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Improvement of Weld Quality by "Intelligent Spot™" Welding Technology†

1. Introduction

Resistance spot welding technologies used in assembly welding of the auto body have an important influence on productivity improvement and quality stabilization in the automobile industry, as the total number of spot welds in one vehicle reaches as many as 3 000–6 000. On the other hand, steel sheets with diverse thicknesses, strengths, and types of coatings are used in automobiles, and adequate consideration must be given to these properties when setting resistance spot welding conditions. For example, in the case of a center pillar, it is necessary to weld 3-sheet lapped joints with a large thickness ratio (ratio of (total sheet thickness of the joint) / (thickness of the thinnest sheet, which is positioned on the outer side of the joint)), comprising an outer panel (thin sheet of mild steel), reinforcement member (thick sheet of high tensile strength steel), and inner structure (thick sheet of high tensile strength steel). However, it is known that formation of nuggets on the thin mild steel sheet is in principle difficult in resistance spot welding of joints with such high sheet thickness ratios. A welding technology that solves this problem had been strongly desired.

JFE Steel developed the "Intelligent Spot™ Welding Technology"[1–3] as a new resistance spot welding technology that solves the inherent problem of welding joints with high sheet thickness ratios, and studied its practical application with customers. The following presents an outline of this innovative welding technology.

2. Outline of Intelligent Spot™ Welding Technology

2.1 Welding Mechanism

The Intelligent Spot™ Welding Technology is a technology which enables resistance spot welding of joints with high sheet thickness ratios by multi-step control of the electrode force and welding current during welding. **Figure 1** shows a schematic diagram of the welding current/electrode force pattern and fusion zone formation process in this technology. The welding process is divided into two steps. In Step 1, adequate heat generation between the thin sheet and thick sheet is achieved by applying low electrode force, short weld time, and high welding current conditions. In Step 2, a nugget is formed between the two thick sheets using high electrode force and a long weld time. **Photo 1** shows the results of direct observation with a high speed video camera of the nugget formation process in Intelligent Spot™ Welding. Here, the edges of a 3-sheet lapped joint comprising sheets with thicknesses of 0.7 mm, 2.3 mm, and 2.3 mm (sheet thickness ratio: 7.6) were welded. A 270 MPa grade galvannealed steel sheet (270GA) was used in the thin sheet (0.7 mm), and 780 MPa galvannealed steel sheets (780GA) were used in the thick sheets (2.3 mm). As can be clearly seen in the video sequence, in Step 1 using low electrode force, a fusion zone was formed between the thin sheet and the adjoining thick sheet, and in Step 2, when the electrode force was increased, the heat generation position shifted to the center between the two electrodes, and a fusion zone was formed between the two thick sheets.

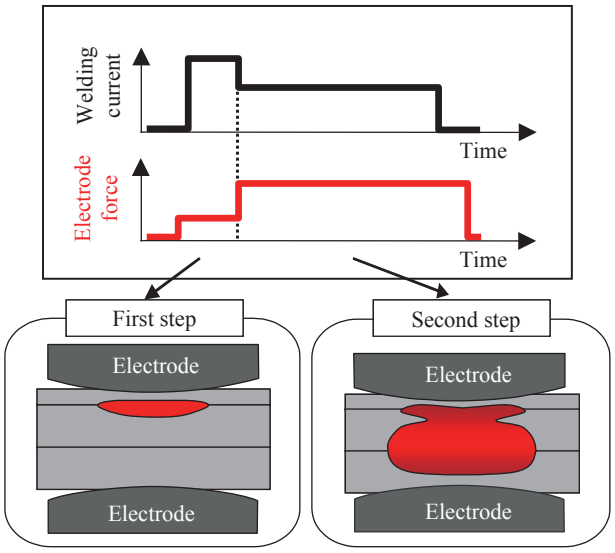

Fig. 1 Schematic illustration of Intelligent Spot™ welding process for three-sheet-joint with higher sheet thickness ratio

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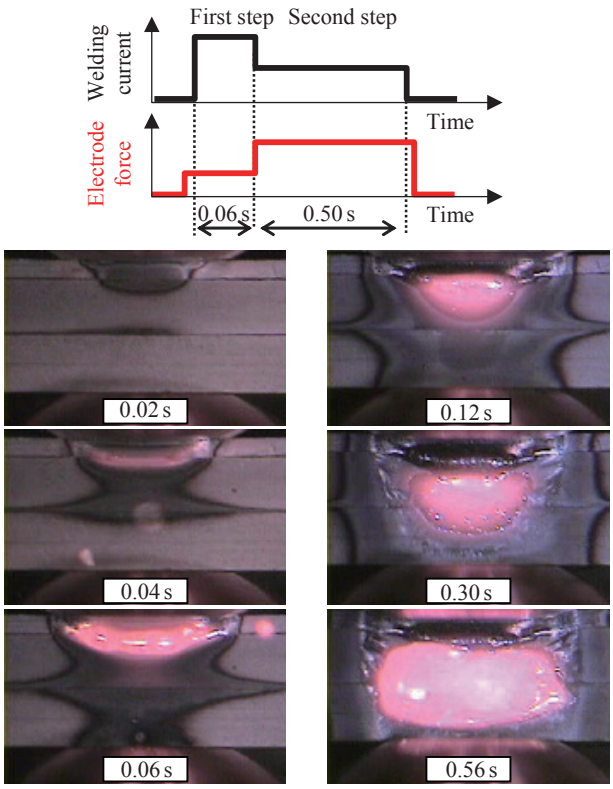


Photo 1 Nugget formation process in Intelligent Spot™ welding observed by high speed video camera

2.2 Results of Laboratory Welding

Photo 2 shows cross-sectional macrostructures of the fusion zone formed by conventional resistance spot welding and Intelligent Spot™ Welding of the above-mentioned joint (270GA: 0.7 mm - 780GA: 2.3 mm - 780GA: 2.3 mm). In both cases, the joint cross section displays a nugget diameter of substantially $4\sqrt{t}$ (t: sheet thickness) between the two thick sheets. However, nugget formation between the thin sheet and the thick sheet can be observed only with Intelligent Spot™ Welding.

The results of an investigation of the acceptable current range of the Intelligent Spot™ Welding technology with this joint are shown in **Fig. 2**. With conventional

Servo-actuated single-phase alternating current pedestal type resistance spot welder						
Upper electrode: Dome radius type (φ8 mm), Lower electrode: Dome flat type (φ6 mm)						
Sheet stack-up	270GA:0.7 mm - 780GA:2.3 mm - 780GA:2.3 mm 270GA: 270 MPa Grade galvannealed steel sheet 780GA: 780 MPa Grade galvannealed steel sheet					
Primary force and current			Cooling time	Secondary force and current		
Force	Weld time	Welding current		Force	Weld time	Welding current
0.5 kN	0.10 s	9 kA	0.02 s	3.0 kN	0.40 s	I_2

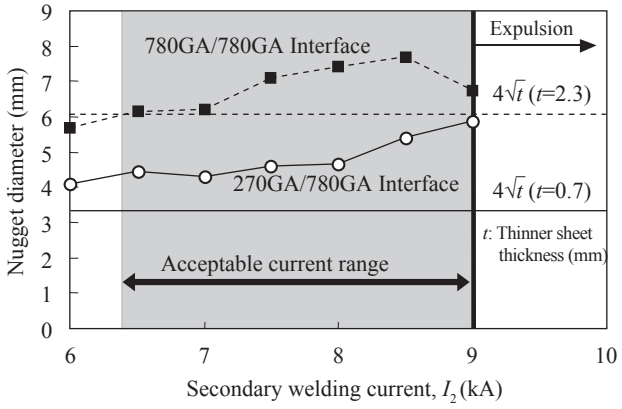
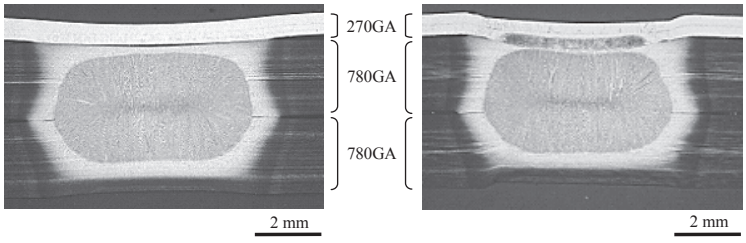


Fig. 2 Acceptable current range of Intelligent Spot™ welding

resistance spot welding, it is difficult to obtain the nugget between the thin sheet and thick sheet with this joint without causing expulsion. In contrast, a wide acceptable current range of approximately 2.5 kA was obtained by using the developed welding technology.

2.3 Effects

Due to the inherent problem of nugget formation between the thin sheet and thick sheet in joints with high sheet thickness ratios, auto makers limit the sheet thickness ratio up to approximately 4–5, and there are cases in which makers sacrifice productivity and design freedom, for example, by welding only two sheets at a time by staggered welding. Furthermore, even within the limit range, it is necessary to use an excessive welding current for two thick sheets in order to secure the nugget diameter between the thin sheet and thick sheet in joints with high sheet thickness ratios, and as a result, expulsion tends to occur easily. This was also a problem because the spatter generated in this process adhered to



(a) Conventional resistance spot welding (b) Intelligent Spot™ Welding

270GA: 270 MPa Grade galvannealed steel sheet
780GA: 780 MPa Grade galvannealed steel sheet

Photo 2 Comparison of cross section macros of three sheets joint with high sheet thickness ratio

other parts, and additional labor was required for its removal.

By applying Intelligent Spot™ Welding, it has become possible to weld joints with high sheet thickness ratios that are not currently used, and since it is possible to relax the constraints on the sheet thickness ratio, reduction of time for staggered welding and greater design freedom are expected. Moreover, expulsion can be reduced because it is no longer necessary to set an excessive welding current even within the limit range of the sheet thickness ratio. Thus, this technology is also expected as a low expulsion technology.

3. Examples of Application

In joint research and development of this technology with automobile makers, studies were carried out considering the effects of various types of disturbances in actual auto assembly lines, and practical application has already begun. For example, Intelligent Spot™ Welding has been applied to some center pillars, which have a high sheet thickness ratio, and its effectiveness in reducing expulsion has also been confirmed.

4. Conclusion

In addition to developing various new high performance steel sheets which respond to the requests of customers, JFE Steel is also actively engaged in development of manufacturing technologies such as press forming technologies, welding technologies, and others to enable full use of the outstanding features of those steel sheets. This report introduced the JFE Steel's Intelligent Spot™ Welding Technology for use in auto body assembly. JFE Steel will continue to develop effective and efficient automobile assembly welding technologies that contribute to auto body weight reduction and improved crashworthiness by expanding the applications of JFE's "Only One" and "Number One" products.

References

1) Okita, Yasuaki; Ikeda, Rinsei; Ono, Moriaki; Yasuda, Koichi. Yosetsu Gakkai Zenkoku Taikai Koen Gaiyo. 2006, no. 78, p. 164–167.
2) Ikeda, Rinsei; Okita, Yasuaki; Ono, Moriaki; Yasuda, Koichi. Materia Japan. 2009, vol. 48, no. 2, p. 76–78.
3) Ikeda, Rinsei; Okita, Yasuaki; Ono, Moriaki; Yasuda, Koichi; Terasaki, Toshio. Quart. Jour. Jpn. Welding Soc. 2010, vol. 28, no. 1, p. 141–148.

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