diffused to the blank material around to form a heat affected zone. The fraction of martensite will increase in the zone. Martensite is making the area become brittle. With the crack grows further into the blank, the elongation of the non-affected area is greater. Then the failure mode will turn to the ductile failure. At the same time, the stress flow in the material during the crack growth micromechanically will be observed as macroscopical bending.

4. Conclusion

The simplified methodology for RSW performance evaluation has been established with weld cycles and weld current. Each of the parameters will affect the material properties micromechanically. The weld cycles will conduct a peak value in optimization in elastic region and necking region, after then the mechanical performance will decay. The weld current percentage will be regarding a precise adjustment resort to weld performance. It is able to make ductility of the specimen to linearly controlled. The two-parameter effect analysis on RSW offers more flexibility in rapid parameter testing before massive production.

References

- [1] Nikoosohbat, F. & Kheirandish, S. & Goodarzi, Massoud & Pouranvari, Majid & Marashi, Pirooz. (2010). Microstructure and failure behaviour of resistance spot welded DP980 dual phase steel. *Materials Science and Technology*. 26. 738-744. 10.1179/174328409X414995.
- [2] Biro, Elliot & McDermid, Joseph & Embury, J. & Zhou, Yixiang. (2010). Softening Kinetics in the Subcritical Heat-Affected Zone of Dual-Phase Steel Welds. *Metallurgical and Materials Transactions A*. 41. 2348-2356. 10.1007/s11661-010-0323-2.
- [3] najafi birgani, Ebrahim & Pouranvari, Majid. (2022). EFFECT OF MARTENSITE VOLUME FRACTION ON THE WORK HARDENING BEHAVIOR OF DUAL PHASE STEELS.
- [4] Azzouzi, D., Benkhedda, Y. & Boumeddane, B. Parametric study of the nugget growth in spot welding of 304L stainless steel sheets having equal and unequal thicknesses. *SN Appl. Sci.* 1, 626 (2019). <https://doi.org/10.1007/s42452-019-0655-5>.
- [5] Y. -J. Xia, Z. -W. Su, M. Lou, Y. -B. Li and B. E. Carlson, "Online Precision Measurement of Weld Indentation in Resistance Spot Welding Using Servo Gun," in *IEEE Transactions on Instrumentation and Measurement*, vol. 69, no. 7, pp. 4465-4475, July 2020, doi: 10.1109/TIM.2019.2943981.