Experimental investigation of droplet ejection phenomena in AC gas tungsten arc welding

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Abstract: The droplet ejection from an electrode during Alternating Current Gas Tungsten Arc (AC GTA) welding process was observed using a high-speed camera to clarify the dominant factors of the droplet ejection. In addition, two-color pyrometry was conducted to obtain the surface temperature of the electrode during the welding. As a result, droplets were likely to be ejected from the electrode tip when the welding current was high, when the Electrode Positive (EP) ratio was high, and in the latter half of the EP period. The electrode was heated during the EP period and it decreased in the Electrode Negative (EN) period. Based on these experimental facts, it was easy for droplets to be ejected from the electrode tip when the electrode temperature was high. Moreover, from the estimated forces acting on the molten electrode surface, it was shown that the dominant factor in droplet ejection was the decrease in surface tension due to the decrease in electrode temperature.

Keywords: AC GTA welding, Droplet ejection, Electrode surface temperature.

1. Introduction

AC GTA (Alternating Current Gas Tungsten Arc) welding is an arc welding method in which the electrode polarity is periodically switched. AC GTA welding is used for welding aluminum alloys and other metals with a high melting point oxide layer on their surface. However, it has been reported that part of the molten electrode tip detaches as a droplet during AC GTA welding [1]. Electrode droplets affect not only increasing electrode consumption but also decreasing weld quality because ejected tungsten droplets are mixed into the welded part. Therefore, it is required to prevent the droplet ejection from tungsten electrode. Nevertheless, mechanism of the droplet ejection has not been clarified. In this study, experimental investigations using high-speed camera were conducted to clarify the droplet ejection mechanism.

2. Experimental methods

In order to investigate the influence of welding conditions and timing during an AC cycle, different welding currents and EP (Electrode Positive) ratios were set. EP ratio means the ratio of EP polarity to one AC cycle. Then, electrode appearance was observed for each welding condition using a high-speed camera with a bandpass filter (950 nm). Using visualized images, molten electrode droplets were counted. **Table 1.** shows welding conditions for counting the droplets. Underlines indicate basic conditions.

Table 1. Welding conditions for counting droplets

Welding current	100, 150, 200 [A]
EP ratio	20, 30, 40%
AC frequency	100 [Hz]
Shielding gas	Pure helium
Gas flow rate	25 [L/min]
Nozzle inner diameter	12.7 [mm]
Electrode material	Pure tungsten
Electrode diameter	3.2 [mm]
Electrode tip angle	60 [deg.]
Electrode extension	3.0 [mm]
Arc length	2.0 [mm]
Base metal	Water-cooled copper

Electrode surface temperature was also measured by two-color pyrometry [2]. **Figure 1.** shows the experimental setup for measuring temperature. In this method, two different bandpass filters with center wavelengths of 950 nm and 980 nm were selected. The ratio of emission intensity at the two different wavelengths was obtained. Then, surface temperature of the electrode was obtained by a calibration curve for the ratio of emission intensity and surface temperature.

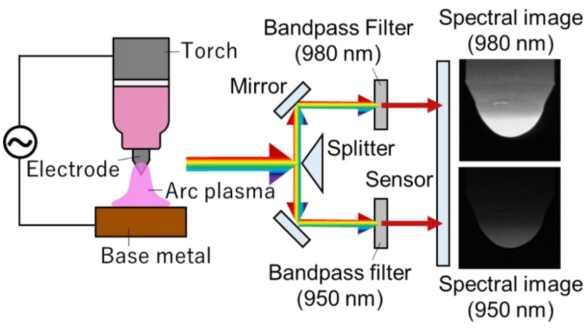

Fig. 1. Schematic illustration of setup for measuring electrode surface temperature.

3. Results and discussion

Figure 2. shows the result of measuring the number and the timing of droplet ejection for each welding current. Plots show average values of five measurements for 0.1 s. The horizontal axis shows the time from start of EP polarity, and the dotted line shows the switch timing from EP polarity to EN (Electrode Negative) polarity. As a result, the number of droplets increased with higher welding current, and droplets were more likely to be ejected in the later EP period.

Figure 3. shows the results of measuring the timing at which droplet ejections occurred. Blue, gray, and orange dotted lines in this graph indicate the timing of switching from EP polarity to EN polarity when the EP ratio was set to 20%, 30%, and 40%, respectively. As a result, it was

confirmed that a lot of droplet ejections occurred from the middle to the latter half of the EP period.

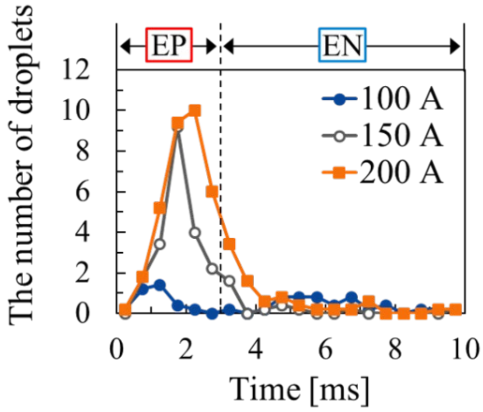

Fig. 2. Number and timing of droplet ejection for different welding currents.

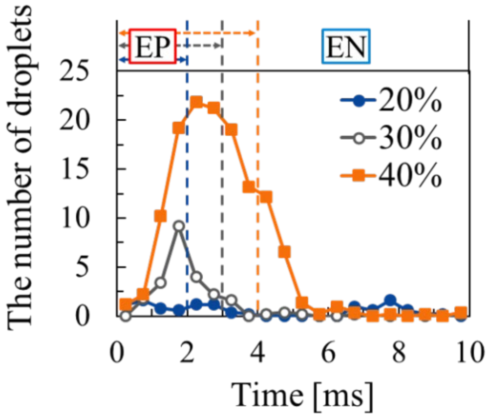

Fig. 3. Number and the timing of droplet ejection for different EP ratios.

Figure 4. shows the measured temperature variation of the electrode tip at each welding current. Plots show the ensemble average over 10 AC cycles. The higher the welding current, the higher the electrode tip temperature at all times. For all welding currents, the electrode temperature increased during the EP period and decreased during the EN period.

Figure 5. shows the balance of estimated forces on the molten electrode surface. In this figure, P_{st}, $P_{j\times B}$, P_{i} and P_{e} indicate the pressure due to surface tension, the pressure due to electromagnetic force, the pressure due to ion collision and the pressure due to electron collision, respectively.

From this result, the largest pressure at any time during the AC cycle was the pressure due to surface tension. This pressure decreased by about 0.2 kPa in the second half of the EP period compared to the EN period and the first half of the EP period. The next largest pressure after the pressure due to surface tension was that due to electromagnetic force of about 0.2 kPa during the EP period and that due to ion collision of about 0.6 kPa during the EN period. These results indicated that surface tension was the dominant force in the change of electrode shape, especially in the EP period. The above results suggested that the dominant factor in droplet ejection was the decrease in surface tension due to the decrease in electrode temperature.

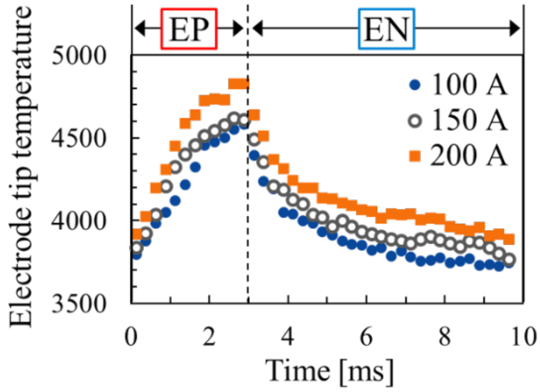

Fig. 4. Electrode surface temperature variation during AC cycles.

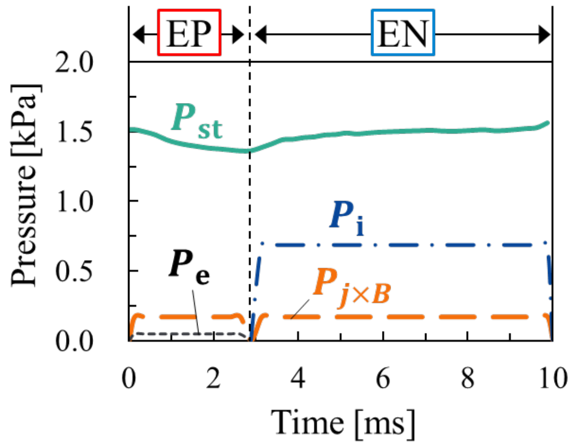

Fig. 5. Estimated result of pressures on the molten electrode surface.

4. References

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