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Resistance spot welding of aluminum alloy sheet 5J32 using SCR type and inverter type power supplies

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ABSTRACT

Purpose: A characteristic was compared and analyzed between the lobe diagram of SCR type resistance spot welding and that of inverter type resistance spot welding of the aluminum alloy sheet 5J32 for the car body.

Design/methodology/approach: Using the lobe diagram on the electrode force, weld time, and weld current which are process variables of the resistance spot welding, the range of optimal welding condition was determined. The low limit of the range of the optimal welding condition was decided by the lower limit of the tensile strength of the aluminum alloy sheet 5J32, and the upper limit was decided by whether an expulsion occurs or not.

Findings: It was found that the range of the optimal welding condition of the inverter type resistance spot welding was larger than the SCR type resistance welding and that the nugget size of inverter type resistance spot welding was larger in the same welding condition.

Research limitations/implications: A comparison was between the lobe diagram at the SCR type on the aluminum alloy sheet 5J32 and the lobe diagram at the inverter type resistance spot welding.

Practical implications: In this study, by comparing the range of the appropriate welding condition of the resistance spot welding between SCR type and inverter type power supplies, the characteristic of the appropriate welding range by the power supply characteristic could be confirmed.

Originality/value: This study compared the characteristic of the resistance spot welding between the SCR type and inverter type power supply using lobe diagram. It was confirmed that the range of appropriate welding conditions of the inverter type resistance spot welding was large.

Keywords: Welding; Aluminium sheet metal; Spot welding; Lobe diagram

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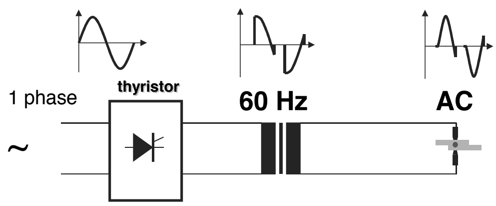
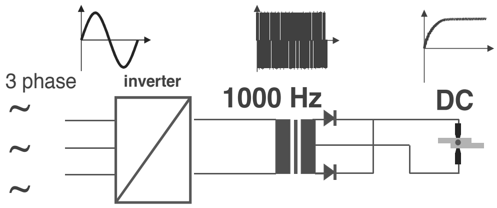
MATERIALS MANUFACTURING AND PROCESSING

1. Introduction

In the vehicle industry, to enhance the fuel efficiency and to decrease the volume of discharging gas by reducing the weight of the car body, the application of aluminum alloy sheet, a light material, is being increased [1-8]. Aluminum alloys have higher thermal and electrical conductivity. In general high thermal conductivity necessitates a high rate of heat input for fusion welding. Aluminum's high thermal and electrical conductivity require higher current, shorter weld time, and more precise control of the welding variables than steel welding.

Table 1.
SCR and inverter spot welding system.

Parameter	SCR type spot welding system	Inverter type spot welding system
Input voltage	440 V	440 V
Frequency	60 Hz	1 kHz
Maximum current	22 kA	40 kA
Maximum electrode force	800 kg_f/cm^2	500 kg_f/cm^2
Block diagram of system		

With the application of aluminum alloy sheet to the car body, a new problem on the weldability of aluminum has been raised. The study on resistance spot welding which occupies almost part of assembly process of car body in the car manufacturing line has become an important issue [9-13].

Resistance spot welding (RSW) is a welding process that joint sheet metal pieces together by applying pressure and passing a large current through localized area while the sheets are fixed together. Resistance spot welding power supply type is divided into SCR (silicon controlled rectifier) type and inverter type [14].

The principle of the SCR type power supply is that by phase controlling the single phase with SCR the output welding current is made, which will be converted into large current through a transformer and applied to the base metal. As the usual power can be used, the control is available at the basis of 60Hz (16.6ms), and it is known that the control cycle is late. As a non-continuity of the electric current in SCR type power supply control occurs, in order to generate the abundant joule heating for melting of metal, the weld time should be lengthy and this makes the weld time and the power consumption to be increased. It is pointed that the peak occurrence at the output current waveform is a bad effect in view of welding quality [15]. On the other hand, the inverter type makes a current control with a high switching IGBT (insulated gate bipolar transistor), and by mounting the diode rectifier at the second side of the high frequency transformer, the DC current is applied to the base metal. The inverter system has a quick control cycle by the PWM (pulse width modulation) switching, accordingly it is a characteristic that a precise current control is possible and by controlling the current frequency, the power consumption can be decreased [16]. Table 1 indicates specifications, schematic diagram, and current waveform of the resistance spot welding of SCR type and inverter type.

In this study, the characteristic of lobe diagram between the SCR type and the inverter type at the resistance spot welding of aluminum 5J32 for the car body was compared and evaluated.

2. Experiments

2.1. Experiments setup

The experiments were performed using 1.0-mm 5J32 aluminum alloy sheet on a SCR type and inverter type RSW machine. The electrodes were dome-type with a spherical surface. Table 2 Show the welding parameters range. The welding current is 16-22 kA, electrode force is 180-420 kg_f/cm^2 and weld time is 3, 7, and 11 cycles.

Table 3 indicates the chemical composition of the base metal, aluminum alloy 5J32. Table 4 indicates the mechanical properties of the base metal. Fig. 1 shows the shape and dimension of the base metal.

Table 2.
Experiments setup

Base metal	Aluminium alloy 5J32 (Thickness 1.0mm)
Current	16 ~ 22 kA
Weld time	3, 7, 11 cycle
Electrode force	180 ~ 420 kg_f/cm^2

Table 3.
Chemical composition of aluminium alloy 5J32 (wt, %)

Si	Fe	Cu	Mn	Mg	Zn	Al
0.03	0.08	0.33	0.01	5.60	0.01	Bal.

Table 4.
Mechanical properties of aluminium alloy 5J32

Mechanical Properties	
Tensile strength	284 N/mm^2
Yield strength	127 N/mm^2
Elongation	32.5 %

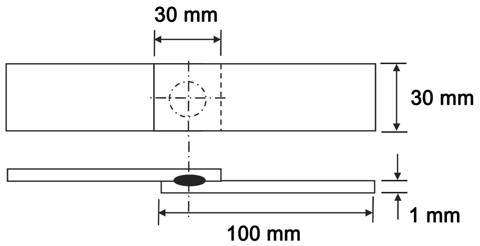


Fig. 1. Schematic illustration of tensile test specimen

2.2. Lobe diagram

A lobe diagram was used for the comparison and evaluation of weldability at the RSW of SCR type and inverter type of the aluminum alloy sheet 5J32 for the car body. Lobe diagram is a graph indicating the evaluation on the RSW weldability that shows the appropriate welding range by changing two factors with fixing one factor among three factors of RSW such as electrode force, weld time, and weld current[17].

In this study, the lobe diagram of weld current – electrode force was used, which was, with fixing the weld time, set the horizontal axis as weld current, and the longitudinal axis as electrode force.

Fig.2 shows the lobe diagram of the weld current – electrode force used in this paper. The left boundary line of the lobe diagram was decided by 1610N, the low limit tensile strength of the welded thin aluminum sheet, and the right boundary line was decided by whether an expulsion occurred or not. Expulsion, which can be observed frequently during resistance spot welding, happens at either the faying surface or the electrode/workpiece interfaces. The latter may severely affect surface quality and electrode life, but not the strength of the weld if it is limited to the surface.

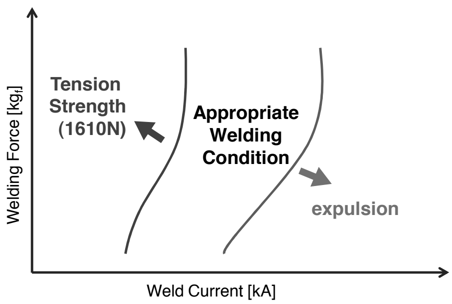


Fig. 2. Current-force lobe diagram

3. Results and discussion

3.1. Evaluation of the lobe diagram

Table 5 show the lobe diagram, from at the SCR type and inverter type resistance spot welding of aluminum alloy sheet 5J32 for the car body.

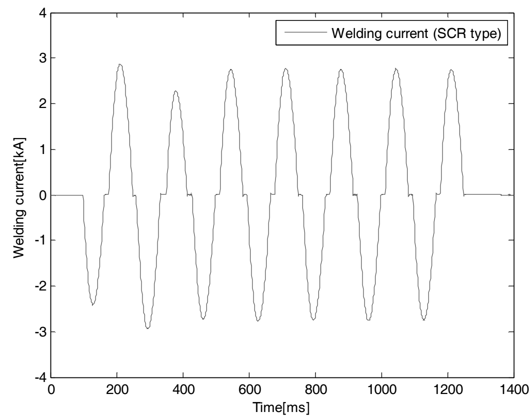
It is found that in the lobe diagram of 3, 7, and 11 cycles of the weld time, the range of the appropriate welding condition from the inverter type RSW is larger than the SCR type RSW.

The reason that the appropriate welding range of the inverter type RSW becomes larger than the SCR type RSW is that the SCR type RSW generates the discontinuity by AC waveform control, while in case of the inverter type RSW, the uniform DC current is applied and the stable welding is available.

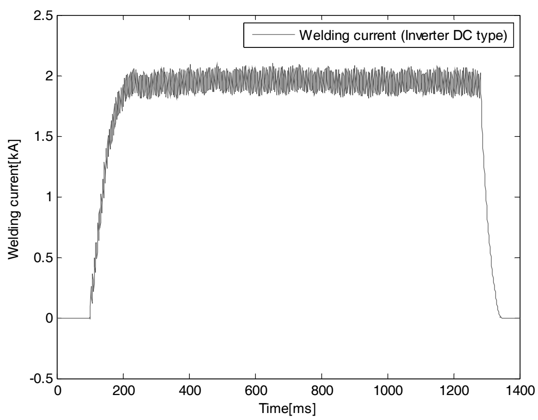
It is found that in the same welding condition, the nugget size of the inverter type RSW becomes bigger than that of SCR type RSW.

The reason that the nugget size of the inverter type RSW becomes larger than the SCR type RSW is that the SCR type RSW generates the discontinuity by AC waveform control, while in case of the inverter type RSW, the uniform DC current is applied and the stable welding is available, thus it can be known that the nugget size becomes bigger.

Fig.3 shows the welding current waveform for SCR type and inverter type RSW system at the welding current is 1.9kA, weld time 9 cycles, and electrode force 300 kg_f/cm^2. Welding currents were compared on the basis of RMS values computed from the voltage signal off the current senor.



(a) Current waveform of SCR type RSW



(b) Current waveform of inverter DC type RSW

Fig. 3. Welding current signals

Table 5.
Experimental results - Lobe diagram

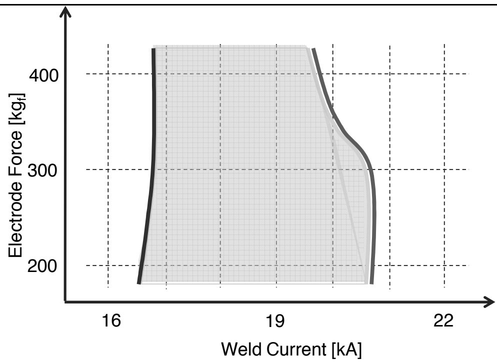
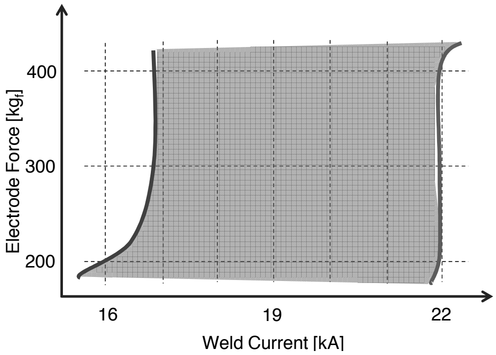
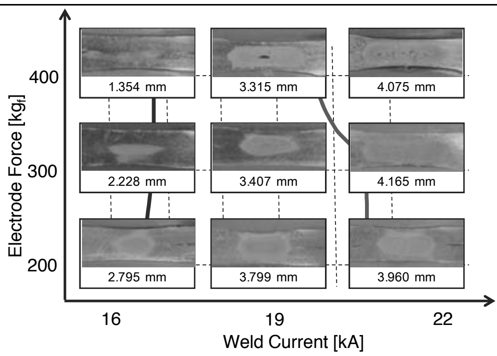
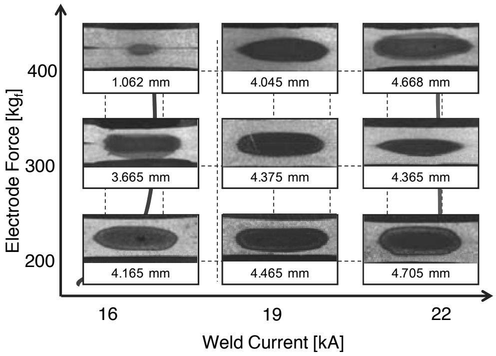
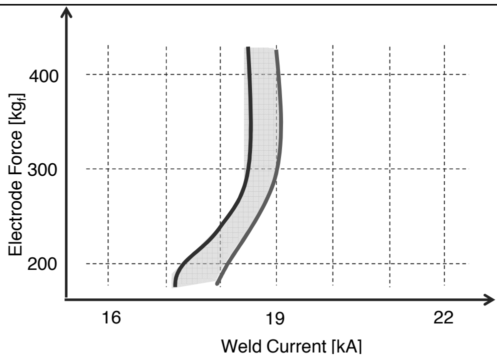
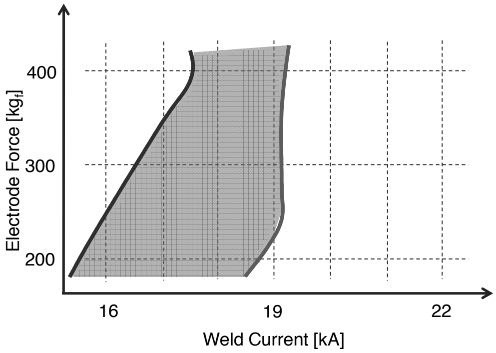
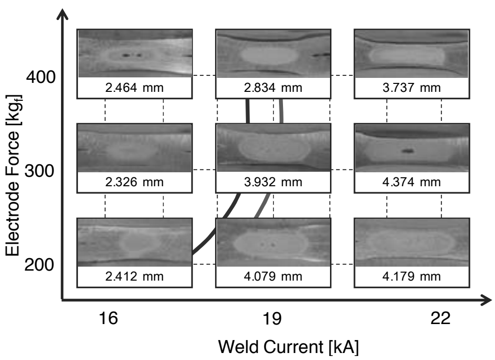
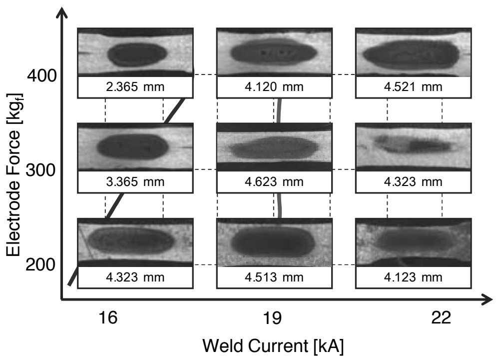
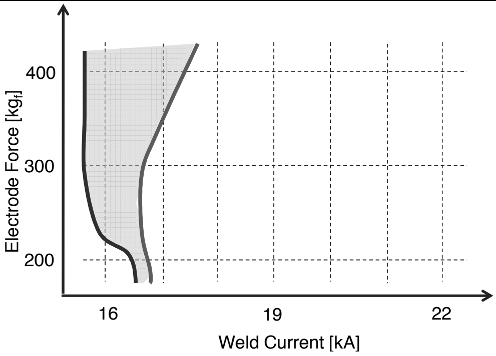
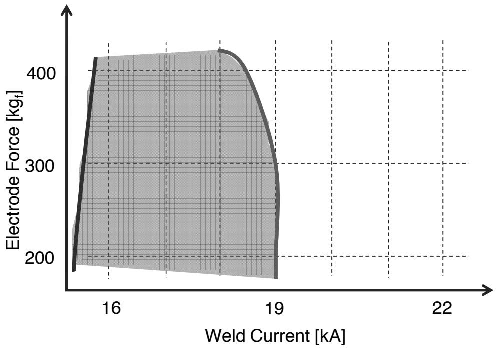
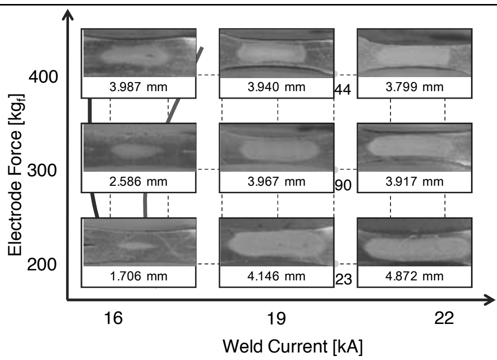
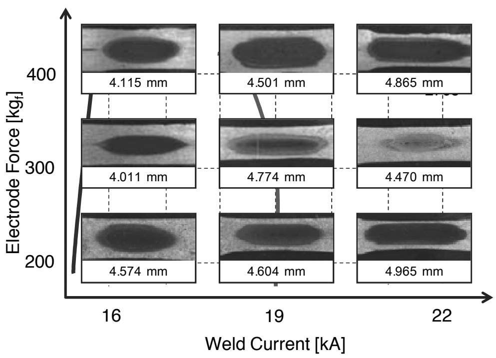
Weld time	Item	SCR type spot welding system	Inverter type spot welding system
3 Cycles	Lobe diagram		
	Nugget size		
7 Cycles	Lobe diagram		
	Nugget size		

Table 5. – Continued

11 Cycles	Lobe diagram		
	Nugget size		

It can be confirmed that as the weld time extends from 3 cycles to 11 cycles, the range of the appropriate welding condition becomes small.

This is because in the RSW of the aluminum alloy the specific resistance is low and the thermal conductivity is high, the welding should be done by the high current in a very short time. Therefore, it can be known that if the weld time becomes lengthy, the spatter occurs by over heat, thus the range of the appropriate welding condition becomes small.

4. Conclusions

This study compared the characteristic of the resistance spot welding between the lobe diagram of SCR type and that of inverter type power supply of the aluminum alloy sheet 5J32 for the car body. Conclusions can be summarized as follows.

- The welding condition range of the inverter type RSW is larger than that of the SCR type RSW.
- The nugget size of the inverter type RSW becomes bigger than the SCR type RSW at the same welding condition.
- The range of the appropriate welding condition is large in the short weld time.

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