Variations the diameter tip of electrode on the resistance spot welding using electrode Cu on worksheet Fe

A.S Baskoro\textsuperscript{1}, Sugeng S\textsuperscript{1}, Agus Sifa\textsuperscript{2}, Badruzzaman\textsuperscript{2}, Tito Endramawan\textsuperscript{2}

\textsuperscript{1}Mechanical Engineering Department, Faculty of Engineering Universitas Indonesia, Depok-Indonesia
\textsuperscript{2}Mechanical Engineering Department, Politeknik Negeri Indramayu, Indramayu-Indonesia
E-mail : ario@eng.ui.ac.id\textsuperscript{1}, agus.sifa@polindra.ac.id\textsuperscript{2}

Abstract. Resistance Spot Weld (RSW) is a welding technology which plays an important role that is often used in industry in large manufacturing industries, especially in the automotive sector, some of the parameters are affecting the welding process that give impact in the weld quality, diameter tip important impact on the resistance spot welding, This study can be categorized as experimental study by using Electrode material such as Cu and Fe Worksheet Materials, with a material thickness of 1 mm, 0.8 mm, and 0.6 mm on each worksheet, and the large diameter of tip electrode \((5\sqrt{t})\) depend on the thickness of worksheet. Testing the material in the electrode and the worksheet by testing the composition and tensile test, and the hardness of the material used are to know the material used certainly. The result of the welding process was done by using the parameters voltage of 8KV, with a duty cycle of 50\% using a variation of the time 8s-10s, and variations the electrode tip diameter that are affected by the thickness of the worksheet \(5\sqrt{t}\), plate thickness used 1 mm, 0.8 mm and 0.6 mm, so that the electrodes was used to a thickness of 1 mm diameter tip electrode 5 mm, thickness 0.8 mm with an electrode tip diameter 4.5 mm and a thickness 0.6 mm with an electrode diameter of 4 mm, with current welding parameter 8kVA, and variations in holding time 10s, 9s and 8s 50\% duty cycle, then testing welds with the standard shear test refers ASTM A370-2012 with more results to a thickness of 0.6 has the ability to withstand greater load on the holding time 8s and 9s,10s, to a thickness 0.8 mm and 1 mm shear test results demonstrate the ability to withstand loads on the holding time of 10s and 9s have a greater ability than 8s on worksheet that has thickness 1 mm at a holding time of 10s, and then Maximum shear test averaging of 36.41 N at a worksheet with a thickness of 0.8 mm (diameter tip 4.5 mm) at a holding time of 8s and a mean minimum shear stress of 23.73 N at worksheet that has thickness 0.6 mm (diameter tip 4 mm).

1. Introduction

Resistance Spot Weld is a welding technology which plays an important role that is used in the manufacturing industry frequently, especially in the automotive sectors, some parameters affect the welding process that impact on the quality of the weld\cite{1,2,3,4,5,6}, diameter tip important impact on the resistance spot welding\cite{11}. Some parameters on the welding process that affects the quality of welding are electrode materials and worksheets used, pressure, time, etc. The electrode can be used on worksheet \(1 + 1\) mm thickness in which the thickness < 3 mm, with diameter tip \(5\sqrt{t}\) that refers to the standard Resistance Welder Manufacture Association (RWMA)\cite{6}.

Heating that has occurred in the area of the electrode tip with the type of electrode angular geometry between 30\°-60\° has a significant temperature changes, the temperature is going 540 \degree C \cite{5}, below is the formula of the welding process heating that affects the shear strength of the worksheet :\cite{2}
Welding heating parameters and electrode geometry affects the nugget size and the shear strength of the worksheet, in this study, the experiments performed used the variation of tip of the electrode (Cu) with Worksheet (Fe), with variations of thickness of the Worksheet (0.6 mm, 0.8 mm, and 1 mm), and variable holding time (8s, 9s and 10s), the aims of this study to determine the ability of the load and shear force of welding results on the worksheet which is influenced by the diameter tip variation of the electrode.

2. Materials

2.1. Electrode
Electrode material used for the experiments using Cu material composition spectrometer test results can be seen in the Table 1.

| Element | Percentage (%) |
|---------|----------------|
| Sn      | 0.0284         |
| Zn      | 0.0165         |
| Pb      | 0.0296         |
| Fe      | 0.0262         |
| Al      | 0.0320         |
| Si      | 0.0236         |
| Cu      | 99.8264        |

From the Table 1, electrode composition test results with the highest percentage of Copper (Cu) amounted to 99.811%, Cu element was declared balance. Furthermore, tensile testing the electrode material was done and the results are as follows Table 2.

| Yield Strength (MPa) | Tensile Strength (MPa) | Strain (%) | Modulus (MPa) | Load Peak (N) |
|----------------------|------------------------|------------|---------------|---------------|
| 121                  | 238                    | 35         | 169           | 27630         |

Testing the tensile test was done by using a tensile testing machine HT-2402 Series (50-250KN) which was performed three times for tensile tests based on ASTM E 8 M [7] and hardness tests performed on the electrode material with the result as presented below Figure 3.
Figure 2. Hardness test (Vickers).

![Hardness Vickers of Electrode](image)

**Figure 3.** Result hardness test of electrode.

From the results of hardness test performed with a load of 1 Kg and duration 10s, it is obtained an average value of 121.6 kg/mm\(^2\) Cu electrode.

2.2. Worksheet

The material used in the welding process for the worksheet are in the form of plates with a thickness of 1 + 1 mm, with test results spectrometry composition as follows;

![Worksheet Specimen](image)

**Figure 4.** Specimen of worksheet.

From the spectrometry test result, it can be seen the composition of electrode material by using ARL 3460 testing machine, room temperature 25\(^\circ\)C, Humidity 51\% as presented Table 3.
Table 3. Composition material of worksheet

| Element | Percentage (%) |
|---------|----------------|
| C       | 0.0498         |
| Mn      | 0.2016         |
| Cr      | 0.0139         |
| Cu      | 0.0126         |
| Al      | 0.0441         |
| Fe      | 99.6481        |

The Table 3. state the value of Fe as much as 99.624%, Fe dominated the composition, however the carbon percentage was only 0.048%. It can be inferred that the sheet plate contains less than 0.25%, it can be categorized to a low carbon steel[14].

Table 4. Tensile test worksheet result

| Yield Strength (MPa) | Tensile Strength (MPa) | Strain (%) | Modulus (MPa) | Load Peak (N) |
|----------------------|------------------------|-------------|---------------|---------------|
| 62                   | 139                    | 0.5         | 36            | 1759          |

Testing the tensile test by using a tensile testing machine HT-2402 Series (50-250KN) with plate-shaped specimens is done three times, for tensile tests based on ASTM [7] and hardness tests performed on the worksheet material as presented Figure 5.

Figure 5. Hardness test of worksheet.

Figure 6. Results hardness test of worksheet.
The result of the hardness, with a load of 1 Kg and duration 10s, testing was conducted twenty-one specimens, the obtained average value of hardness 122.35 Kg / mm² on the work sheet thickness of 1 mm, while the thickness of worksheet 0.8 mm has an average hardness value of 108.37 kg / mm², and the work sheet thickness of 0.6 mm results of tests performed has an average hardness value of 103.95 Kg / mm².

3. Welding experiment process

Figure 7. Geometry of electrode.

Figure 7. determine the diameter of the tip, where the diameter of the tip electrode used refers to the thickness of the material in accordance with the Resistance Welder Manufactureres Association (RWMA)[6] or standard ISO 5182, the thickness of the material used <3 mm, so that a large diameter tip 5√\(t\)[6], the thickness (t) worksheet 1 mm, tip diameter 5 mm on figure 8;

Figure 8. Diameter tip of electrode(Worksheet 1 mm).

Figure 9. Diameter tip electrode(Worksheet 0.8mm).

Figure 9. the use of electrodes to a thickness worksheet 0.8 mm obtained \(5\sqrt{0.8} = 4.47 \approx 4.5\ mm\), diameter tip 4.5 mm.
Figure 10. Diameter tip of electrode (Worksheet 0.6mm).

Figure 10. The use of electrodes to a thickness worksheet 0.6 mm obtained \( (5\sqrt{\pi})[6] = 5\sqrt{0.6} = 4.47 \approx 4.5 \text{ mm} \), diameter tip 4 mm.

Geometry electrodes were produced an angle, the angle formed by 45\(^\circ\), and large diameter tip refers to the thickness of <3 mm[6], the thickness of worksheet 1 + 1 mm diameter tip 5 mm, at a thickness of worksheet 0.8 + 0.8 mm then tip diameter of 4.5 mm, and the thickness of worksheet 0.6 + 0.6 mm then tip diameter of 4 mm. Machines which is used in this study is the spot welding machine MC-8 with specific types as follows Table 5:

Table 5. Spesification machine of spot welding

| System            |                  | 220V(1 Phase) | 50/60 Hz |
|-------------------|------------------|--------------|----------|
| clamp             | Rated Capacity   | KVA          | 8        |
| torch machine     | Duty Cycle       | %            | 50       |
| is modified by    | MaximumMaterial  | mm           | 1 + 1    |
| using pneumatic   | Thickness        |              |          |
|                  | Dimension        | mm           | 380 x 273 x 373 |

System clamp torch machine is modified by using system pneumatic which has pneumatic pressure 0.4 MPa and the force in every electrode as much as 2 Kg, the stages are presented below [2]:

- The first step was determining welding current (Table 3.2).
- The second step is determining the next step welding time parameter variations.
- The third step is connecting worksheet by moving both electrodes.

Table 6. Parameters spot welding

| No  | Welding Current (KVA) | Holding Time (s) | Diameter Tip (mm) | Force (Kg) |
|-----|-----------------------|------------------|-------------------|------------|
| 1   | 8                     | 10               | 5                 | 2          |
| 2   | 8                     | 9                | 4.5               | 2          |
| 3   | 8                     | 8                | 4                 | 2          |
4. Result and discussion
The results of spot welding process can be seen visually Heat affected zone (HAZ) as follows:

Figure 11. Spot welding process.

Figure 12. The visualization of nugget.

Figure 13. Visually size nugget on worksheet a thickness 1 mm.

Figure 14. Visually size nugget on worksheet a thickness 0.8 mm.
Figure 14. Visually impacts shear testing on worksheets that have a thickness of 0.8 mm

![Image](image1.png)

(a) 8s                  (b) 9s                  (c) 10s

Figure 15. Visually size nugget on worksheet a thickness 0.6 mm.

Figure 15. Visually impacts shear testing on worksheets that have a thickness of 0.6 mm, shows the damage to the nugget diameter, the next process was carried out shear tests on the worksheet that has been connected, The results of shear testing material based on ASTM A370-2012 [7] by using the Amsler type testing machine with a capacity of 5 tons of grip movement rate from 1.3 to 2.5 mm / min.

![Graph](graph1.png)

**Figure 16.** Graph results of load shear stress test at a thickness 0.6 mm.

Figure 16. The graph above shown the results of load shear stress tests showed five holding time of testing on different worksheets thickness 0.6 mm, in thickness worksheet 0.6 mm on the welding process using a holding time of 8 s, has an average value load 206 N, with holding time 9s have an average load 204 N and the welding process by using a holding time 10 s had average value of 205 N, from the testing that has been conducted to determine the load on the weld, then no differences were so significant difference in holding time No, but the holding time 8s have a higher load results of 206 N.

![Graph](graph2.png)

**Figure 17.** Graph results of load shear stress test at a thickness 0.8 mm.
On Figure 17, the results of load shear stress test at a thickness worksheet 0.8 mm, the holding time 8s have an average value of load 221 N, and the holding time 9s and 10s had an average value of load 240 N, the difference in holding time 8s have a load rating lower than 9s and 10s have the same load rating 240 N.

![Graph results of load shear stress test at a thickness 1 mm.](image1)

**Figure 18.** Graph results of load shear stress test at a thickness 1 mm.

The graph above on Figure 18, the worksheet thickness 1 mm with a holding time 8s have an average value load 272 N, the holding time 9s have an average value load 270 N and the holding time 10s has a value of 275 N, from the overall test worksheet 1mm thickness at holding time 8s, 9s and 10s had an average load was not significantly different, but the maximum value of the average load on the worksheet thickness 1 mm, occurred in holding time 10s.

![Shear Stress on Thickness 0.6 mm](image2)

**Figure 19.** Shear stress on thickness 0.6 mm.

Figure 19 shown the shear stress test results on the worksheet thickness 0.6 mm, with a holding time 8s have a shear stress value 32.71 N / mm², while the holding time 9s have a value of shear stress 27.58 N / mm² and the holding time 10s have value of shear stress 23.73 N / mm², the worksheet 0.6 mm greater value shear stress at 8s holding time 32.71 N / mm².
Figure 20. Shear stress on thickness 0.8 mm.

On the graph above, the shear stress test results on a worksheet thickness 0.8 mm, the holding time 8s have an average value of shear stress 36.47 N / mm², the holding time 9s have an average value of shear stress 32.43 N / mm², and the holding time of 10s has a shear stress value 28.43 N / mm², the value of shear stress is greater in holding time 8s.

Figure 21. Shear stress on thickness 1 mm.

On the Figure 21, shear test results on the worksheet thickness 1 mm, the holding time 8s have an average value of the shear stress 25.26 N / mm, the holding time 9s have an average value of shear stress 32.92 N / mm² and the holding time of 10s has a value of shear stress 32.41 N / mm², shear stress values occur at the holding time is less than the 8s 9s and 10s holding times, the average value of shear stress on holding time 9s and 10s have the same value.

5. Conclusion
The study result of the welding process is done with the voltage parameters 8KV, with a duty cycle of 50% using a variation of the time 8s-10s, then testing welds with the standard shear test refers ASTM A370-2012 with more results to a thickness of 0.6 has the ability to withstand greater load on the holding time 8s and 9s of the 10s, to a thickness 0.8 mm and 1 mm shear test results demonstrate the ability to withstand loads on the holding time of 10s and 9s have a greater ability than 8s, The worksheet withstands the load at an average minimum value of 198.3 N on a worksheet that has a thickness of 0.6 mm at a holding time of 10s and an average maximum value of 308.3 N, on worksheet that has thickness 1 mm at a holding time of 10s, and then Maximum shear test averaging of 36.41 N at a worksheet with a thickness of 0.8 mm (diameter tip 4.5 mm) at a holding time of 8s and a mean minimum shear stress of 23.73 N at worksheet that has thickness 0.6 mm (diameter tip 4 mm)
6. References

[1] Amirthalingam, M., van der Aa, E. M., Kwakernaak, C., M. Hermans, M. J., & Richardson, I. M. (2015). Elemental segregation during resistance spot welding of boron containing advanced high strength steels. *Welding in the World*, 59(5), 743–755. http://doi.org/10.1007/s40194-015-0250-3

[2] Baskoro, a. s., &Muzakki, h. (2016). The Effect of Welding Time and Welding Currents on Weld Nugget and Tensile Properties of Thin Aluminum al100 by Micro Resistance Spot Welding, 11(2), 1050–1055

[3] Brokmeier, H. G. (2011). Non-destructive evaluation of strain-stress and texture in materials science by neutrons and hard X-rays. *Procedia Engineering*, 10, 1657–1662. http://doi.org/10.1016/j.proeng.2011.04.277

[4] Ho, J. E., Wei, P. S., & Wu, T. H. (2012). Workpiece property effect on resistance spot welding. *IEEE Transactions on Components, Packaging and Manufacturing Technology*, 2(6), 925–934. http://doi.org/10.1109/TCPMT.2011.2175226

[5] Mikno, Z., &Bartnik, Z. (2016). Heating of electrodes during spot resistance welding in FEM calculations. *Archives of Civil and Mechanical Engineering*, 16(1), 86–100. http://doi.org/10.1016/j.acme.2015.09.005

[6] Neville, T., Williams, British Steel, Resistance Spot Welding, Welding, Brazing and Soldering ASM Handbook. Vol.6 page 684–692, ASM International

[7] John R, Newby and friends, Mechanical Testing ASM Handbook. Vol.8 , ASM International

[8] Pal, T. K., &Bhowmick, K. (2011). Resistance Spot Welding Characteristics and High Cycle Fatigue Behavior of DP 780 Steel Sheet. *Journal of Materials Engineering and Performance*, 21(4), 280–285. http://doi.org/10.1007/s11665-011-9850-2

[9] Shasha, L., Yuhang, W., &Weiping, Z. (2014). Microstructure and Wear Resistance of Laser Clad Cobalt-based Composite Coating on TA15 Surface. *Rare Metal Materials and Engineering*, 43(5), 1041–1046. http://doi.org/10.1016/S1875-5372(14)60097-7

[10] Spitz, M., Fleischanderl, M., Sierlinger, R., Reischauer, M., Perndorfer, F., & Fafilek, G. (2015). Surface lubrication influence on electrode degradation during resistance spot welding of hot dip galvanized steel sheets. *Journal of Materials Processing Technology*, 216, 339–347. http://doi.org/10.1016/j.jmatprotec.2014.09.011

[11] Wang, B., Hua, L., Wang, X., Song, Y., & Liu, Y. (2016). Effects of electrode tip morphology on resistance spot welding quality of DP590 dual-phase steel. *International Journal of Advanced Manufacturing Technology*, 83(9–12), 1917–1926. http://doi.org/10.1007/s00170-015-7703-0

[12] Zhao, D., Wang, Y., Lin, Z., & Sheng, S. (2013). An effective quality assessment method for small scale resistance spot welding based on process parameters. *NDT & E International*, 55, 36–41. http://doi.org/10.1016/j.ndteint.2013.01.008

[13] Zhang, X., Zhang, Y., & Chen, G. (2006). Weld quality inspection based on on-line measured indentation from servo encoder in resistance spot welding. In *Conference Record - IEEE Instrumentation and Measurement Technology Conference* (pp. 1353–1356).

[14] Callister William , (1994). *Materials Science and Engineering and Introduction*, Deparment of Materials Science and Engineering The University of Utah (New York: John Wiley and Son Inc)

[15] Sifa A, Endramawan T. Identification of the Quality Spot Welding used Non Destructive Test-Ultrasonic Testing(Effect of Welding Time). In IOP Conference Series: Materials Science and Engineering 2017 Mar (Vol. 180, No. 1, p. 012101). IOP Publishing.

Acknowledgments

Directorate of Research and Community Service-Ministry of Research, Technology and Higher Education, and To Department of Mechanical Engineering, Faculty of Engineering, University of Indonesia, and Department of Mechanical Engineering-State Polytechnic of Indramayu.