

Study of the effect of welding current on the mechanical properties of materials welded by resistance spot welding

Mansour Mohammed Ali¹, Ahmed Aouda Al-Roubaiey²

^{1,2}Department of Metallurgy, College of Materials Engineering, University of Babylon, Iraq
mat113.mansur.mohammed@student.uobabylon.edu.iq¹,
mat.ahmed.aouda@uobabylon.edu.iq²

Abstract

Resistance spot welding of dissimilar materials is more difficult than welding similar materials due to the different physical, chemical, and mechanical properties of the base metals. This study investigated the influence of key welding parameters, such as peak current, on the shape, microhardness, and tensile shear stress-bearing capacity of different welds when welding low-carbon steel with high-strength low-alloy (HSLA) steel. This study was conducted using only a variable welding current, while keeping other parameters constant. The bearing capacity, hardness, and weld nugget size of the material exhibited a linear relationship with the welding current, and the weldability of low-carbon steel with HSLA steel was found to be satisfactory. At a welding current of 8 kJ, the bearing capacity exhibited a maximum value (in kgf) of 217

Keywords: Resistance Spot Welding, Resistance welding, Weldability, Low Carbon Steel, HSLA Steel, Tensile Shear Load, Welding Parameters, Mechanical Properties.

1. INTRODUCTION

Resistance spot welding is one of the oldest of the electric welding processes in use by industry today. It came into use in the period 1900-1905. The weld is made by a combination of heat, pressure and time. As the name resistance welding implies, it is the resistance of the material to be welded to current flow that causes a localized heating in the part. The pressure exerted by the tongs and electrode tips, through which the current flows, holds the parts to be welded in intimate contact, before, during, and after the welding current time cycle. The required amount of time current flows in the joint is determined by material thickness and type, the amount of current flowing, and the cross-sectional area of the welding tip contact surfaces [1, 2, 3, 4]. Although the problem of joining

dissimilar metals is occurring with increasing frequency, not much valuable data in this respect are available. The reason is that each joint is really a special case, and both the metallurgical and design factors must be viewed, in terms of how the joint will operate under specific stresses and environments. Welding dissimilar metals has always presented a problem, due largely to the different ways in which metals respond to heat stresses and therefore the different strains on each side of the weld that joins them [3, 4]. In a joint between two dissimilar metals, the metallurgy of both base metals and the weld metal must be taken into account, because the weld metal is a composite of the fused base metals of three dissimilar metals and may actually be involved in these joints. It is often easier to make satisfactory joints between dissimilar metals by resistance welding than by arc welding, since the problem of fluxing or provision of an inert atmosphere does not arise, and the technique available often minimize the danger of the formation of brittle intermetallic compounds within the joint [3,4]. Steels with very low carbon content, usually up to 0.13% C, are good welding steels, but they are not the best for high-speed production welding. Steels with very low carbon content are more ductile and easier to form than higher carbon steels. They are used for applications requiring considerable cold forming, such as stamping or rolled or formed shapes [4]. A group of low alloy steels that are designed to provide better mechanical properties and sometimes greater resistance to atmospheric corrosion than conventional carbon steels are known as HSLA steels. They are not considered to be alloy steels in the normal sense because they are designed to meet specific mechanical properties rather than a chemical composition. Carbon content of HSLA steels rarely exceeds 0.28% and is usually between 0.15% and 0.22% [4]. Strength of HSLA steels is between those of carbon steels and the high quenched

and tempered steels. Typical applications of HSLA steels include support and panels for truck bodies, railways cars, mobile homes, and other transportation equipment. The weldability of most HSLA steels is similar to that of mild steels. HSLA steels can also be joined by a resistance spot welding process. When a spot-welding process is used for these steels, they can be welded with about the same current and time setting used for low carbon steels. However higher electrode force may be needed because of the higher strength of these steels [4]

2. MATERIALS AND EXPERIMENTAL METHODS

The dissimilar materials selected in the present work for the study are low carbon steel and HSLA steel. The chemical composition of both materials is shown in Table 1. Both materials were cut into pieces in dimensions of 76 mm x 19 mm x 1 mm. Before welding, the surfaces of the all samples were cleaned mechanically. Materials samples were spot welded in a stationary Rocker-arm, AC (alternating current) spot welding machine which is capable of 1–8 KA weld current as shown in Figure 1. Welding was carried out by using air cooled conical Cu electrodes having a contact surface diameter of 3 mm. Welding was performed by overlapping the plates linearly to fabricate the specimens for tensile shear test shown schematically in Figure 2. For the joining, 4, 5, 6 KA peak currents were applied while the other welding parameters were kept constant.

The tensile-shear test is the most widely used method for determining the strength of resistance spot welds. Tensile shear testing was carried out on the servo hydraulic type universal testing machine. This test is used mainly to establish ultimate shear strength when the specimen is tested in tension. Hardness is the ability of a metal to resist penetration, to resist abrasive wear, or to resist the absorption of energy under impact load, accordingly these can be thought of as penetration hardness, wear hardness, and rebound hardness. Hardness measurement can provide information about the metallurgical changes caused by welding. The Vickers and Knoop tests make relatively small indentations and are thus well suited for hardness measurement of the various regions of the HAZ for fine scale traverses. In the present work, Vickers hardness testing was performed by applying a load of 500 g for 10 seconds.

3. RESULTS AND DISCUSSION

The most important factors that affect weld quality are surface appearance, strength and ductility, weld nugget size, weld penetration, sheet separation, and internal discontinuities. Surface appearance of the welded dissimilar materials [5,6] is shown in Figure 3. Normally the surface appearance of a spot weld should be relatively smooth, round or oval in the case of contoured work, and free from surface fusion, electrode deposits pits, cracks and deep electrode indentation [5,6]. In this study, smooth weld surface appearance is almost obtained in the case of low carbon steel specimens. However, the weld surface appearance for HSLA is not as smooth as low carbon steel.

The nugget size is a critical parameter in the determination of spot weld quality. Therefore, the diameter or width of the fused zone must meet the requirements of the appropriate specifications or the design criteria [5,6]. The relationship between nugget size and peak weld current was determined in this study. The result is shown graphically in Figure 4. Results from Figure 4 also show that, increases in energy input, which was caused essentially by the enhancement of peak current, increases with the nugget size of the weld. Similar studies on different grade of steels by different researchers show that the enhancement of peak current increased the nugget size of the welded metals [6, 7, 8, 9, 10, 11, 12, 13, 14]. In this study, the nugget size of HSLA steel weld was found to be bigger than that of low carbon steel weld at the same welding current. From Figure 9, tensile shear load

bearing capacity of low carbon steel is more than HSLA steel, followed by the combination of both materials. So it is understandable that the weldability of low carbon steel is more than that of HSLA steel, followed by the combination of these materials. Ductility is also one of the most important factors that effect the spot weld quality. The ductility of a resistance weld is determined by the composition of the base metal and the effect of high temperatures and subsequent rapid

cooling on that composition. The nearest thing to ductility measurement is the hardness test since the hardness of metal is usually an indication of its ductility [5, 6]. Therefore, the hardness measurement was performed on the weld nugget.

The effect of peak current on the hardness across the weldment was determined and the result is shown in Figure 10. As seen in Figure 10, the increment in welding current results in an increase in the hardness of both materials. This increase in hardness value is mainly due to the increase in energy input, which causes more heating in specimens, and stress hardening takes place in the welding zone, due to the rapid cooling of weld metal. Sheet separation is also one of the factors that affects the spot weld quality, occurring at faying surfaces, due to the expansion and contraction of the weld metal and the forging effect of the electrodes on the hot nugget [5, 6]. During this study, no separations were obtained. This may be due to higher thickness of welded specimens. The fracture characteristics of tensile shear specimens were also evaluated. Results show that failure occurred at the weld interface of welded materials. This also may be due to higher thickness of welded specimens.

4. CONCLUSION

analyzing the results of various tests, the following can be concluded: The size of the nugget increases with increasing welding current. This is due to increased resistance at the electrode and steel surface, as well as to the heat generated by passing a higher electric current. The shear and tensile stress tolerance of the welded materials increased with increasing maximum welding current due to the increased nugget size.

The hardness of the materials increased with increasing welding current. This is because, as the current increases, the heat generated by welding increases, followed by an increased cooling rate of the material, leading to stress hardening. In all cases, welded samples failed at the weld surface. This is due to the increased thickness of the welded samples.

5. REFERENCES

- [1] Resistance Spot Welding, American Welding Society, Safety and Health Fact Sheet No. 21, 1999.
- [2] Handbook for Resistance Spot Welding, Miller Electric Mfg. Co., 2005.
- [3] Khanna O. P., Welding Technology, Dhanpat Rai Publications, 16th Edition, 2007.
- [4] Parmar R. S., Welding Engineering and Technology, Khanna Publishers, 1st Edition, 1997.
- [5] Welding processes, AWS welding handbook, Vol. 3. London, England American Welding Society, 7th edition, Macmillan Press Ltd; 1980.
- [6] Hasanbasoglu A. and Kacar R., Resistance Spot Weldability of Dissimilar Materials (AISI 316L-DIN EN 10130-99 Steels), International Journal of Materials and Design, Vol. 28, pp. 1794-1800, 2007.
- [7] Zhou M., Zhang H. and Hu S. J., Relationships between Quality and Attributes of Spot Welds, Welding Journal, Vol. 77, pp. 72-77, 2003.
- [8] Dursun O Zurek, An Effect of Weld Current and Weld Atmosphere on the Resistance Spot Weldability of 304L Austenitic Stainless Steel, International Journal of Materials and Design, Vol. 29, pp. 597-603, 2008.
- [9] Feramuz Karci, Ramazan Kacar and Suleyman Gunduz, The Effect of Process Parameter on the Properties of Spot Welded Cold Deformed AISI304 Grade Austenitic Stainless Steel, International Journal of Materials Processing Technology, Article in press ELSEVIER. 2008.
- [10] Ghosh P. K. and Patel V. K., Resistance Spot Repair Welding Of Spot Welded Steel Sheet, International Journal of Materials and Manufacturing Processes, Vol. 20, Issue 2, pp. 187-204, 2005.
- [11] Ghosh P. K, Gupta P.C., Ramavtar and Jha B. K, Resistance Spot Weldability of Phase Steel Sheet Comparatively Thick C-Mn-Cr MoDual, ISIJ International, Vol. 30, Issue 3, pp. 233-240, 1990.
- [12] Shinji Fukumoto, Kana Fujiwara, Shin Toji and Atsushi Yamamoto, Small-Scale Resistance Spot Welding of Austenitic Stainless Steels, International Journal of Materials Science and Engineering, Article in press ELSEVIER. 2008.
- [13] Marashi P., Pouranvari M., Amirabdollahian S., Abedi A. and Goodarzi M., Microstructure and Failure Behavior of Dissimilar Resistance Spot Welds between Low Carbon Galvanized and Austenitic Stainless Steels, International Journal of Materials Science and Engineering, Vol. 480, pp. 175-180, 2008.
- [14] Mukhopadhyay G., Bhattacharya S. and Ray K. K., Strength Assessment of Spot-Welded Sheets of Interstitial Free Steels, International Journal of Materials Processing Technology, Article in press ELSEVIER. 2008.
- [15] Oscar Martin, Pilar De Tiedra, Manuel Lopez, Manuel San-Juan, Cristina Garcia, Fernando Martin and Yolanda Blanco, Quality Prediction of Resistance Spot Welding Joints of 304 Austenitic Stainless Steel, International Journal of Materials and Design, Article in press ELSEVIER. 2008.

- [16] Kong X., Yang Q., Li B., Rothwell G., English R. and Ren X. J., Numerical Study of Strengths of Spot-Welded Joints of Steel, International Journal of Materials and Design, Vol. 29. pp. 1554-1561, 2008.
- [17] Chao Y. J., Ultimate strength and failure mechanism of resistance spot weld subjected to tensile, shear, or combined tensile/shear loads. J Eng Mater Technol, pp. 125-32, 2003.
- [18] Aslanlar S., The effect of nucleus size on mechanical properties in electrical resistance spot welding of sheets used in automotive industry. Mater Des, Vol. 27, pp. 125-31, 2006.

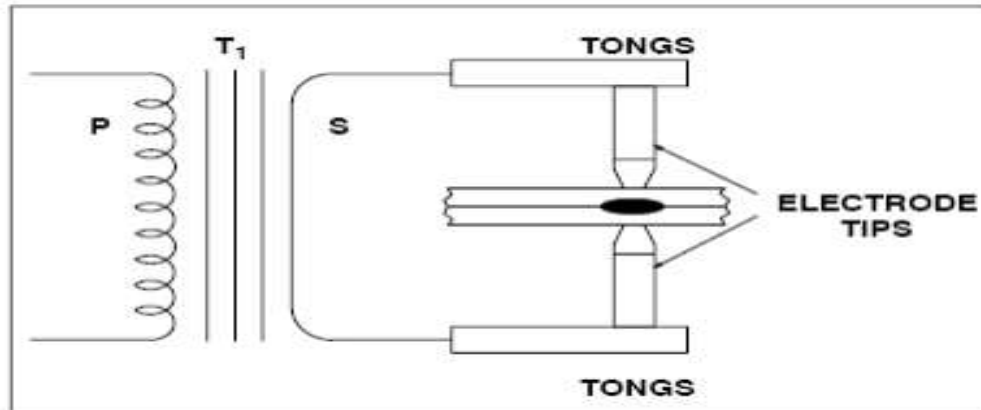


Figure 1. Resistance Spot Welding Machine with Work.

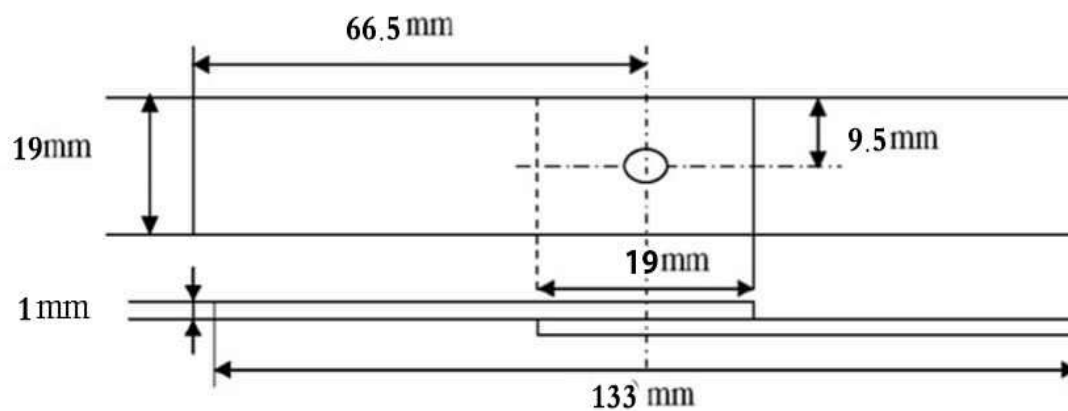


Figure 2. Tensile Shear Test Samples

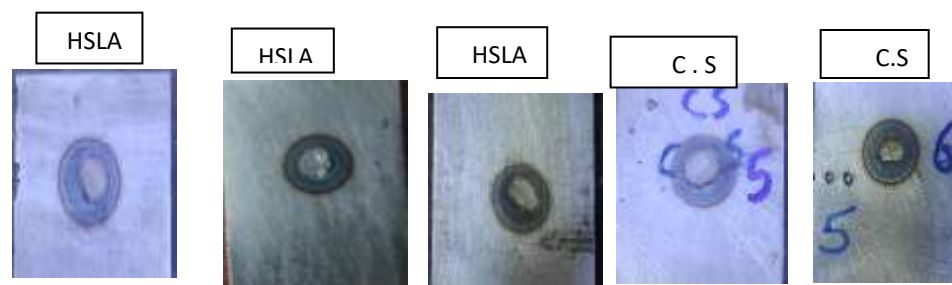


Figure 3. Low Carbon Steel Specimens and High Strength Low Alloy Steel Specimens.

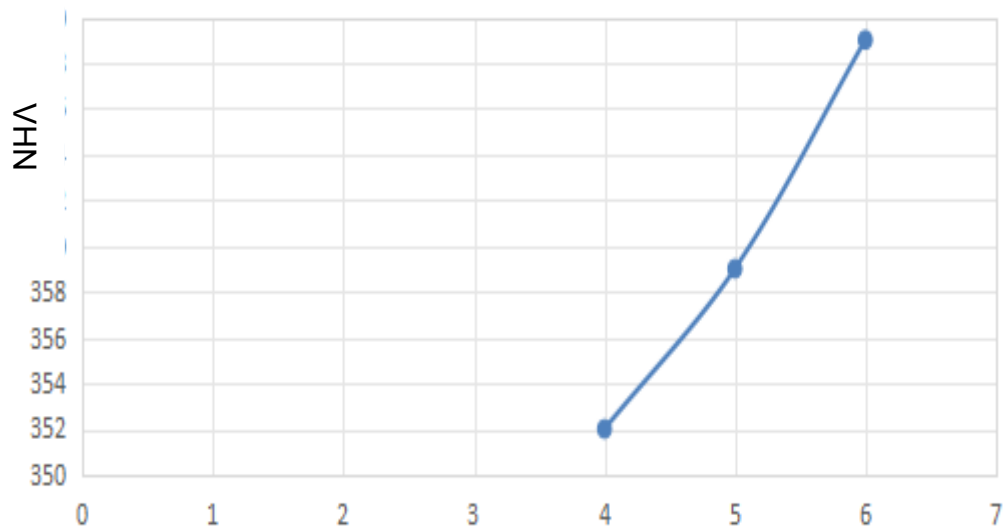
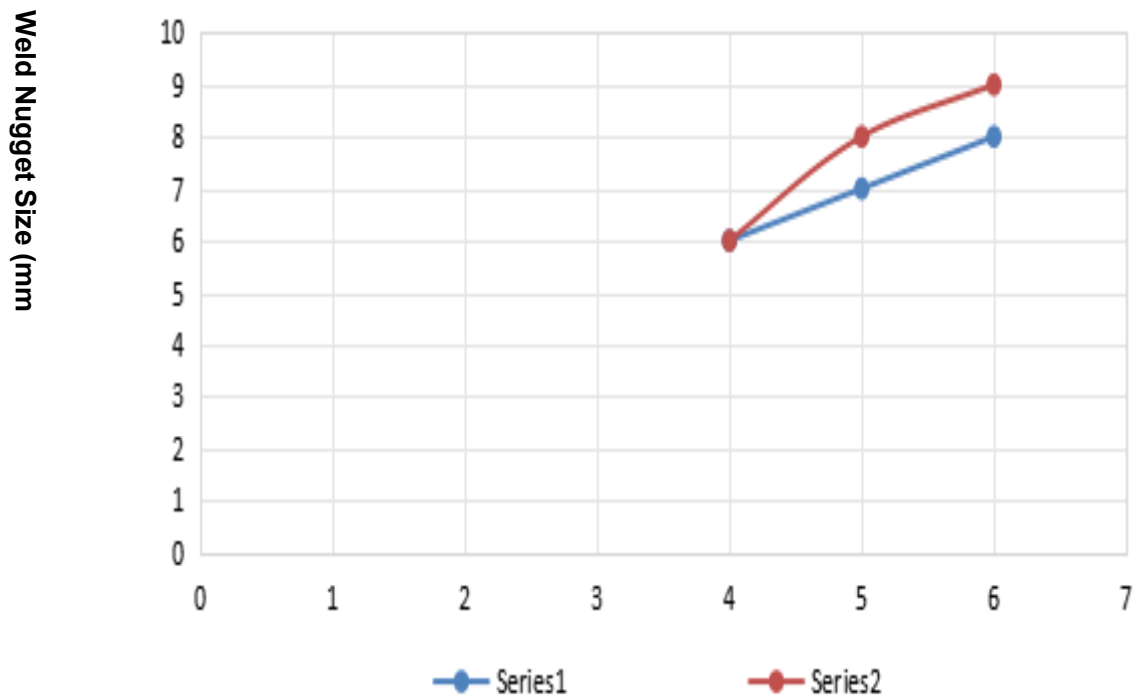


Figure 10. Hardness Variation According to Welding Current

Table 1. Chemical composition of materials (wt %)

Element%	C	Si	Mn	P	S	Cr	Al	Ni	Ti	Nb	Cu	Fe
HSLA 500AL	0.13	0.60	1.70	0.030	0.026	0.087	0.013	0.061	0.15	0.100	0.20	Ball
LCS	0.0501	0.0017	0.002	0.001	0.007	0	0.013	0.03	0	0	0	Ball

Table 2. Tensile Shear Strength Bearing Capacity

Materials Welding Current	Bearing Capacity of Dissimilar Materials Specimens (Kg)
4	76
5	113
6	217