Proceedings of the 3rd International Congress APMAS2013, April 24–28, 2013, Antalya, Turkey

Effect of Welding Current on Mechanical Properties of Welding Joints in SPA-C Steel Sheets in Resistance Spot Welding

N. Akkas and E. Ilhan

Sakarya University, Faculty of Technology, Department of Mechanical Engineering, 54187, Sakarya, Turkey

This paper presents an experimental study on resistance spot welding of SPA-C steel sheets used in side wall and roof in rail vehicles. SPA-C steel sheets having 2.3 mm thicknesses were joined by using resistance spot welding as lap joint. A timer and current controlled resistance spot welding machine having 120 kVA capacity and a pneumatic application mechanism with a single lever was used to prepare the specimens. Welding periods were chosen as 5, 10, 15, 20, 25, and 30 cycles and also welding currents were increased from 6 kA up to 14 kA by rise of 0.5 kA. The electrode force was kept constant at 6 kN. The prepared welding specimens were exposed to tensile-shear and tensile-peel tests and the obtained results were supported by diagrams and, finally, appropriate welding parameters were advised to the users.

DOI: 10.12693/APhysPolA.125.497

PACS: 81.20.Vj

1. Introduction

Resistance spot welding (RSW) is an inexpensive and effective way to join metal sheets [1]. RSW is a widely used joining process for fabricating sheet metal assemblies such as automobiles, truck cabins, rail vehicles, and home applications due to its advantages in welding efficiency and suitability for automation [2]. Like any other welding process, the quality of the joint in RSW is directly influenced by welding input parameters. A common problem faced by manufacturer is the control of the process input parameters to obtain a well welded joint with required strength. Therefore the tensile-shear and tensile-peel strength of the joint in RSW is an important index to welding quality [3]. In this study atmospheric corrosion resistant steel sheets were selected as materials to be spot welded.

2. Experimental studies

The materials studied are SPA-C steel sheets having 2.3 mm thicknesses, which are used in rail vehicle bodies. The chemical composition and the mechanical properties of the sheet are, respectively, shown in Tables I and II. The sheets were welded by RSW by fixing electrode form, materials type, cooling water flow rate and electrode force and changing welding current and time. All series were exposed to tensile-shear and tensile-peel tests in order to determine the joint strengths.

TABLE I

Chemical composition of steel sheets used in experiments (wt%).

C	Si	Mn	P	S	Cr	Ni	Mo	Al	Cu
0.0997	0.397	0.433	0.0913	0.0016	0.605	0.257	0.0066	0.0450	0.331

A timer and current controlled RSW machine having 120 kVA capacity and pneumatic application mechanism with a single lever was used in the experiments. The electrode force was continuously measured and controlled during the experiments. Also welding current values were calculated and controlled by means of a current transformer which is set on upper level of welding machine and an ampere meter continuously. Weld time, hold time, and clamping time were adjusted automatically by electronic devices of machine. Welding was carried out by using water cooled conical Cu–Cr electrodes having a contact surface of the same diameter (7 mm).

TABLE II

Mechanical properties of the sheet steel.

yield strength [MPa]	430
tensile strength [MPa]	550
total elongation [%]	45

The specimens are prepared as shown in Fig. 1 and cleaned ultrasonically. After that, these parts were overlapped with 30 mm spacing and welded. For joining, 5, 10, 15, 20, 25, and 30 cycles (1 cycle = 0.02 s) weld time were applied while other welding parameters such as applied electrode pressure (6 kN) and clamping and hold times of electrode (25 cycles) were kept constant. The welding current was increased from 6 to 14 kA by 0.5 kA increments.

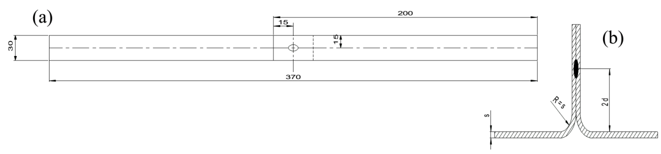

Fig. 1. The dimensions of the (a) tensile-shear specimens and (b) the tensile-peel specimens.

The welded parts were exposed to tensile-shear and tensile-peel tests in a testing machine in laboratory conditions. The tensile speed was kept constant during test. The values given as tensile-shear and tensile-peel strength

Fig. 2. Breaking failure samples observed in (a) tensile-shear tests, and (b) tensile-peel tests.

are the maximum values read from the scale of the machine. During the tests, three types of breaking failure were observed: (1) separation, (2) knotting, (3) tearing. Samples of them are shown in Fig. 2.

3. Results and discussion

3.1. *Effect of welding current on tensile-shear strength*

In low welding current application, small weld nugget diameters were obtained and similarly lower tensile-shear strength value than that of base-metal was measured due to low heat application to welding zone. As a result, break type was observed as separation. However, the tensile-shear strength increases with increasing weld current. This situation is depicted in Fig. 3. So, break type was observed as knotting.

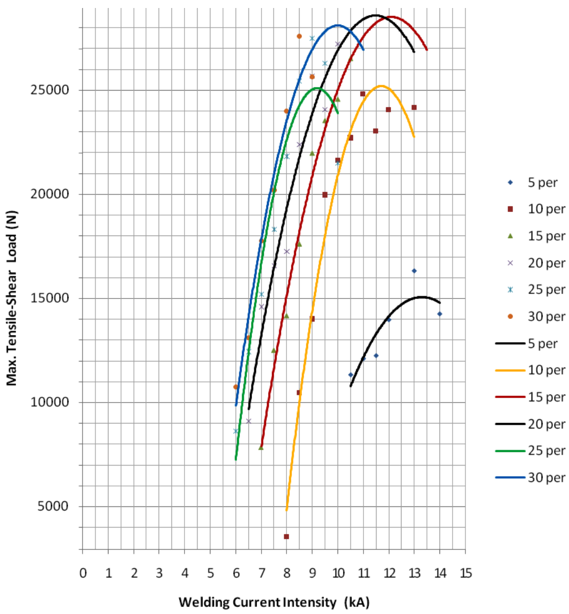

Fig. 3. Effect of welding current on tensile-shear load of weld joints.

In long welding time and high welding current application, cross-section area decreases, as a result, tensile-shear strength of joint decreases. Electrodes react to work piece due to excessive heating of them which cannot be compensated by cooling water. In addition, weld nugget spurts out between two sheets resulting in the decrease in diameter. This may be a reason for decreasing trend of tensile-shear strength shown in Fig. 4. At the same time, an over-coloured, retained structure with deep electrode marks and deformations was determined in weld zone.

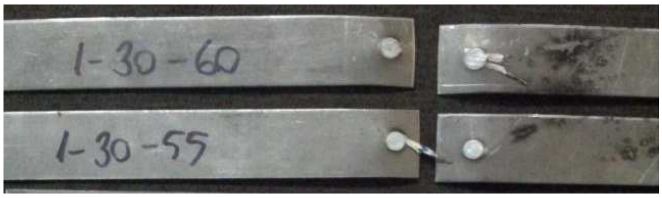

Fig. 4. Spurt out failure observed in weld nuggets.

TABLE III

Results of tensile-shear tests.

Welding time [per]	Welding current [kA]	Max. tensile--shear load [N]
5	13	16325
10	11	24800
15	10.5	26518
20	9	25678
25	9	27500
30	8.5	27596

The measured tensile-shear strength values in 5, 10, 15, 20, 25, and 30 cycles are tabulated in Table III. The values in 5 cycles were lower than that of 10, 15, 20, 25, and 30 cycles. The maximum point was reached in 30 cycles for 8.5 kA current range.

3.2. *Effect of welding current on tensile-peel strength*

In low welding current and short time application, small weld nugget diameters were obtained and similarly lower tensile-shear strength value. As a result, break type was observed as separation. However, the tensile-peel strength increases with increasing weld current. This situation is depicted in Fig. 5. So, breaking failure modes detected in tensile-peel tests change from separation to knotting, tearing from the weld nugget and tearing from the base-metal with the increasing welding current. Maximum tensile-peel strength value was gained in 30 cycles at approximately 7.5 kA welding current. The measured tensile-peel strength values in 5, 10, 15, 20, 25, and 30 cycles are tabulated in Table IV.

TABLE IV

Results of tensile-peel tests.

Welding time [per]	Welding current [kA]	Max. tensile--shear load [N]
5	14	926
10	13	3589
15	9.5	4840
20	9	5198
25	8	5765
30	7.5	6184

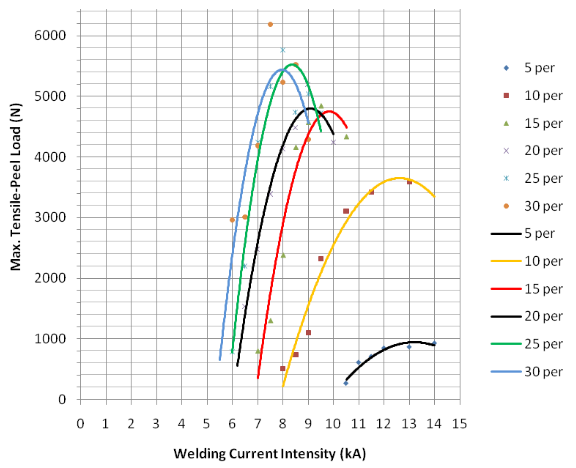

Fig. 5. Effect of welding current on tensile-peel load of weld joints.

4. Conclusion

As a result of the work performed at 6 kN electrode force, the obtained results and some suggestions are given below.

In the joining of SPA-C steel sheets, maximum tensile--shear strength is obtained at 8.5 kA welding current in 30 cycles. When the high surface quality is prior to strength, 9 kA welding current for 20 cycles welding time or 8.5 kA welding current for 25 cycles welding time are enough.

In the joining of SPA-C steel sheets, maximum tensile--peel strength is obtained at 7.5 kA welding current in 30 cycles. This value is approximately a quarter of the one obtained in tensile-shear strength, which shows the sensitivity of SPA-C sheets welded by RSW to tensile--peel tests.

Acknowledgments

The authors wish to thank Sakarya University Scientific Research Foundation (project number: 2010-05-04-004) for their support.

References

[1] M. Vural, A. Akkus, *J. Mater. Proc. Technol.* **153-154**, 1 (2004).

[2] Z. Hou, Ill-Soo Kim, Y. Wang, C. Li, C. Chen, *J. Mater. Proc. Technol.* **185**, 160 (2007).

[3] S.M. Hamidinejad, F. Kolahan, A.H. Kokabi, *Mater. Des.* **34**, 759 (2012).