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Welding Time Effect on Mechanical Properties in Resistance Spot Welding of S235JR(Cu) Steel Sheets Used in Railway Vehicles

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In this paper, S235JR(Cu) steel sheets were welded by electrical resistance spot welding method. Their thickness was 2 mm and joints were prepared in overlap joint form. 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 periods 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 obtained welding joints were exposed to tensile-peel and tensile-shear tests. As a result of these experiments, the maximum tensile-shear and tensile-peel strength are obtained in 30 period welding time for 8.5 kA welding current.

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1. Introduction

Resistance spot welding (RSW) is an inexpensive and effective way to join metal sheets [1]. It has excellent techno-economic benefits such as low cost, high speed and suitability for automation which makes it an attractive choice for auto-body assemblies, truck cabins, rail vehicles and home appliances. Each spot welding is not performed on the same condition because of the alignment of sheets and electrodes as well as the surface condition. For that reason, a spot welding process needs the optimum process condition that can afford allowance in parametric values for good quality of welding [2]. Therefore, in this study the relationship between welding time and tensile strength of joint in S235JR(Cu) in resistance spot welding was investigated.

2. Experimental

2.1. Theory

In the electrical resistance spot welding, two or three overlapped or stacked stamped components are welded together as a result of the heat created by electrical resistance. This is provided by the work pieces as they are held together under pressure between two electrodes. The heat required for these resistance welding processes is produced by the resistance of the work pieces to an electric current passing through the material. Also, the welding process is generally performed in less than one second. This time is called as period [2].

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2.2. Experimental studies

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
0.0902	0.164	0.513	0.0149	0.0063	0.0183	0.0481	0.0068	0.0349	0.273

The materials studied are S235JR(Cu) steel sheets having 2 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.

TABLE II

Mechanical properties of the sheet steel.

Yield strength [MPa]	320
Tensile strength [MPa]	435
Total elongation [%]	52

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 upper lever 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). The welding process was carried out for the specimen in specific dimensions; see Fig. 1. For joining, 5, 10, 15, 20, 25 and 30 periods (1 per = 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 periods) were kept constant. The welding current was increased from 6 to 14 kA by 0.5 kA increments.

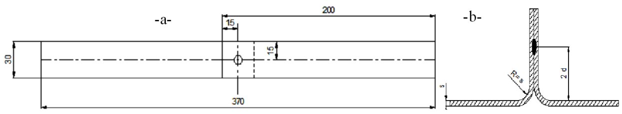

Fig. 1. The dimensions of the tensile-shear specimens (a) and the tensile-peel specimens (b).

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 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.

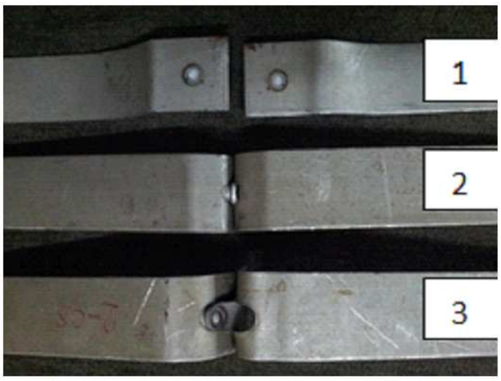

Fig. 2. Breaking failure samples observed in tensile-shear tests and tensile-peel tests.

3. Results and discussion

3.1. Effect of welding time on tensile-shear strength

In the light of results obtained from diagrams in Fig. 3, increasing welding times cause high heat input to weld zone and extending weld nugget, so the tensile-shear strength of joints increases [3–5]. It increases from 9.5 kA to 10 kA in 5 periods welding times. In 10 periods, tensile-shear strength of specimens increases from 8 kA to 10 kA. In 15 periods, tensile-shear strength of specimens increase sharply up to 9 kA and then this increment continues with a lower rate. In 20 period welding times, tensile-shear strength of specimens increases fast up to 8.5 kA where the maximum point is for this period.

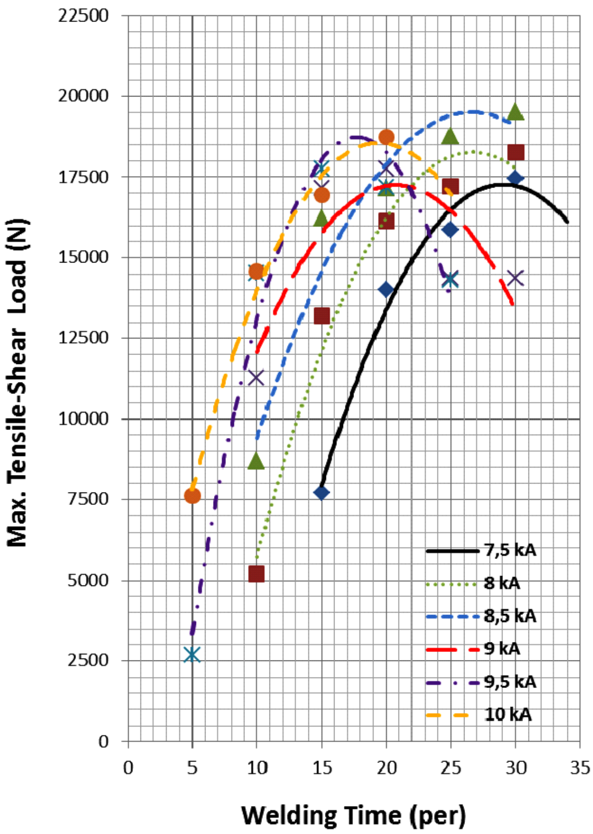

Fig. 3. Welding time effect on tensile-shear force of joints.

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

In 25 period welding times, tensile-shear strength of specimens increases up to 8.5 kA and it decreases after 8.5 kA. In 30 period welding times, tensile-shear strength of specimens increases up to 8.5 kA where the maximum point is for all periods and it decreases after 8.5 kA. In low welding time application, small weld nugget diameters were obtained; similarly, lower tensile-shear strength value than that of base-metal was measured due to low heat application to welding zone [5]. As a result, break type was observed as separation. However, the tensile-shear strength increases with increasing welding time. Therefore, break type was observed as knotting [3, 4]. In long welding time and high welding current application, cross-section area decreases; as a result, tensile-shear strength of joint decreases [5]. 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, which leads to decrease in the 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.

3.2. Effect of welding time on tensile-peel strength

As seen in tensile-shear strength, increasing welding time causes high heat input to weld zone and extending weld nugget, so the tensile-peel strength of joints also increases from 8 kA to 10 kA in 10 periods welding times and from 7.5 kA to 10 kA in 15 periods welding times. In 20 periods, a straight increase is seen in tensile-peel strength up 9 kA. In 25 period, tensile-peel strengths of specimens increase fast up to 8.5 kA where the maximum point is for this period. In 30 period welding times, tensile-peel strengths of specimens increase up to 8.5 kA where the maximum point all periods and then it decreases sharply after this point (Fig. 5) due to excessive heat formation and long welding time in specimen.

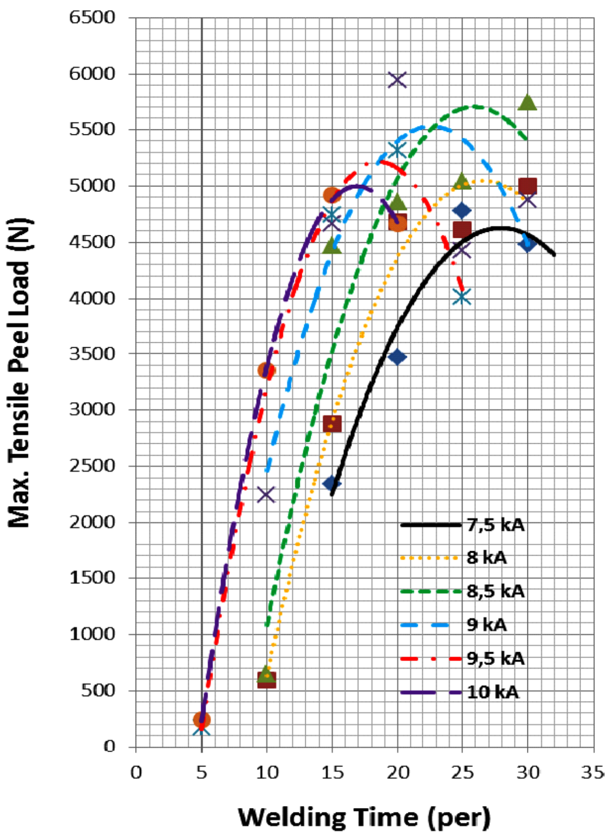

Fig. 5. Welding time effect on tensile-peel force of joints.

4. Conclusion

Welding time effect on tensile-peel strength and tensile-shear strength were researched by using related diagrams and the optimum welding currents and times were advised. 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 S235JR(Cu) steel sheets, maximum tensile-shear strength is obtained in 30 period for 8.5 kA welding current. When the high surface quality is prior to strength, 20 period welding time for 9 kA welding current or 25 period welding time for 8.5 kA welding current are enough. In the joining of S235JR(Cu) steel sheets, maximum tensile-peel strength is obtained in 30 period welding time for 8.5 kA welding current. This value is approximately a quarter of the one obtained in tensile-shear strength, which shows the sensitivity of S235JR(Cu) sheets welded by resistance spot welding to tensile-peel tests.

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