

Method of Controlling Arc Welding on an Ultrathin Sheet

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ABSTRACT

A positive proportional relation between arc length and arc illumination was found to apply in arc welding. By applying this relation, a control technology was developed that maintains arc length at a constant fixed value during welding. This control is able to maintain a fixed arc length of 1.0 mm or less, a result which is not possible with conventional arc voltage control. This method produces a stable, uniform melting on ultrathin sheets 0.5 mm thick or less through the application of low-current, low-voltage welding.

1. Introduction

The conventional steel sheet used in automobiles is about 0.6 – 1.6 mm thick. Energy saving and environmental measures increasingly call for a change to ultrathin sheets primarily for use in vehicle body and exhaust assembly components and in the reforming system parts used in fuel cell development. The effort to improve weld quality is important for the use of ultrathin sheets.

The use of ultrathin sheets 0.5 mm thick or less is more likely to result in burn through, lack of fusion, deposition on the electrode, and the like. Consequently, the stable provision of an appropriate welding heat input becomes an issue. This also necessitates use of a clamping jig during welding procedures to fix the base material firmly in place so that it does not deform under the heat input. There are many shapes, however, that cannot be fixed in place with a clamping jig.

2. Concerns with Conventional Technology

In arc welding, it is important to maintain stability of the arcing that is the heat source. It requires control that brings the electrode extremely close to the base material and holds a constant fixed arc length. This arc length is a crucial technical element for the stability of weld quality on an ultrathin sheet. It has been considered extremely difficult, however, to control this length accurately.

Current methods for measuring the arc length include laser and photographic sensors. However, there are concerns with these techniques, since a laser sensor tends to malfunction when its receiver picks up the powerful arcing light and camera sensors cannot accurately measure distance. Figure 1 shows experimental results for welding currents of 20 A, 50 A, and 80 A using the conventional detection control method of arc voltage. The arc voltage becomes unstable

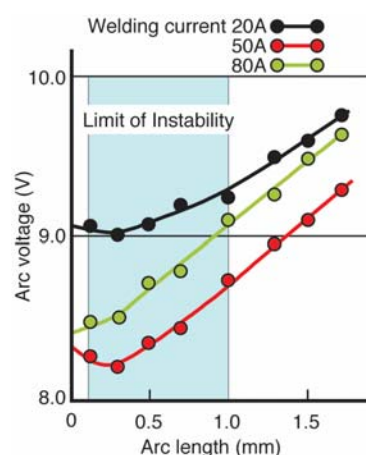


Fig. 1 Relation between arc length and arc voltage

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when the arc length is 1.0 mm or less, so it is clear that the arc length cannot be fixed during those times.

3. Relationship between Arc Length and Size of the Melton Pool Caused by Arcing

Figure 2 shows the relationship between the arc length and the diameter of the molten pool (the diameter of melting metal) when the current is constant and the arc length is varied to 0.25, 0.50, 0.75, 1.00, and 1.25 mm. Table 1 shows the welding conditions during those measurements.

Measurement of the melting diameter on the front and back sides of the sheet shows that the melting diameter becomes larger when the arc length is shorter, and there is little difference between the melting diameter on the front and reverse sides. This shows that the thermal energy of the arcing is consumed more efficiently in melting the base material when the arc length is shorter.

Table 1 Welding condition

Base material	SUS316L
Thickness	0.5mm
Material of electrode	Tungsten
Diameter of electrode	1.6mm
Welding current	27A
Welding time	0.25s
Welding method	TIG

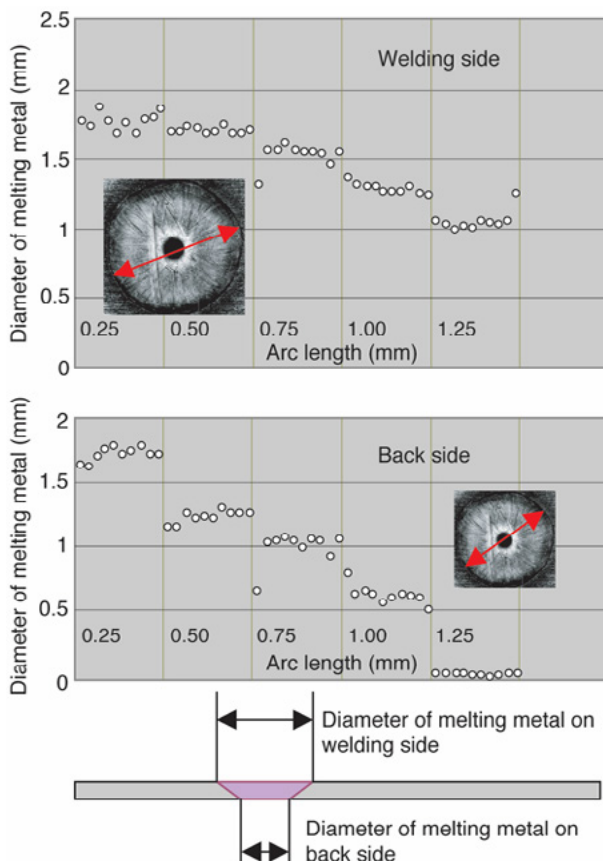


Fig. 2 Relation between arc length and diameter of melting metal

4. The Characteristic of the Relationship Between Arc Optical Illuminance and Arc Length

During the investigation of potential control technologies to replace conventional arc length control and arc voltage control, it was noticed that changing the arc length would cause minute changes in the arcing light. An experiment was therefore conducted on the relationship between arc optical illuminance and arc length using the experimental TIG welding apparatus shown in Fig. 3. An illumination meter was placed at a distance of 150 mm from the center of the welding electrode in order to measure changes in the arcing light. The welding current was set at the minimum of 20 A and maximum of 81.25 A for which past hand welding results were available. A stainless steel sheet 1.6 mm thick was selected in order to avoid burn through or deformation during measurement. Table 2 shows the other conditions.

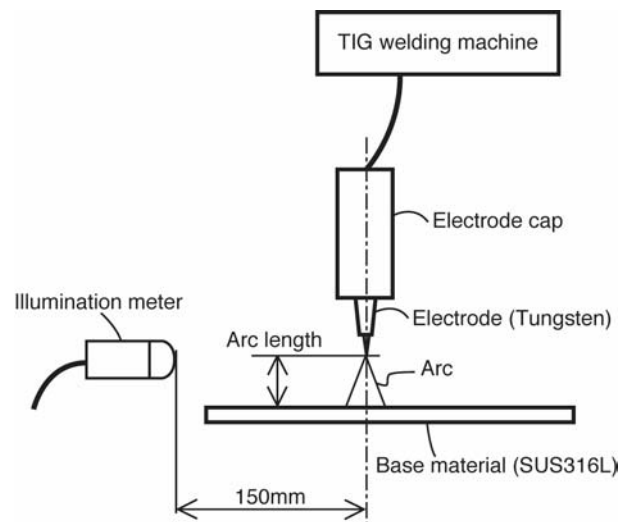


Fig. 3 Experimental apparatus of arc length change and arc optical illuminance

Table 2 Condition of arc length change and arc optical illuminance experiment

Base material	SUS316L
Thickness	1.6mm
Material of electrode	Tungsten
Diameter of electrode	1.6mm
Extension of electrode	16mm
Distance of electrode and illumination meter	150mm
Welding method	TIG

Table 3 shows the results of the experiment. Figure 4 shows the relationship between arc illuminance and arc length with the welding current at 20 A and 81.25 A. It was found that arc illuminance and arc length remained in a directly proportionate relationship even when the arc length was 1 mm or less, where it had previously been thought difficult to control. It was reasoned from these results that it may be possible to control arc length by keeping the welding current fixed and monitoring the illuminance.

Table 3 Result of experiment

Arc length at welding current 20A				
Arc length (mm)	0.17	0.39	0.61	0.98
Illuminance (Lx)	36.7	399	449	564

Arc length at welding current 81.25A					
Arc length (mm)	0.25	0.5	1.0	2.0	3.0
Illuminance (Lx)	2006	2650	4620	8315	12649

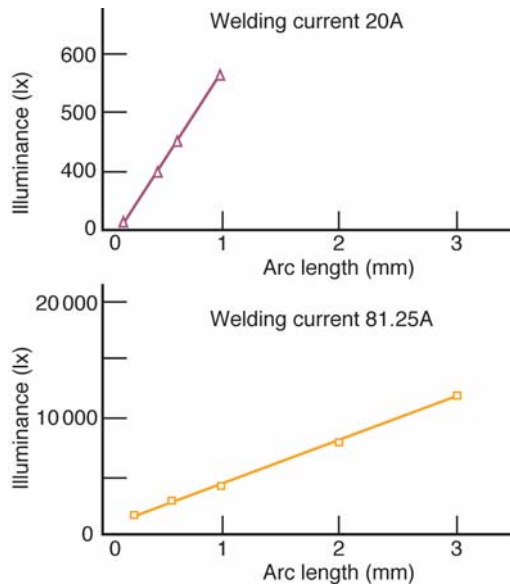


Fig. 4 Relation between arc length and illuminance

5. Control Using Arc Illuminance

Figure 5 shows the method of control using arc illuminance as described above. The information from the arc illuminance sensor undergoes analog/digital conversion and is taken as the illuminance voltage signal. This is sent to the CPU and judged for its difference from a preset standard voltage. The mechanism then controls the arc length by moving the torch and electrode vertically to a fixed height. Figure 6 shows the control flow. ST stands for program step.

- 1) The optimum arc length is set according to the base material and the arc illuminance voltage at that point is input to the CPU as the standard voltage V_{st} (ST01).
- 2) Arc illuminance is measured using the illuminance sensor after welding begins (ST02).
- 3) That voltage signal V_{ac} is sampled (ST03).
- 4) V_{ac} is compared with the reference voltage V_{st} (ST04).
- 5) If $V_{ac} < V_{st}$, then the torch is raised (ST05).
- 6) If $V_{ac} > V_{st}$, then the torch is lowered (ST06).
- 7) If $V_{ac} = V_{st}$, then the arc length can be judged to be correct, so that torch height is maintained (ST07).

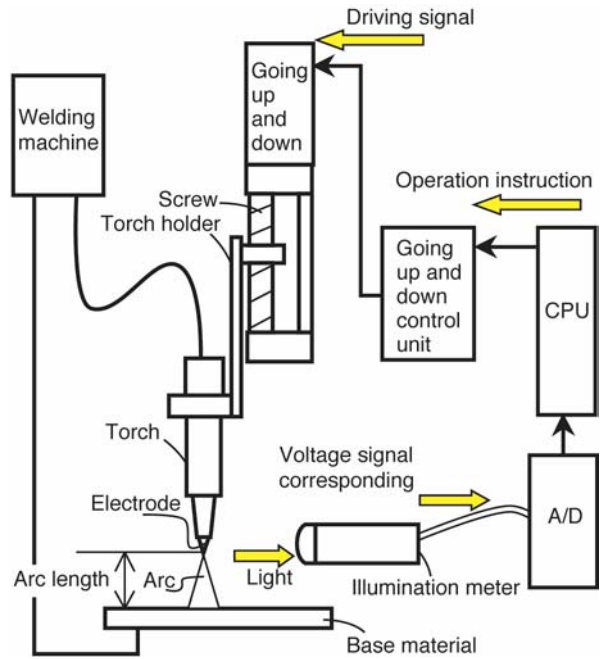


Fig. 5 Arc length controller

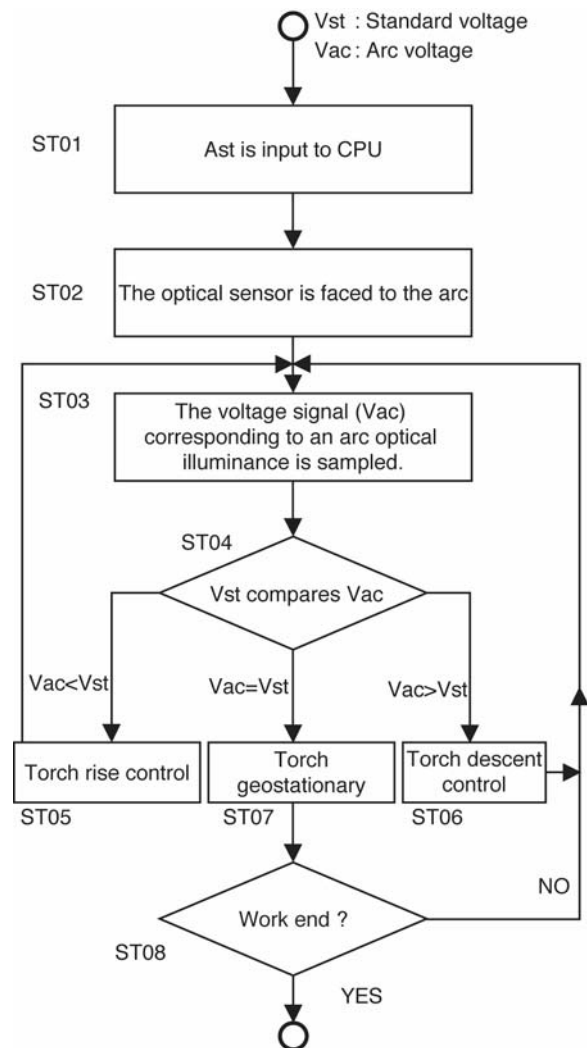


Fig. 6 Arc welding control flow chart

- 8) If the welding work end signal is received, the flow is terminated (ST08).
- 9) If a work end signal is not received, then the flow returns to ST03 and control continues.

The above flow was implemented in an arc welding robot used for actual welding. The test specimen was given a wave form at the welding point to make it easier to confirm correct control of the arc length and vertical control of the torch. Figure 7 shows how the movement was observed with the arc length set to 0.5 mm and the torch moved straight across the workpiece at a fixed speed. As a result, the above control was able to produce a weld with a uniform melting width by moving the torch at a fixed arc length maintained relative to the wave-formed base material, as shown in Fig. 8.

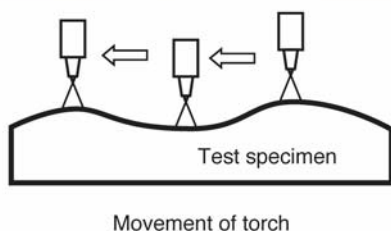
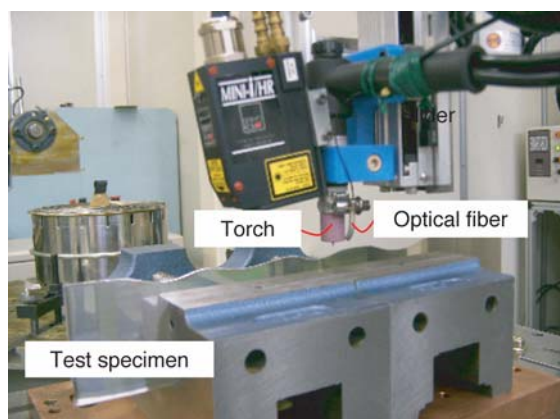


Fig. 7 Arc length control experiment

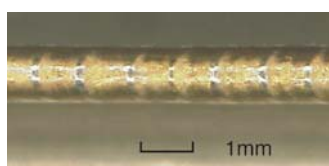


Fig. 8 Form of weld state

Next, Fig. 9 shows the welding experiment conducted using a sheet 0.5 mm thick. The workpiece was made in an L shape and the torch was run over it at a constant speed without using a clamping jig. The results show that a melt form with a uniform, stable appearance could be welded. This was achieved despite the ultrathin sheet and the complex shape. This is shown in Fig. 10.

Figure 11 is an illustration of the welding of a prototype heat exchanger. The sheets of 0.3 mm thick stainless steel sheet were joined together using an edge joint and welded in a loop. The arc length stays stable with a welding current of



Fig. 9 Experiment without jig

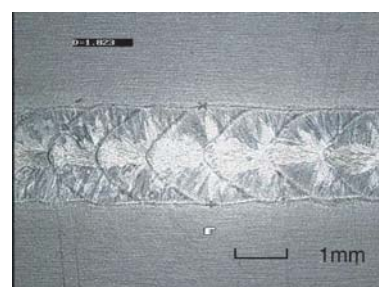
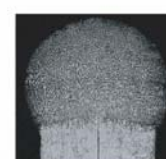


Fig. 10 Form of weld state



Before Welding



After Welding

Fig. 11 Welding and observation of weld

20 A, and the result obtained shows that heat input was kept uniform in the weld area and no irregularity was found in the weld freezing structure.

6. Study and Experiment in the Use of Arc Illuminance

It was known through experimentation up to this point that arc illuminance has a correlation with arc length. This study and experiment was carried out to determine whether arc illuminance would change when the weld joint form was different.

Figure 12 shows the workpiece made for the experiment. The joint for Sec A-A had a butt joint cross-section, while Sec B-B had a butt joint with a groove forming a gap. Figure 13 shows the illuminance converted to a voltage value on the vertical axis and the weld length on the horizontal axis. The illuminance voltage can be seen to rise from the point where there is a groove. These results suggest that arc illuminance can be applied to detect whether the joint form is a butt joint, a groove joint, and so on.

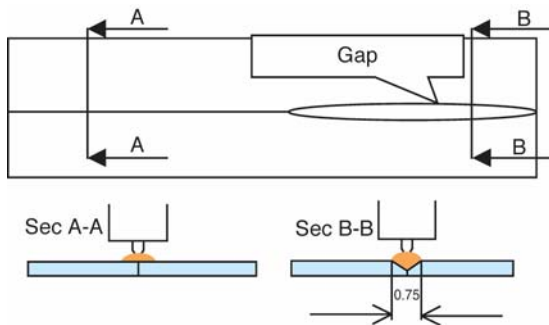


Fig. 12 Experiment sample

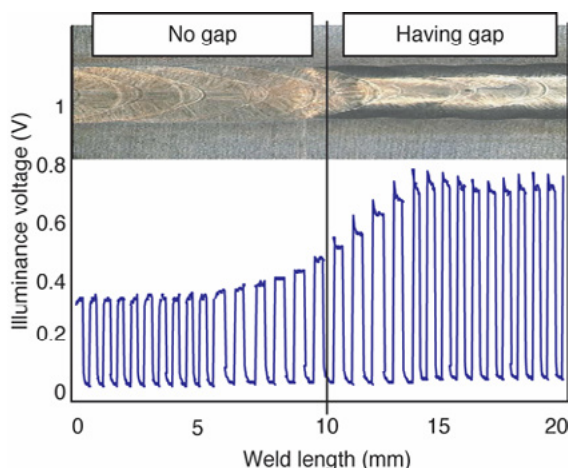


Fig. 13 Relation between gap and arc illuminance

7. Summary

This method of arc length control enabled automatic welding of ultrathin sheet 0.5 mm thick without using powerful clamps.

- 1) It was determined that arc illuminance has a positive proportional relationship to arc length when the arc length is 1 mm or less.
- 2) Development of arc length control technology making use of the above relationship achieved stable, uniform melting quality with ultrathin sheets 0.5 mm thick or less.
- 3) Changes in arc illuminance can be used to detect gaps and different forms of joint.

This technology is being utilized on prototype parts for reforming systems in fuel cell development.

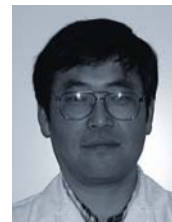
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