Single-Sided Resistance Spot Welding for Auto Body Assembly

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Single-side access holds promise for applications that normally are difficult to resistance spot weld such as hydroformed and closed-section parts

Resistance spot welding (RSW) has been widely employed in sheet metal fabrication for several decades. The automotive industry, for example, prefers RSW because it is a simple and cost-effective joining method. Resistance spot welding is performed on thousands of spots for every passenger vehicle; therefore, each welded spot has its own importance not only with regard to quality but also for production manufacturing.

Because of the nature of a conventional RSW machine, sheet metals have to be inserted between upper and lower electrodes. However, this introduces various limitations for RSW of an automotive body assembly:

1) In order to make a weld on the autobody floor, a large C-type gun is needed to access the weld spots. Sometimes the mouth size of the gun is larger than 1 m resulting in it being hard to teach and maintain.

2) Many welding spots are located in closed-section parts that an ordinary RSW gun cannot access. In those cases, arc or laser beam welding techniques can be alternatives to RSW; however, both processes have their own weak points. Arc welding has thermal deformation and quality control issues. While laser beam welding has unique advantages, it is very expensive.

3) New joining methods are needed for newly developed sheet metal forming technology. Hydroformed parts are usually difficult to join with conventional RSW due to the high electrode force and their geometry.

This article focuses on developing a new RSW technology and its potential for improving the traditional RSW issues. A new welding system was designed that could make a weld using single-sided access with low electrode force. Using the system, spot welds were made using only single-sided access with or without a backing plate. Various tests were completed to understand the characteristics of the system. Weldability lobe curves were also determined in terms of welding time and current along with electrode force. Finally, this technique was applied to a number of automotive assembly cases and the results were discussed.

Experimental Setup

The experimental procedure was divided into two stages: lab-oriented specimen tests and field-oriented automotive parts tests. Lab-oriented tests were done by tensile-shear coupon — Fig. 1. In order to investigate the effect of a backing plate on weld quality, copper backing plates (electrodes) were used with and without holes. Figure 1A depicts the size and arrangement of the coupons. Figure 1B shows an experimental setup for single-sided spot welding with a backing plate. A holed (30-mm) backing plate was used to simulate single-sided spot welding without a backing plate — Fig. 1C.

Field-oriented tests were made using real automotive parts and a robot system. Welding was performed on a specially designed single-sided welding machine. Thanks to the high-grade transformer and

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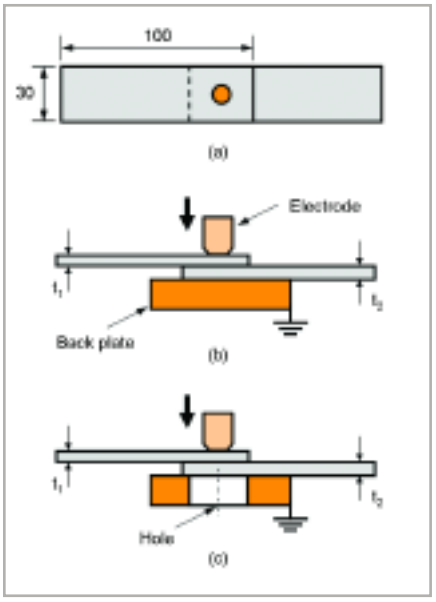

Fig. 1— Experimental setup for tensile-shear test coupon. A — Size of coupons (mm); B — single-sided RSW with backing plate; and C — single-sided RSW without backing plate.

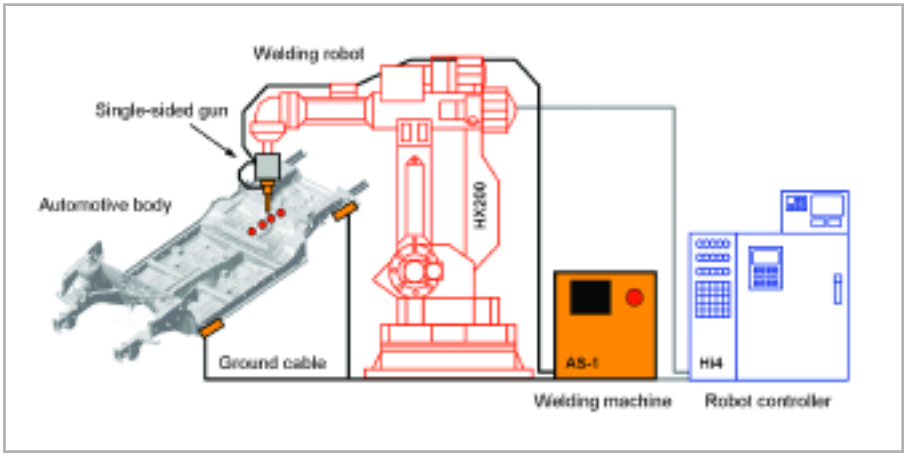

Fig. 2 — Configuration of the single-sided RSW system.

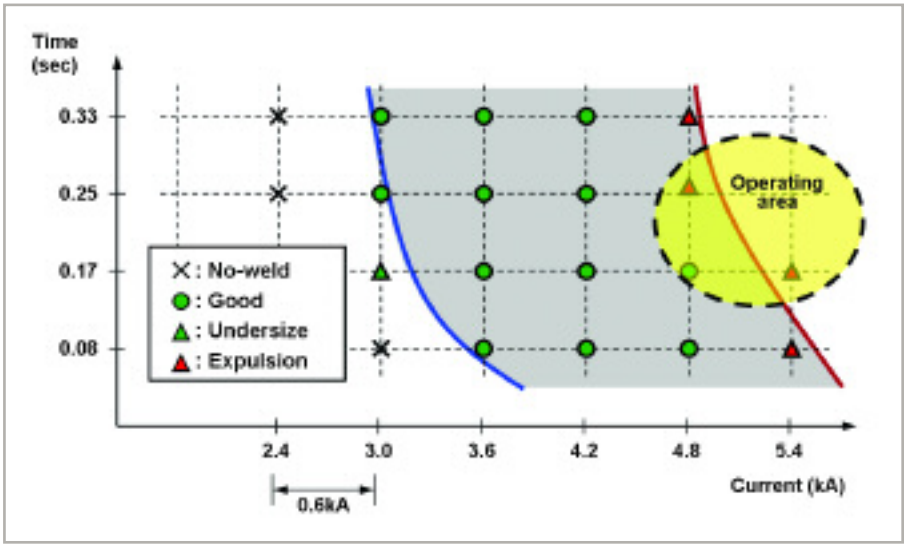

Fig. 3 — Typical single-sided RSW weldability lobe curve.

fine inverter control of the machine, it is possible to extend the secondary cable up to 20 m. A robot system with a 200-kg maximum load capacity was used to maintain proper reaction force of the single-sided welding gun. Schematic configuration of the system is shown in Fig. 2. Secondary cables were connected with a single-sided welding gun and ground plates. The robot controller integrated and managed all the actions of the welding and communication.

Results and Discussion

The results reported in this section describe the characteristics of the single-sided RSW machine and its application examples. Various types of closed-section spots were tested and showed good results. A few limitations and challenges of the system are also discussed.

Weldability Lobe Curve

Welding was performed on various combinations of automotive sheet metals (0.7- to 1.6-mm thickness, coated, uncoated, advanced high-strength steel, with or without a backing plate, etc.). The typical weldability lobe curve of single-sided RSW is shown in Fig. 3. The experimental setup of Fig. 1B was used with coated steel [0.8t (upper sheet) + 1.4t (lower sheet)]. Because of the low electrode force (500 N), acceptable welds were obtained at a relatively low current range.

Large Panel with Members and Brackets

In order to make a weld with members and brackets on the large panel, such as the center floor of the auto body, a large C-type gun is needed to access in the middle of the panel. Since complicated jig fixtures and clamping devices are located underneath the panel, it is very hard to teach the robot the right position with proper cycle time — Fig. 4A. Once the single-sided RSW system is adopted for this application, fixture and clamping units can be dramatically reduced — Fig. 4B. Thanks to the easy access to the weld spots, cycle time also can be decreased.

Hydroformed Parts

Hydroformed auto parts are getting used more widely due to their flexible geometry and high stiffness. A recent application is reported in which body members and pillars are replaced with hydroformed parts. The most challenging issues with regard to using hydroformed parts in the body-in-white are joining them with other structures, such as panels, reinforcements, brackets, etc., due to their closed-section geometry. While arc or laser welding can be a solution, the single-sided RSW technique can be another great solution. Once brackets or flanges are welded onto hydroformed parts (Fig. 5), those parts are easily assembled with conventional RSW.

Preassembled Parts

Usually, large parts are assembled at original equipment manufacturers (OEMs). This means the OEMs need large facilities with complicated manufacturing processes. Once parts are provided as a preassembled unit, lean assembly line manufacturing can be achieved with a minimum number of production cells. As shown in Fig. 6, package tray panels are assembled with three stages. In this case,

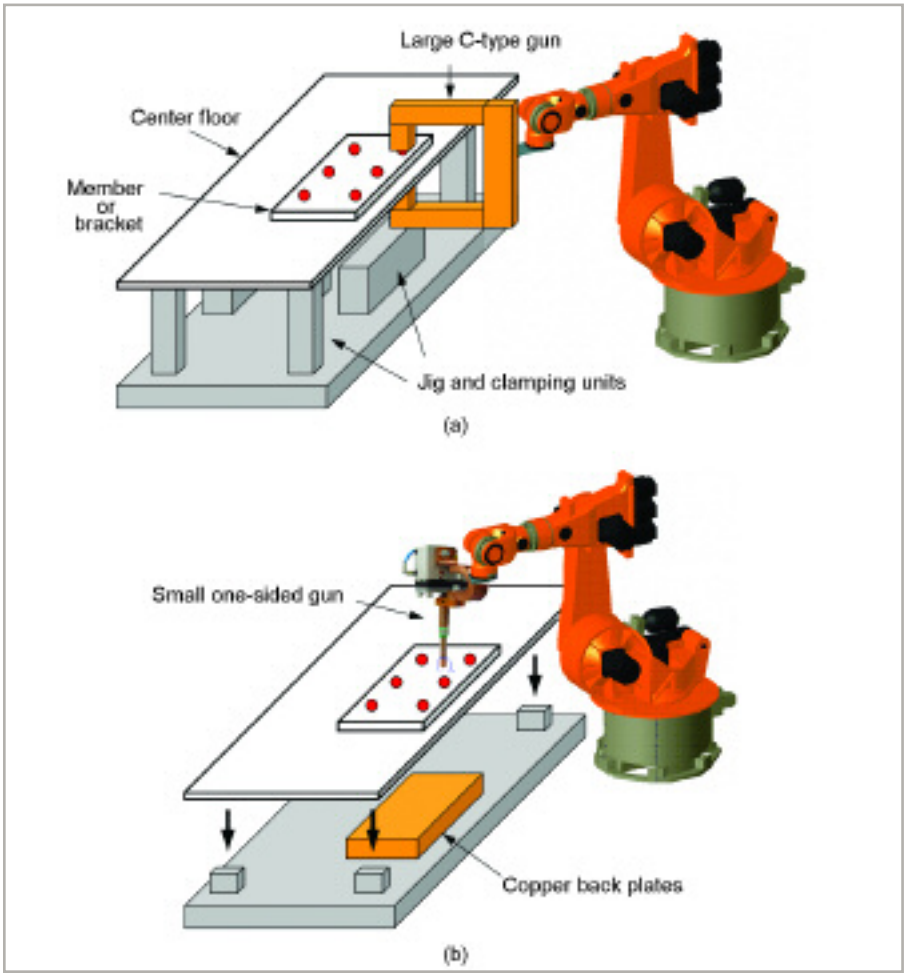

Fig. 4 — Single-sided RSW of a large panel. A — Large C-type gun with jig and clamping units; and B — single-sided gun with backing plates.

the package tray side panel has to be welded in the first stage and then the side outer panel is assembled, resulting in body side complete. After that, this complete is built together with a package tray at a later assembly station. However, if the package tray assembly is preassembled (Fig. 7), the manufacturing process can be reduced to two stages; body side complete stage and its joining stage with package tray assembly. In order to assemble package tray panels on the body side complete, a single-sided welding technique is needed. While arc or laser beam welding may not be a perfect solution due to the gap issue of the end of the panel edge, single-sided RSW has sufficient electrode force to control the gap.

Other Applications

Since the single-sided RSW system was developed to make closed-section welds, various other applications have been presented. Low electrode force and long secondary cables make the system feasible at an automated body line with proper cycle time. The following applications have been tested; the benefits are also listed.

- Closed section parts: alternatives for conventional single-sided welding processes.
- Jig-less clamping units for laser beam welding: easy-to-control gaps for coated steel.
- Flexible configuration of production line: no more limitations on closed section.
- Indentation-free welds (backing plate side): good appearance with low electrode force.
- Mismatched parts: relatively robust for gap/mismatch issues.

There are many advantages of using the single-sided RSW system. It offers a simple system configuration and easy-access capability. Other advantages include the need for smaller facilities, shorter cycle times, easy maintainance, effortless robot teaching, etc.

Limitations and Challenges

Even though single-sided access of spot welding gun gives us a great advantage, a few limitations and challenges have to be

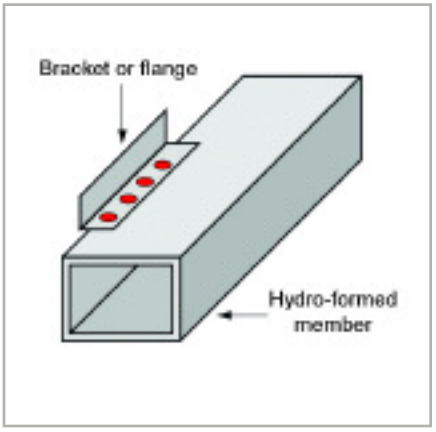

Fig. 5 — Single-sided RSW of hydroformed parts.

considered to guarantee a good-quality weld. First, the thickness of the upper sheet should be no more than 1.4 mm. A weld can be made with thicker sheet; however, due to the low electrode force, it is very hard to set up a point contact between sheets where proper current density is needed for molten nugget. Second, lower sheets have to have a certain amount of stiffness to support the single-sided electrode force. Therefore, geometry and thickness of the lower sheets are very important. Basically, two-sheet welding is recommended unless the geometric structure of the third or forth sheet is strong enough to maintain electrode force.

Conclusions

An automated single-sided RSW system was introduced and various applications to automotive body assembly are discussed in this research. The weldability lobe curve shows that operating points can be found at a relatively low welding current range due to the low electrode force. Because only single-side access is necessary to make a good weld, great potential advantages can be found in the joining of large panels. The single-sided system can also be used for applications that are difficult to spot weld, such as hydroformed or closed-section parts. Due to the simple system configuration and easy-access capability, productivity can be increased by improving cycle time and reducing maintenance efforts. Although some limitations exist, this technique can be a great alternative to conventional single-sided sheet metal joining processes. ◆

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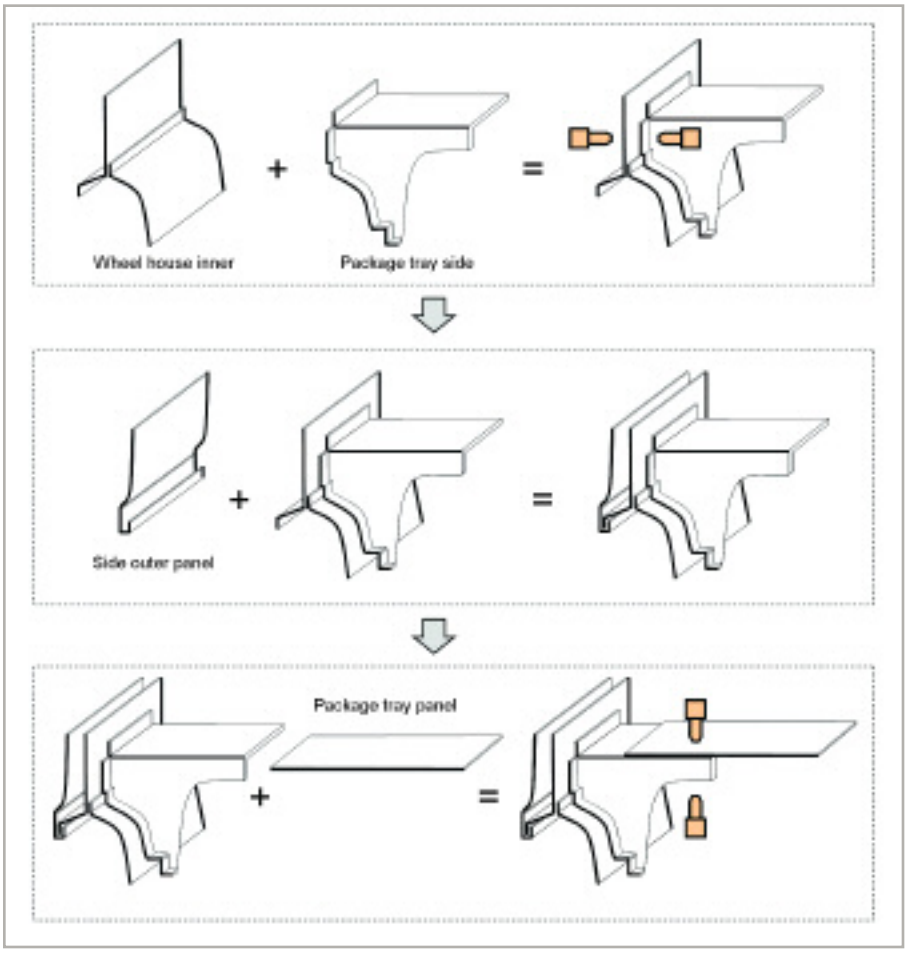

Fig. 6 — Conventional way to build package tray panels.

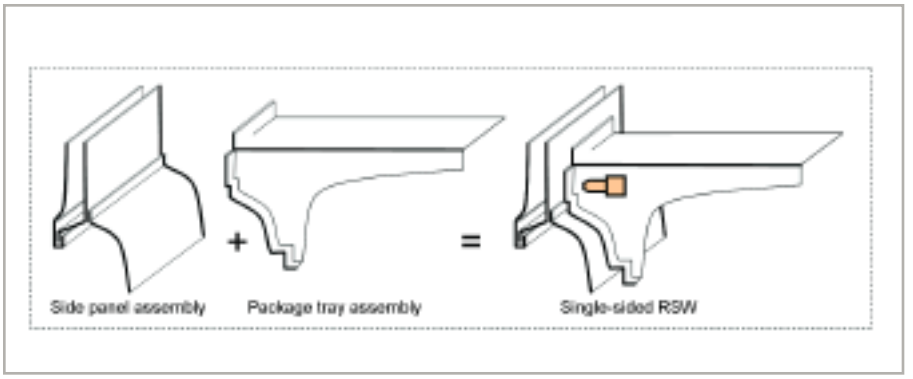

Fig. 7 — Proposed way to build preassembled package tray panels.

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