WELDING *Journal*

August 2011

On-the-Job Safety

Controlling Shop Costs

Bonus: The American Welder

PUBLISHED BY THE AMERICAN WELDING SOCIETY TO ADVANCE THE SCIENCE, TECHNOLOGY, AND APPLICATION OF WELDING
AND ALLIED JOINING AND CUTTING PROCESSES, INCLUDING BRAZING, SOLDERING, AND THERMAL SPRAYING

SUPPLEMENT TO THE *WELDING JOURNAL,* AUGUST 2011
Sponsored by the American Welding Society and the Welding Research Council

Analysis of Spot Weld Growth on Mild and Stainless Steel

Nugget growth by varying current and weld time was analyzed in joining mild steel, austenitic stainless steel, and dissimilar steels

BY A. ARAVINTHAN AND C. NACHIMANI

ABSTRACT

Resistance spot welding (RSW) is an important technology in various industries for joining two or more metals. Joining dissimilar base metals has become very common among mechanical assemblies. Hence, this experiment was carried out to analyze the growth of a spot weld in a mixed joint of mild and 302 austenitic stainless steels. Basically, the growth of a spot weld is determined by its parameters such as current, weld time, electrode tip, and force. However, other factors such as electrode deformations, corrosion, different thicknesses, and material properties also affect the weld growth. This investigation was intended to analyze only the effects of nugget growth on mild steel, stainless steel, and mixed steels with respect to the variation of current and weld time. As such, the force and the electrode tips were constant throughout the experiments. The welded samples were all equal size and underwent tensile, hardness, and metallurgical testing to characterize the formation of weld nuggets. The tensile tests showed significant relationship between differing current increments and sufficient weld time to attain a proper weldment. The hardness distributions were measured from the unwelded area on one side of the sample and moved through the regions of the heat-affected and fusion zones and ended at the unwelded area on the other side. The hardness was altered due to heat treatment, and the metallurgical views support this phenomenon.

Introduction

The spot welding process joins two or more metal sheets together through fusion at a certain point (Ref. 1). It is a simple process that uses two copper electrodes to press the work sheets together and force high current to pass through it. The growth of the weld nugget is, therefore, determined by its controlling parameters such as current, weld time, electrode tips, and force (Ref. 2). In this experiment, the current and weld time were varied to see the weld growth, while the electrode tips and force remained constant. The entire work was carried out to observe the weld growth in mild steels joints, stainless steels joints, and both steels in a mixed joint for the same current and weld time (Ref. 3).

Experimentation

In this experiment, a JPC 75-kVA spot welding machine was used. The machine was capable of joining up to 5-mm-thick base metals for various materials. It uses a pneumatic-based electrode actuation system to produce up to 15 kN of force, and a current range varying from 1 to 25 kA. However, this experiment used only a constant of 3 kN of force for the entire weld schedules at increments of 6, 7, and 8 kA. The weld time was varied from 10 to 20 cycles with 5 as the interval. The electrode tips were 0.5 mm^2 in the round area. The base metals for these experiments were mild steel and 302 austenitic stainless steel (Table 1). Initially, a weld schedule (Table 2) was developed to accomplish these experiments. A standard size (200 × 25 × 1 mm) for the base metals was prepared (Fig. 1) and welded according to the weld schedule as lap joints. The first category was only the mild steel joints, whereas, the second category was only 302 austenitic stainless steel. The third category was mixed base metals of mild and 302 austenitic stainless steels. A total of 200 pairs of welded samples were developed for tensile, hardness, and metallurgical tests (Refs. 4, 5).

KEYWORDS

Dissimilar Steels
Pull Test
Resistance Spot Welding
Spot Weld
Stainless Steel
Weld Nugget
Weld Hardness

Results and Discussion

Hardness Test

The hardness of the welded areas for the mild steel seemed to be higher than the stainless steel and the mixed steels (Ref. 6). Forty-five pairs of samples were analyzed and found that the average of unwelded areas was 54 HRB, and the average of welded areas was 98 HRB. The hardness increment was 44 HRB (81%). These hardness increments were surmized to be the result of heat treatment due to high thermal conductivity and low resistivity of the materials (Ref. 7). Figure 2 shows the hardness of the mild steels.

The hardness of 302 austenitic stainless steels did not change very much as compared to mild steels. This was because of the nature of the material. The heat treatment effect is not supported by the chromium composition of the material (Ref. 8). The effect was reduced by the thermal conducting factors as well as the electrical resistance. The average of unwelded area was 75 HRB and the average of welded area was 85 HRB. The average increment (13%) was only 10 HRB. The results are graphically shown in Fig. 3.

A. ARAVINTHAN (aravinthan.a@nottingham.edu.my)*, assistant professor, and C. NACHIMANI* (nachi.charde@nottingham.edu.my)*, research assistant, are with Department of Mechanical, Material and Manufacturing Engineering, The University of Nottingham Malaysia Campus, Selangor Darul Ehsan, Malaysia.*

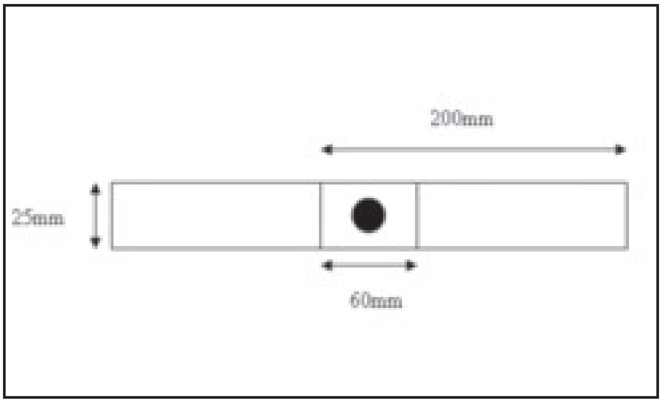

Fig. 1 — Schematic of the test sample.

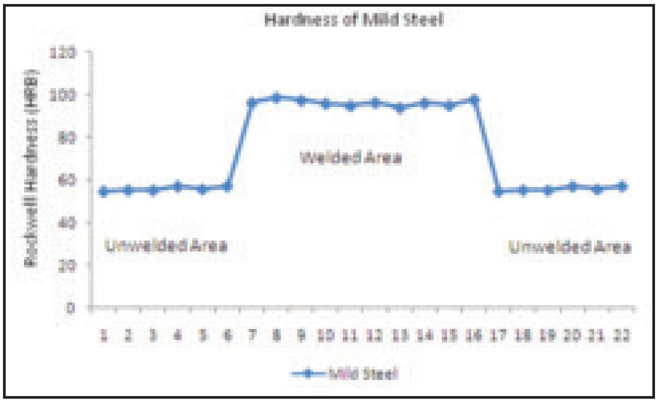

Fig. 2 — Hardness diagram for mild steel.

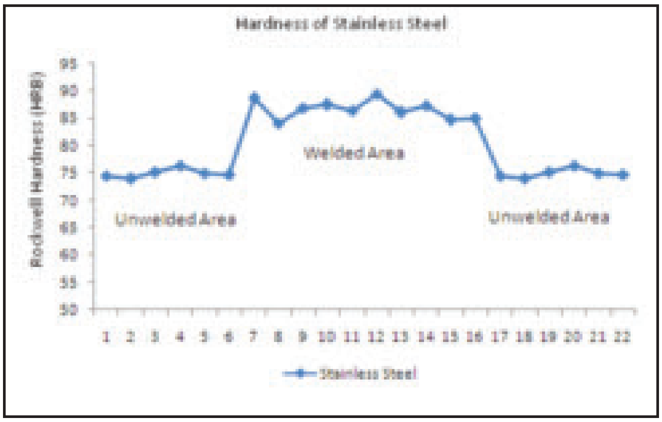

Fig. 3 — Hardness diagram for stainless steel.

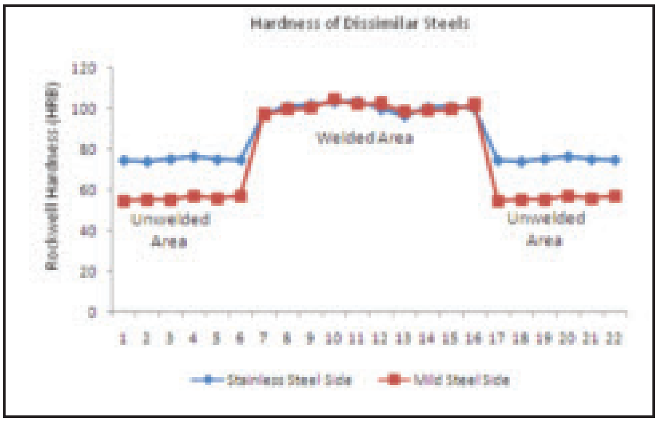

Fig. 4 — Hardness diagram for stainless and mild steels joined.

The final test on hardness was carried out on the dissimilar metal welded sheets. One side of the material was mild steel and the other side was stainless steel, as shown in Fig. 1. The hardness increased slightly on both sides of the weld compared to the mild and stainless steels categories. For instance, the mild steel hardness was found to be 54 HRB at the unwelded areas, whereas, the welded region was 100 HRB. It has increased slightly compared to the mild steel category of 98 HRB. The stainless steel side also increased almost to the mild steel values (101 HRB). It increased from 75 to 101 HRB. Although it fluctuated slightly up and down, the values remained in the region of deviation. The hardness values are plotted against each other in Fig. 4.

Table 1 — Chemical Composition of Mild Steel and 302 Austenitic Stainless Steel

Mild Steel

Element	Maximum wt-%
C	0.23
Mn	0.90
P	0.04
S	0.05

302 Austenitic Stainless Steel

Element	Maximum wt-%
C	0.15
Cr	17–19
Ni	8–10
Mn	2.00
Si	1.0
S	0.03
P	0.04

Tensile Test

The strength of the welded samples was tested using tensile peeling methods for the mild steel, stainless steel, and mixed steels. Figure 5 shows the tensile strength with respect to increments of current and weld time.

Tensile test results showed that when welding current and weld time were increased, the strength was also increased as reported in the literature (Refs. 4, 5).

Table 2 — Weld Schedule

Samples Number	Material[(a)]	Electrode Tips (mm^2)	Force (kN)	Current (kA)	Weld Time (Cycle)
1–5	MS & SS	0.5	3	6	10
6–10	MS & SS	0.5	3	6	10
11–15	MS & SS	0.5	3	6	10
16–20	MS & SS	0.5	3	7	15
21–25	MS & SS	0.5	3	7	15
26–30	MS & SS	0.5	3	7	15
31–35	MS & SS	0.5	3	8	20
36–40	MS & SS	0.5	3	8	20
41–45	MS & SS	0.5	3	8	20

(a) MS – Mild Steel; SS – Stainless steel