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Inverter DC resistance spot weldability of 590 MPa galvannealed steel for automotive applications

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ABSTRACT

Purpose: This study analyzes resistance spot weldability of coated and uncoated DP 590 steels.

Design/methodology/approach: To compare the resistance spot weldability of coated (GAFC590, galvannealed) and uncoated (SPFC590) steels, tensile strength test and macro-section test were conducted for the resistance spot welds. Acceptable welding conditions were determined as a function of the resistance spot welding process parameters such as electrode force, welding time, and welding current. The lower limit of the welding lobe was the minimum shear tension strength for 590 MPa-grade steel while the upper limit was determined whether or not expulsion was detected.

Findings: Galvannealed steel required more welding current than uncoated steel. Acceptable welding current condition and welding lobe were changed depending on whether steel is coated or not.

Research limitations/implications: This study is forced on inverter DC resistance spot weldability of 590Mpa-grade steels for automotive application.

Practical implications: This study confirms the weldability of galvannealed steel by comparing resistance spot weldability depending on whether or not the steels is coated.

Originality/value: This study analysed resistance spot weldability depending on whether or not steel sheets are coated, where SPFC590 uncoated steel) and GAFC590 (galvannealed steel) were used. The required spot welding current for galvannealed steels was higher than the uncoated steel and welding lobes for coated and uncoated steels were determined.

Keywords: Galvannealed steel; Uncoated steel; Resistance spot welding; SPFC590; GAFC590; Inverter DC spot welding system; Welding lobe

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MATERIALS MANUFACTURING AND PROCESSING

1. Introduction

Resistance spot welding is a process that uses joule heat obtained from resistance to the flow of welding current through the sheet metals from electrodes.

In automobile industry, corrosion-resistant galvannealed steel is widely used. Resistance spot welding is the most important welding process in assembling automobile parts. To maintain high welding quality, it is important to set acceptable welding conditions and minimize electrode wear.

The inverter DC resistance welding has been used in various fields such as aluminum welding, car body welding and railroad car welding. In general, inverter DC type is more efficient than SCR AC type in terms of power consumption, welding range and electrode wear.

In this paper, weldability has been evaluated depending on whether or not 590 MPa steel is coated. In the inverter DC welding system, weldability has been compared between the uncoated steel SPFC590 (1.0 mmt) and the galvannealed steel GAFC590 (1.0 mmt) through the shear tension test and macro section test.

2. Experiments

2.1. Inverter DC welding system

The inverter DC welding system usually uses 3-phase power sources. After rectifying 3-phase power sources using six diodes or thyristors, DC power which were smoothened through the capacitor called 'DC Link' are obtained. The voltage formed in the DC Link plays a role of power to an inverter. An inverter generates single-phase voltage by configuring IGBT in H-bridge type. The frequency of the voltage formed at this time is higher than 60 Hz which is used in the SCR AC welding system. In general, the switching frequency of 1 kHz is used. Using a transformer, current is amplified while voltage is reduced. The power amplified in the transformer is rectified again with diode and converted into DC after passing through a reactor. Figure 1 shows an inverter DC welding system.

2.2. Experiments setup

The welding conditions to test weldability depending on whether or not 590 MPa steels is coated is mentioned in Table 1 and Table 2. Table 1 states welding conditions for uncoated steel while Table 2 shows welding conditions for coated steel. Electrode force ranged from 200 to 400 kgf while welding time ranged from 4 to 12 cycles.

Table 1.
Welding condition of uncoated steel, SPFC590 1.0 mmt

Weld Current [kA]	4, 5, 6, 7, 8, 9
Weld Time [cycle]	4, 6, 8, 10, 12
Electrode Force [kgf]	200, 300, 400

* One cycle is equivalent to 1/60 sec

Table 2.
Welding condition of galvannealed steel, GAFC590 1.0 mmt

Weld Current [kA]	4, 5, 6, 7, 8, 9, 10, 11
Weld Time [cycle]	4, 6, 8, 10, 12
Electrode Force [kgf]	200, 300, 400

Fig. 2 shows the shape and dimensions of specimen. In terms of welding electrode, domed chrome-copper electrode has been used.

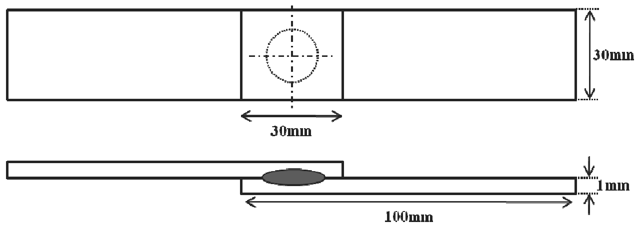


Fig. 2. Schematic illustration of weld specimen

2.3. Evaluation of weldabillity

The resistance spot weldability can be accessed through shear tension test and macro section test. To test the weldability of uncoated steel and galvannealed steel a shear tension test has been performed using a universal tester which can apply up to 30 tons of load. After etching the section in the weld part, nugget width has been measured. Then, welding lobe has been obtained based on the result of the shear tension test and whether or not expulsion has occurred.

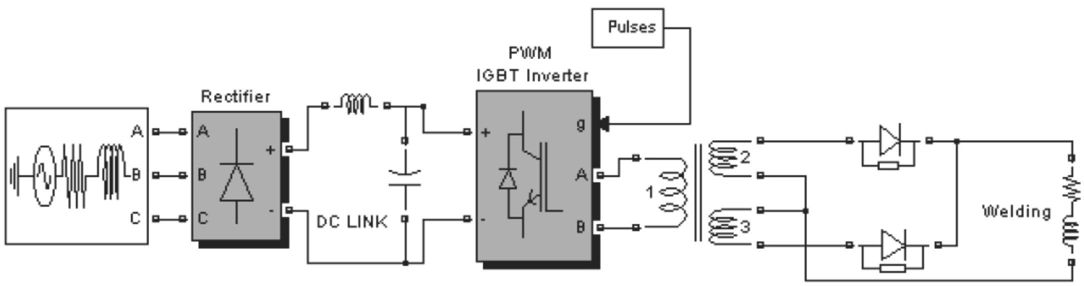


Fig. 1. Inverter DC welding system

A welding lobe is a graph which represents allowed welding range by fixing one factor and changing two remaining factors among electrode force, weld time and weld current. After fixing electrode force, in this paper, the horizontal and vertical axes were set to weld current and weld time respectively. Fig. 3 shows the example of weld current-weld time welding lobe.

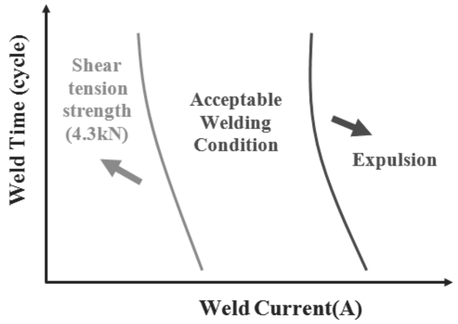


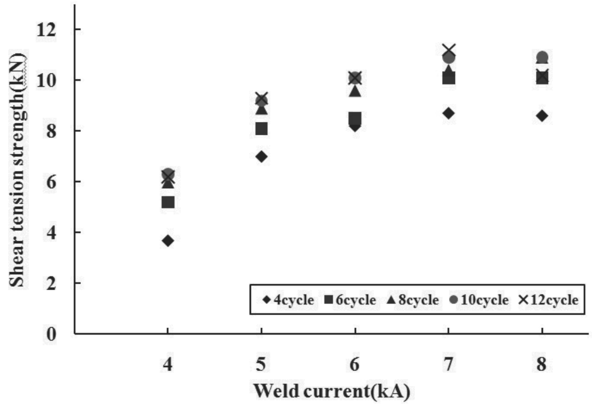
Fig. 3. Welding lobe (weld current-weld time)

3. Results and discussion

3.1. Shear tension strength

Figures 4-7 show the results of shear tension tests on 590 MPa steel over the change in electrode force. As weld current and weld time increased, shear tension strength increased. Fig. 4 reveals a shear tension strength graph at electrode force of 200 kgf. Fig. 4(a) shows the result of shear tension test on uncoated steel while Fig. 4(b) reveals the result of shear tension test on coated steel. According to the two figures, it is confirmed that shear tension strength increased with increase in weld current. However, shear tension strength stayed the same or rather declined when expulsion occurred due to high weld current. The strength increased when weld time increased under the same weld current. When a certain time passed, however, shear tension strength stayed the same. In addition, uncoated steel was bigger than coated steel in terms of shear tension strength in the weld joint.

a) SPFC590, 1.0mmt



b) GAFC590, 1.0 mmt

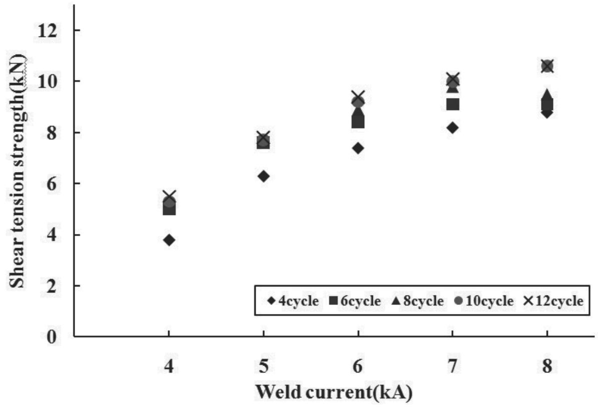
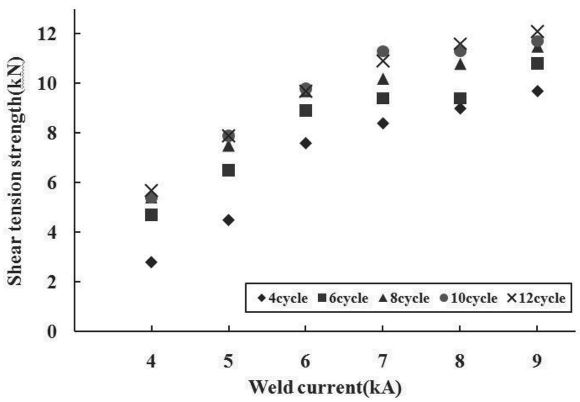


Fig. 4. Shear tension strength for 200 kgf of electrode force

a) SPFC590, 1.0mmt



b) GAFC590, 1.0 mmt

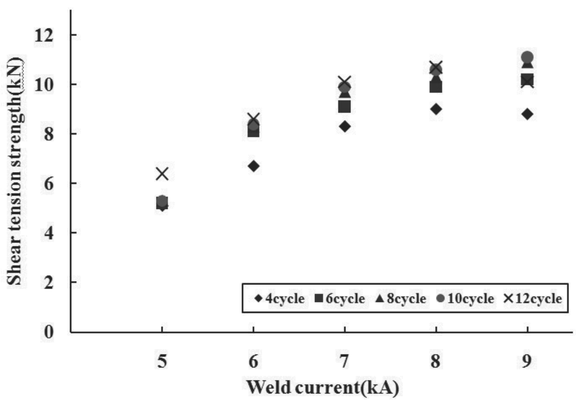


Fig. 5. Shear tension strength for 300 kgf of electrode force

a) SPFC590, 1.0mmt b) GAFC590, 1.0 mmt

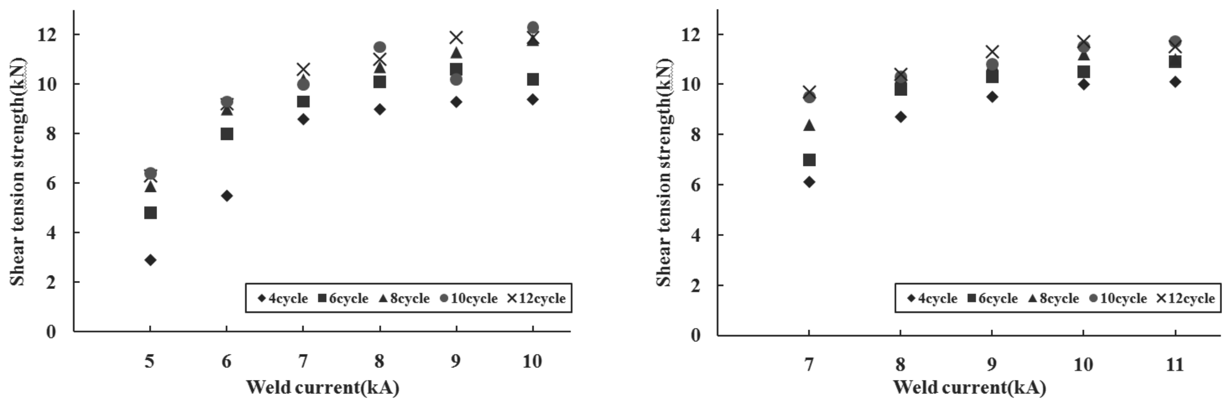


Fig. 6. Shear tension strength for 400 kgf of electrode force

Figs. 5 and 6 show the results of shear tension test at 300 kgf and 400 kgf of electrode force respectively. Even though the results were similar to the result (200 kgf) shown in Fig. 4, shear tension strength decreased as electrode force increased under the same welding conditions.

Fig. 7 shows a graph which has compared two steel in terms of shear tension strength with change in electrode force under the same welding conditions (weld current: 7 kA, weld time: 10 cycles, electrode force: 200/300/400 kgf). Under the same welding conditions, uncoated steel was higher than coated steel in terms of shear tension strength in the spot-welded joint. Therefore, it has been confirmed that coated steel requires more welding current and longer weld time to get shear tension strength equivalent to uncoated steel.

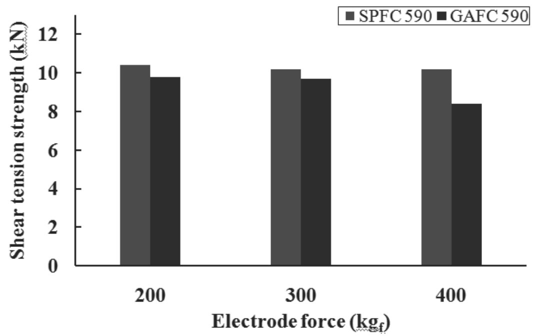


Fig. 7. Shear tension strength at same welding condition

3.2. Macro section test

Fig. 8 shows comparison of nugget width under the same welding conditions. The welding conditions were 7 kA in weld current, 10 cycles in weld time and 200/300/400 kgf in electrode force. Uncoated steel was bigger than galvannealed steel in terms of nugget width because contact resistance decreased in the beginning due to low melting point of zinc in galvannealed steel. As a result, resistance heating and nugget width decreased.

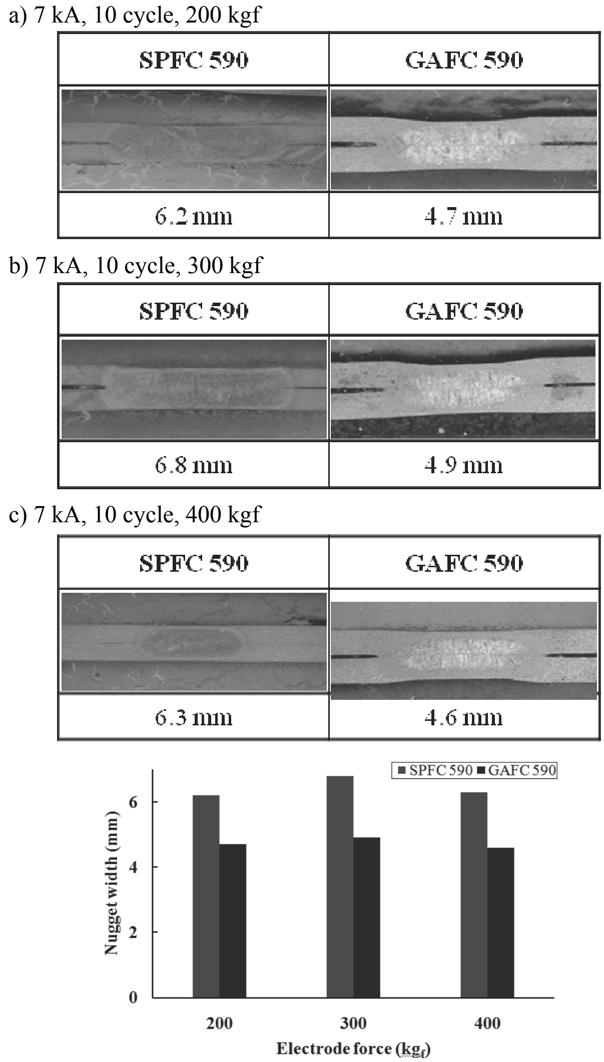


Fig. 8. Nugget width for SPFC590 and GAFC590

3.3. Welding lobe

Figures 9-11 show the results of welding lobes depending on whether or not 590 MPa steel is coated. In this paper, fracture shape in the welding lobe has been shown to analyze fracture mode as well as acceptable welding range. The interfacial fracture in the weld part was marked in a circle while plug fracture in the base metal was shown in a diamond shape.

In terms of acceptable welding current range, the galvannealed steel was wider than the uncoated steel at 200/300/400 kgf of electrode force.

The coated steel GAFC590 required more welding current than the uncoated SPFC590 in acceptable welding conditions at all three electrode forces. The reason is that the presence of molten coatings at the faying surfaces during welding could reduce contact resistance and result in reduction of joule heatging.

As the electrode force increased, the required welding current also increased for SPFC 590 and GAFC590.

a) SPFC590, 1.0 mmt b) GAFC590, 1.0 mmt

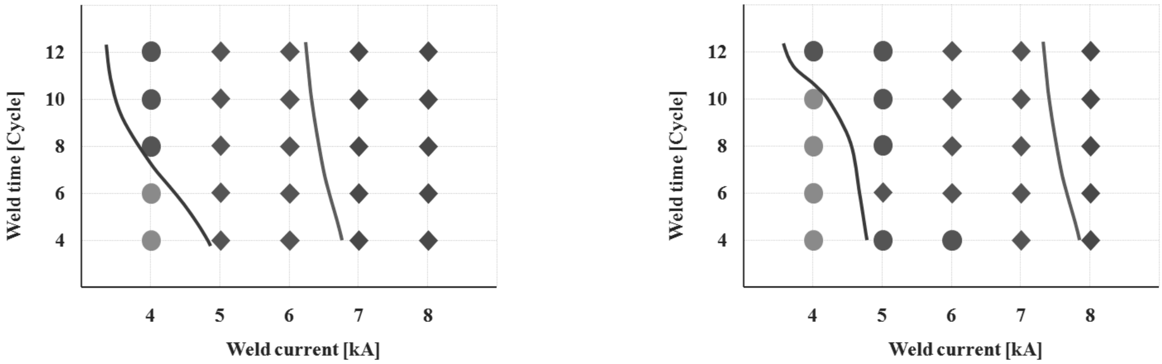


Fig. 9. Welding lobe of 200 kgf

a) SPFC590, 1.0mmt b) GAFC590, 1.0 mmt

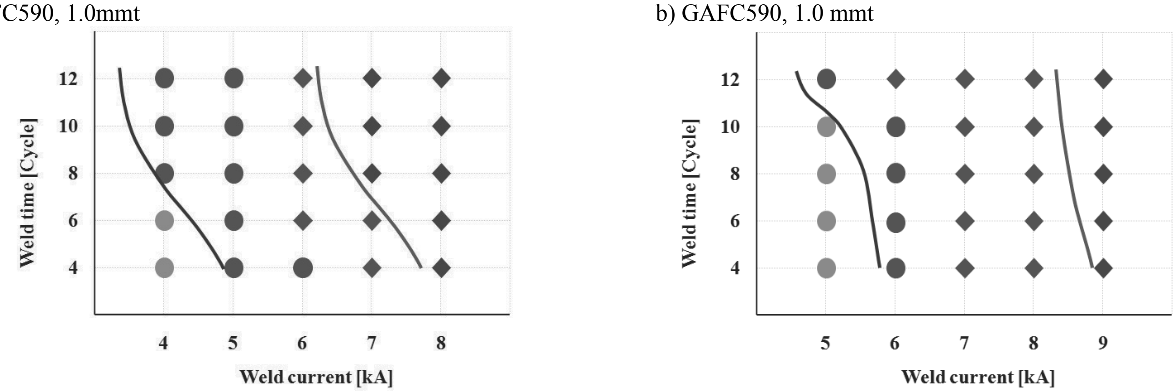


Fig. 10. Welding lobe of 300 kgf

a) SPFC590, 1.0 mmt b) GAFC590, 1.0 mmt

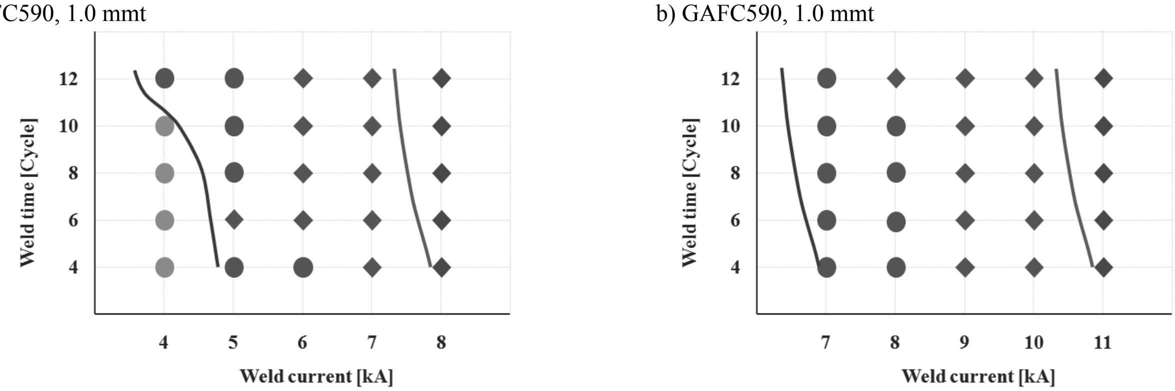


Fig. 11. Welding lobe of 400 kgf

4. Conclusions

To assess weldability depending on whether or not 590 MPa steel is coated, an inverter DC welding system has been used. In this paper, the uncoated steel SPFC590 (1.0 mmt) and the galvannealed steel GAFC590 (1.0 mmt) have been used. Then, weldability has been compared depending on whether or not the steel is coated through shear tension test and macro section test. In addition, welding lobes have been obtained and compared. As a result, the following conclusion has been obtained:

1. Under the same welding conditions, the galvannealed steel GAFC590 showed less shear tension strength than the uncoated steel SPFC590.
2. Under the same welding conditions, SPFC590 showed less nugget size than GAFC590.
3. As electrode force increased, acceptable weld current range increased, and interfacial fracture in the weld part was mostly observed at the high current phase.
4. GAFC590 was wider welding lobes than SPFC590 at 200/300/400 kgf of electrode force.

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