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# The Effect of Welding Current on Nugget Sizes in Resistance Spot Welding of SPA-C Steel Sheets Used in Railway Vehicles

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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 10, 15, 20, 25 and 30 periods and also welding currents were increased from 6 kA up to 11.5 kA by rise of 0.5 kA. The electrode force was kept constant at 6 kN. The nugget sizes of prepared welding specimens were calculated by means of an optical microscope and the obtained results were supported by diagrams and, finally, appropriate welding parameters were advised to the users.

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## 1. Introduction

Resistance spot welding (RSW) is a joining process in which coalescence of the metal sheets is produced at the faying surface by the heat generated at the joint by the resistance of the work to the flow of electric current [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.

The thermomechanical process of resistance spot welding is a complicated phenomenon which involves mechanical, electrical, thermal and metallurgical factors. These factors in combination with the welding parameters have a significant influence on weld nugget development and final geometry. In order to consistently produce sound weld nuggets, it is necessary to understand these complicated phenomena and evaluate the role of the major metallurgical factors and processing parameters [1].

The purpose of this work was to investigate the effect of welding current on the resistance spot weld quality of atmospheric corrosion resistant steels such as surface appearances, nugget width, nugget height, nugget size ratio. The macrostructure of the welded samples was evaluated.

## 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.

TABLE I

Chemical composition of steel sheets [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 |

TABLE II

Mechanical properties of the sheet steel.

| | |
|---|---|
| Yield strength [MPa] | 430 |
| Tensile strength [MPa] | 550 |
| Total elongation [%] | 45 |

A timer and current controlled RSW machine having 120 kVA capacity and pneumatic application mechanism with a single lever was used in the experiments. Welding was carried out by using water cooled conical Cu–Cr electrodes having a contact surface of the same diameter (7 mm).

The specimens were overlapped with 30 mm spacing and welded. For joining, 10, 15, 20, 25 and 30 periods 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 11.5 kA by 0.5 kA increments.

Nugget widths ($d_1$), nugget heights ($d_2$) were measured and also nugget size ratios ($d_2/d_1$) were calculated by means of an optical microscope. Weld nugget geometry is shown in Fig. 1. The effect of welding current on nugget size was investigated by putting obtained results in related diagrams.

## 3. Results

In low welding current application, small weld nugget diameters were obtained due to low heat application to welding zone [2–4]. As a result, break type was observed as separation as shown in Fig. 2a. However, the nugget

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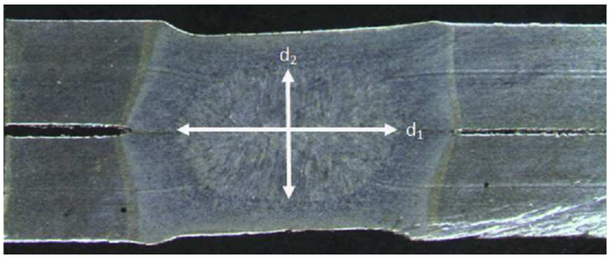


Fig. 1. Weld nugget geometry.

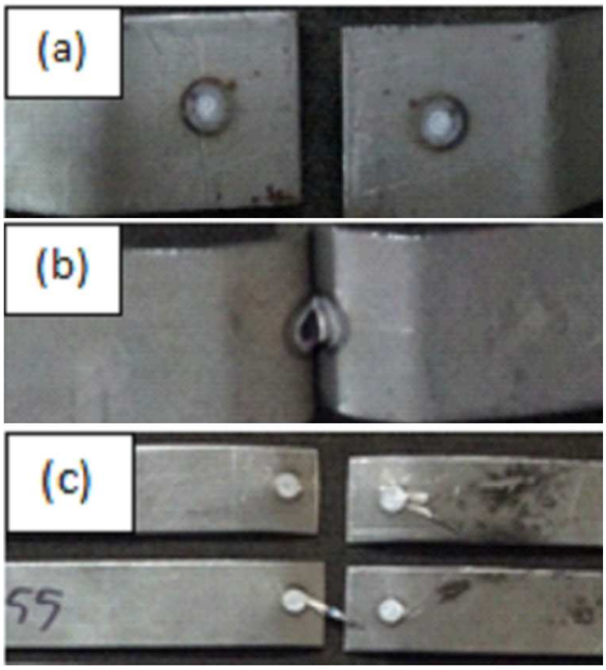


Fig. 2. (a) Separation failure, (b) knotting failure and (c) spurt out failure observed in weld nuggets.

width increases with increasing weld current [2–4]. This situation is depicted in Fig. 3. Therefore, break type was observed as knotting as shown in Fig. 2b.

In high welding current application, cross-section area decreases [2–4]. Electrodes react to work piece due to excessive heating of them which cannot be compensated


Fig. 3. The effect of welding current on nugget width.

by cooling water. In addition, weld nugget spurts out between two sheets resulting in the decrease in nugget width as shown in Fig. 2c. At the same time, an over-coloured, retained structure with deep electrode marks and deformations was determined in weld zone.

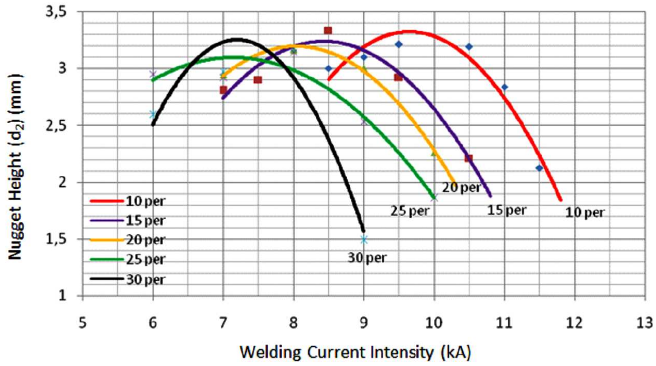


Fig. 4. The effect of welding current on nugget height.

Despite the increasing weld current as shown in Fig. 4, nugget height is decreased. Welding current is directly proportional to the amount of heat being generated. Increased welding current results in increased heat generation. Therefore, molten metal quantity is increased. However, excessive welding current results in expulsion due to nugget overgrowth. This can introduce weld defects into the weldment, such as voids and excessive electrode indentation. Therefore, nugget height decreases. Besides, nugget size ratio is increased to a certain value as shown in Fig. 5. After that value, it is reduced, because nugget height due to increased electrode indentation is reduced.

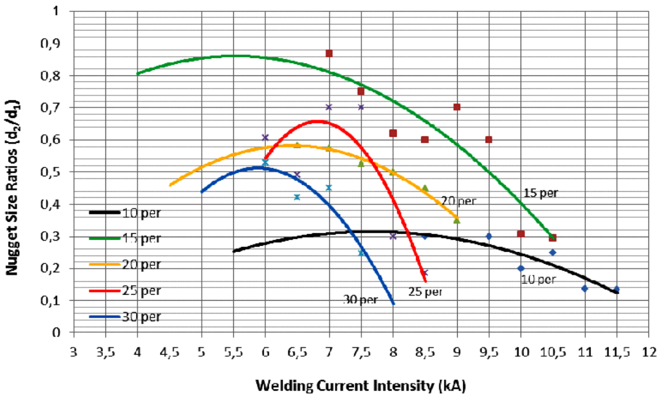


Fig. 5. The effect of welding current on nugget size ratios.

## 4. Conclusions

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

In low welding current intensity, small weld nugget widths were obtained due to low heat application to welding zone. As a result, break type was observed as separation.

In high welding current intensity, cross-section area decreases. Weld nugget spurts out between two sheets resulting in the decrease in nugget width.

When the high surface quality is prior to strength, 9 kA in 20 periods or 8.5 kA in 25 periods are enough. Since the depth of electrode indentation into material is not exceeded, the 30% of sheet thickness limit was accepted for a good surface quality.

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