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Measurement of dynamical variation in two-dimensional temperature distribution of TIG pulsed-arcs *

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TIG pulsed-arc welding is suitable for back-bead welding, thin plate welding and so on, because the heat source properties can be controlled by current waveform. The heat flux onto the base metal is affected mainly by thermal conduction and electron condensation from the arc. Both factors strongly depend on the temperature distribution and current path in the arc. In order to clarify the heat source properties of TIG pulsed-arc, dynamic variation in two-dimensional temperature distribution of TIG pulsed-arc was measured through Fowler-Milne method with a high speed video camera as a first step of the study. As a result, it was found that the arc column was expanded in radial direction and the maximum arc temperature was 20,000K during the peak current of 200A. On the other hand, the width of the arc column decreased especially in the downstream region of the arc and the maximum arc temperature fell to 17,500K during the base current of 50A.

Key Words: TIG, Pulse, Arc, Welding, Spectroscopic Analysis

1. Introduction

TIG pulsed-arc welding is suitable for back-bead welding, thin plate welding and so on, because the heat source properties can be controlled by current waveform. The heat flux onto the base metal is affected mainly by thermal conduction and electron condensation from the arc. Both factors strongly depend on the temperature distribution and current path in the arc.

In order to clarify the heat source properties of TIG pulsed-arc, information on temperature distribution of the arc plasma is required. Therefore, in this study, dynamic variation in two-dimensional temperature distribution of TIG pulsed-arc was measured through Fowler-Milne method with a high speed video camera as a first step of the study.

2. Experimental procedure

A schematic diagram of experimental observation is shown in Fig.1. In this study, the radiation from the TIG arc on a water cooled copper anode was observed. The radiation was diffracted to the specific wavelength (696.5nm) in the monochrometer shown in Fig. 2 and recorded as the two dimensional image by the high speed camera (Photron, FASTCAM-512PCI). The temperature distribution of TIG arc was calculated from the intensity distribution in the image through the Fowler-Milne method [1]. In this experiment, we used tungsten cathodes with the conical tip angles of 45 degrees and 60 degrees. The shielding gas composition was pure argon. The welding currents were set to be 50A, 100A, 150A or 200A for comparison with experimental results and simulation results in the literature to confirm validity of these experimental results. Moreover, time variation in temperature distribution of TIG pulsed arc was also observed. The peak and base currents were 200A and 50A, respectively. The frequency was 50Hz.

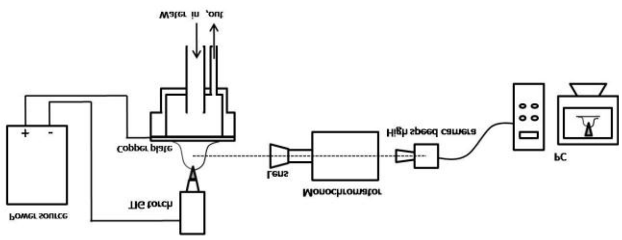

Fig.1 Schematic diagram of observation.

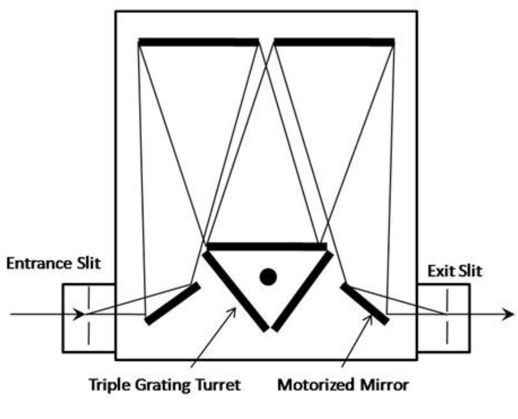

Fig.2 Schematic diagram of monochromator.

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Intensity observed by the camera is determined by integration of radiant intensity from the arc along the line of sight as shown in Fig. 3. The radiant intensity distribution is calculated from the integrated intensity with Abel inversion. The radiant intensity from the arc is theoretically calculated from the equation (1).

$$I_{nm} = A_{nm} h \nu_{nm} N_0 \frac{g_n \exp\left(-E_n/kT\right)}{\sum_j g_j \exp\left(-E_j/kT\right)} \quad (1)$$

Where A_{nm} is transition probability, h is Planck constant and ν is frequency, N_0 is particle number density under the LTE assumption, g_n is statistical weight, E_n is level energy, T is temperature, k is Boltzmann constant.

Fig. 4 shows relationship between the intensity ratio (normalized intensity) and temperature at wavelength of 696.5nm (ArI) obtained with the above equation. It is seen that the intensity of ArI is maximized at 15000K.

Fig. 5 shows concept of inversion from the intensity to the temperature. The temperature in the upper left of the max. intensity region corresponding to 15000K is obtained from the relationship between intensity ratio and temperature over 15000K in Fig. 4 and that of the lower right is obtain from the relationship under 15000K.

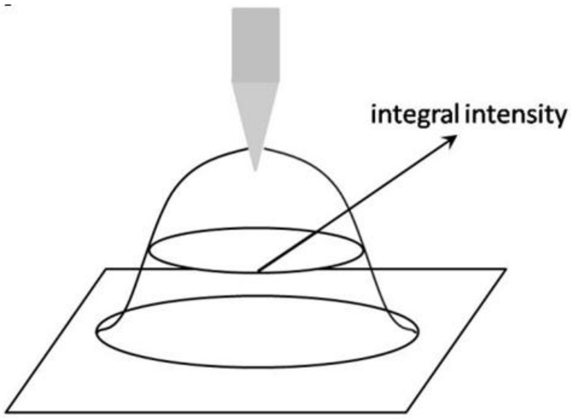

Fig.3 Concept of integrated intensity along line of sight.

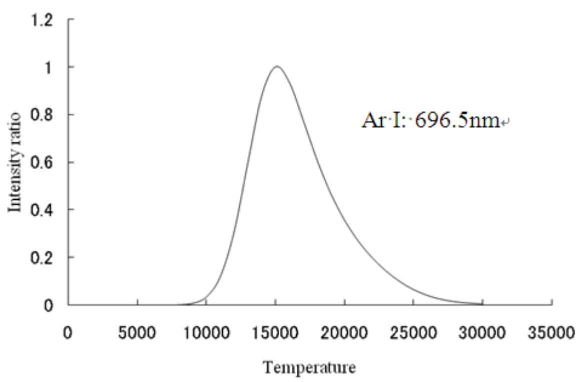

Fig.4 Relationship between temperature and intensity ratio at 696.5nm (Ar I).

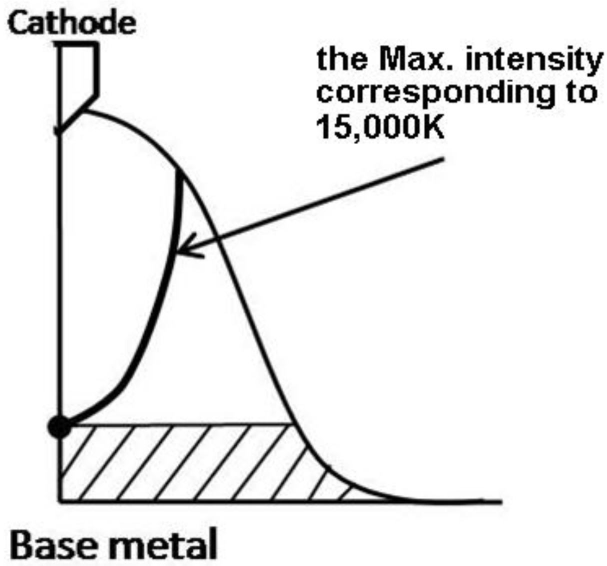

Fig.5 Concept of inversion from the intensity to the temperature.

3. Result and discussion

Fig.7 shows temperature distributions in radial direction below 1mm from cathode tip as shown in Fig. 6. The cathode tip angle was 45 degrees , arc current was 100A and arc length was 5mm. The measured temperature distribution was compared to the experimental result in the literature[2)] to confirm the validity of our experimental results. It was found that both results were in good agreement and the validity of our experimental results was confirmed.

Fig.8 shows comparisons of temperature distributions of (a) experimental results and (b) simulation results in the literature[3)] at contact tip angle 60 degrees, arc current 150A and arc length 5mm. It was seen that the both the maximum temperatures were approximately 17,500K and both temperature contours of 10,000K, 12,500K and 15,000K were in good agreement.

Fig.9 shows the comparison of temperature distributions in cases of conical tip angles of (a) 45degrees and (b) 60 degrees. The arc current is 100A and the arc length is 5mm. The both maximum temperature are about 17,500K. It was found that the arc in case of conical tip angle of 45 degrees was more constricted than that of 60 degrees. It seems that the proposing of effect of conical tip angle on maximum arc pressure[4)].

Fig.10 shows current waveform for TIG pulsed arc and Fig.11 shows time variation of temperature distributions of TIG pulsed arc at the times (A) ~ (D) marked in Fig. 10. As a result, it was found that the arc column was expanded in radial direction and the maximum arc temperature was 20,000K during the peak current of 200A. On the other hand, the width of the arc column decreased especially in the downstream region of the arc and the maximum arc temperature fell to 17,500K during the base current of 50A.

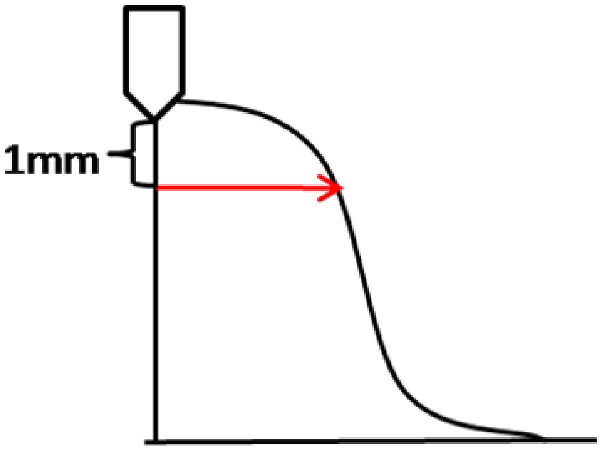

Fig.6 Position where the radial temperature distribution shown in Fig. 7 was measured.

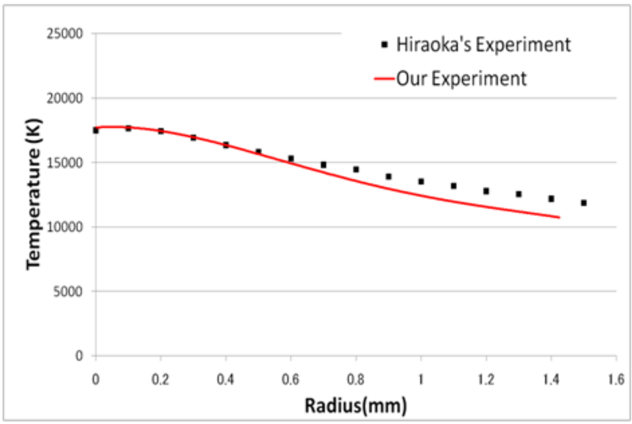

Fig.7 Temperature distributions in radial direction below 1mm from cathode tip.

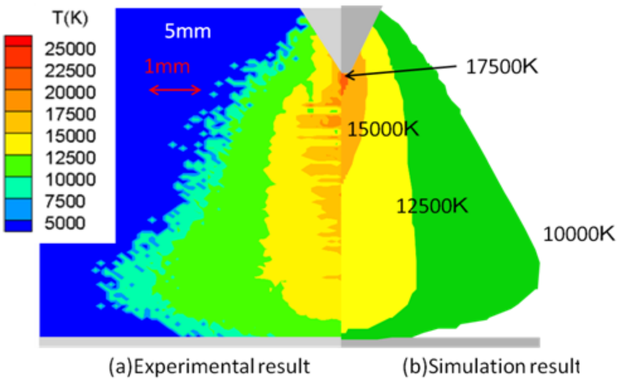

Fig.8 (a) Experimental result and (b) simulation result of two-dimensional temperature distributions.

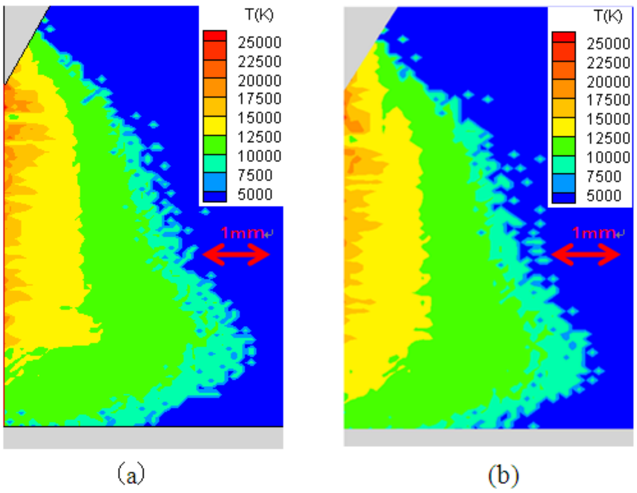

Fig.9 Comparison of temperature distributions between cases of conical tip of (a) 45°and (b) 60°.

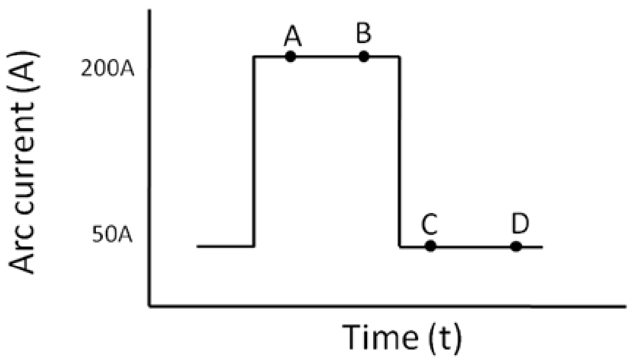

Fig.10 Current waveform of TIG pulsed arc.

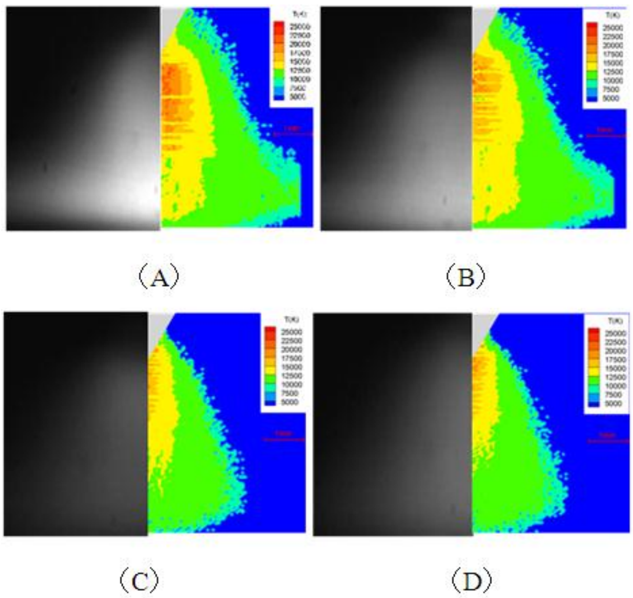

Fig.11 Time variation of temperature distributions of TIG pulsed arc at the times (A) ~ (D) marked in Fig. 10.

4. Conclusions

The dynamic variation in two-dimensional temperature distribution of TIG pulsed-arc was measured through Fowler-Milne method with a high speed video camera as a first step of the study. Consequently, it was found that the arc column was expanded in radial direction and the maximum arc temperature was 20,000K during the peak current of 200A. On the other hand, the width of the arc column decreased especially in the downstream region of the arc and the maximum arc temperature fell to 17,500K during the base current of 50A.

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