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Microstructure and failure behavior of dissimilar resistance spot welds between low carbon galvanized and austenitic stainless steels

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Abstract

Resistance spot welding was used to join austenitic stainless steel and galvanized low carbon steel. The relationship between failure mode and weld fusion zone characteristics (size and microstructure) was studied. It was found that spot weld strength in the pullout failure mode is controlled by the strength and fusion zone size of the galvanized steel side. The hardness of the fusion zone which is governed by the dilution between two base metals, and fusion zone size of galvanized carbon steel side are dominant factors in determining the failure mode.

Keywords: Resistance spot welding; Failure mode; Fusion zone size; Stainless steel

1. Introduction

The quality and mechanical behavior of resistance spot welds (RSW) significantly affect durability and crashworthiness of vehicle [1]. Overload failure mode of spot welds is a qualitative measure of the weld reliability. Generally, the spot weld failure occurs in two modes: interfacial and pullout. In the interfacial mode, failure occurs through nugget, while in the pullout mode, failure occurs by complete (or partial) nugget withdrawal from one sheet. Load carrying capacity and energy absorption capability for those welds which fail under the overload interfacial mode are less than those welds which fail under the overload pullout mode. To ensure the reliability of the spot welds during vehicle lifetime, process parameters should be adjusted so that the pullout failure mode is guaranteed [2,3].

Dissimilar resistance spot welding can be more complex than similar welding due to different thermal cycle experienced with each metal. Despite of various application of dissimilar RSW, reports in the literature dealing with mechanical behaviors of them are limited. The objective of this research is to investigate and analyze failure behavior of dissimilar resistance spot welds between low carbon steel and austenitic stainless steel.

2. Experimental procedure

A 1.1 mm thick galvanized low carbon and 1.2 mm thick austenitic stainless steel sheets were used as the base metals, in this research. The chemical composition of galvanized steel (GS) and stainless steel (SS) is given in Table 1. Spot welding was performed using a 120 kVA ac pedestal type resistance spot welding machine, controlled by a PLC. Welding was conducted using a 45° truncated cone RWMA Class two electrode with 7-mm face diameter. Schematic representation of the weld schedules selected for this investigation is shown in Fig. 1.

The static tensile–shear test samples were prepared according to ANSI/AWS/SAE/D8.9-97 standard [4]. Fig. 2 shows the sample dimensions. Tensile–shear tests were performed at a crosshead of 2 mm/min with an Instron universal testing machine. Peak load and failure energy (measured as the area under the load–displacement curve up to the peak load) were extracted from the load–displacement curve. Failure mode was determined from the failed samples.

Samples for metallographic examination were prepared using standard metallography procedure. Optical microscopy was used to examine the microstructures and to measure physical

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Table 1
Chemical composition of test materials (wt.%)

	Element										
	C	Mn	P	S	Si	Cr	Ni	Mo	Cu	Nb	Fe
Austenitic stainless steel	0.035	1.08	0.038	0.004	0.388	18.47	9	0.561	0.462	0.016	Base
Galvanized steel	0.065	0.404	0.018	0.017	0.095	0.017	0.032	0.004	0.053	0.001	Base

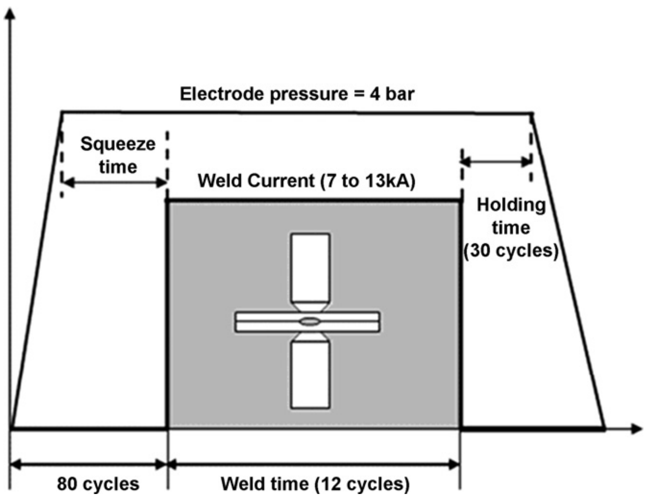

Fig. 1. Schematic of welding schedule used in this investigation.

weld attributes. After complete separation in the tensile–shear test failure location of samples was examined with optical microscope.

Microhardness test, a technique that has proven to be useful in quantifying microstructure–mechanical property relationships, was used to determine the hardness profile in vertical (through thickness) and horizontal directions (50 μm away from weld centerline for galvanized steel side and stainless steel side), using a 100 g load on a Shimadzu microhardness tester.

3. Results and discussion

3.1. Microstructure and hardness profile of the joint

Fig. 3 shows a typical macrostructure of a dissimilar resistance spot weld between galvanized low carbon steel and austenitic stainless steel. As can be seen, the joint region consists of three distinct structural zones: (i) fusion zone (FZ) or

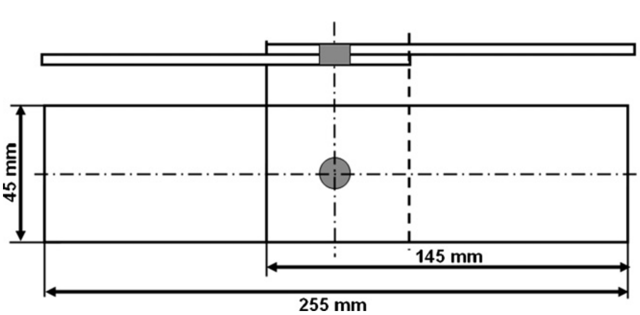

Fig. 2. Dimensions of tensile–shear test specimens.

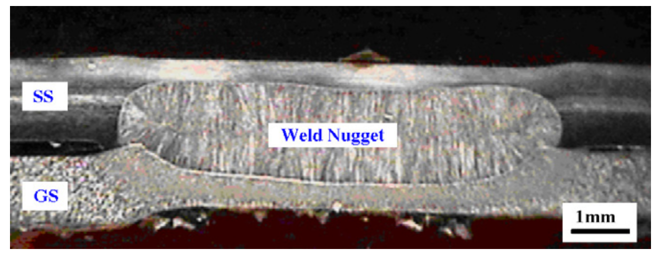

Fig. 3. Macrostructure of dissimilar RSW between galvanized steel and stainless steel.

weld nugget, (ii) heat affected zone (HAZ), and (iii) base metal (BM).

One of the important features of the weld nugget is its asymmetrical shape such that fusion zone size (FZS) and penetration depth of stainless steel side are larger than those of galvanized steel side. Electrical resistance and thermal conductance control heat generation and heat dissipation which in turn, affect weld nugget formation and its growth [5]. Differences in the thermal conductivity and electrical resistivity of two steel sheets lead to an asymmetrical weld nugget in dissimilar metal joints. Lower electrical resistance of carbon steels, which is even lower for low carbon galvanized steel sheet, and its higher thermal conductivity compared to stainless steel leads to smaller fusion zone in the former.

HAZ in the galvanized steel side is wider than that in the stainless steel side, which can be related to higher thermal conductivity of galvanized steel.

Fig. 4 shows that the FZS of both stainless and galvanized steel sides increases with the welding current at a decreasing rate with the exception of really high currents

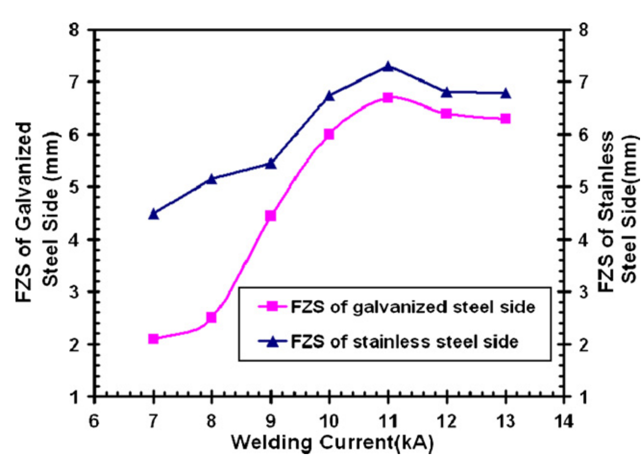

Fig. 4. Effect of welding current on the FZS of galvanized and stainless steel side.