Experimental study of oxygen absorption behavior in gas tungsten arc using carbon dioxide

Y. Asai[1] , H. Komen[1] , M. Tanaka[1] , M. Nomoto[2] , K. Watanabe[2] and T. Kamo[2]

[1] *Joining and Welding Research Institute, Osaka University, Osaka, Japan*
[2] *Nippon Steel Corporation, Chiba, Japan*

Abstract: One of the techniques to improve the penetration depth of gas tungsten arc welding is to apply carbon dioxide gas as a shielding gas using a double shielding torch. In this study, an experimental investigation was conducted to clarify the behavior of carbon dioxide to establish a guideline for controlling the oxygen contamination that affects the toughness of a welded part by this welding process. As a result, it was suggested that carbon dioxide gas was transported to the vicinity of the central axis of a tungsten electrode by the vortex generated near the electrode. Then, oxygen dissociated from carbon dioxide increased the oxygen concentration in the gas flowing on a base metal surface.

Keywords: carbon dioxide, gas tungsten arc welding, oxygen concentration measurement

1. Introduction

Gas tungsten arc (GTA) welding is one of welding processes and has the advantages of producing a welded part with toughness, ductility, and corrosion resistance. On the other hand, GTA welding has disadvantages that a penetration depth is shallow and inert gas is expensive compared with other welding processes. Therefore, many studies have been conducted to improve the penetration depth in this welding process and to expand the range of GTA welding. For example, in order to improve the penetration depth, GTA welding with a double shielding torch using carbon dioxide was developed [1,2]. However, the behavior of carbon dioxide to establish a guideline for controlling the oxygen contamination that affects the toughness of a welded part by this welding process has not been clarified. Hence, in this study, carbon dioxide behavior in arc plasma was investigated when carbon dioxide was applied to the shielding gas by the double shielding torch.

2. Experimental Procedure

Figure 1. shows a schematic illustration of double shielding torch used in this study. As shown in the figure, inert gas flowing around the electrode to protect it was defined as the inner gas, and gas flowing outside the inner gas was defined as the outer gas.

First of all, the oxygen concentration in the gas flowing on the base metal surface so as to investigate the amount of oxygen on the base metal surface. Figure 2. shows a schematic illustration of experimental setup for oxygen concentration measurement. This experimental setup consisted of a double shielding torch, TIG welding power source, a circular water-cooled copper with a small hole, an oxygen analyzer, and a data logger. Oxygen concentration was measured by aspirating gas through a small hole in the water-cooled copper at 60 mL/min.

In order to the entrainment of carbon dioxide into arc plasma, the shielding gas flow was visualized by the schlieren method. Figure 3. shows a schematic illustration of experimental setup for the schlieren method. This experimental setup consisted of a double shielding torch, a water-cooled copper, a spherical mirror, a plane mirror, a high-speed video camera, a laser beam source, a half mirror, a knife edge, a pin hole and a band-pass filter (640 nm). The laser wavelength was 640 nm and the exposure time was set to 123 μs, the frame rate was set to 8000 fps.

Table 1. shows welding conditions used in this experiment. The basic conditions used in this study were a welding current of 80 A, argon as the inner gas, the inner gas flow rate of 15 L/min, carbon dioxide as the outer gas, the outer gas flow rate of 15 L/min, arc length of 3 mm, and extension length of 5 mm. The oxygen concentration on the base metal surface was measured under conditions different from the basic conditions for each outer gas and extension length. In addition, visualization of shielding gas was conducted when the outer gas was set to carbon dioxide.

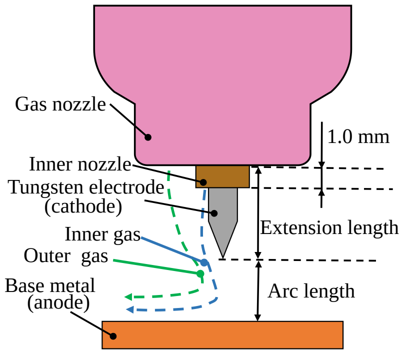

Fig. 1. Schematic illustration of double shielding torch.

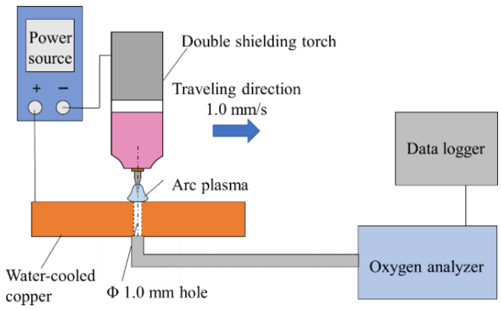

Fig. 2. Schematic illustration of experimental setup for oxygen concentration measurement.

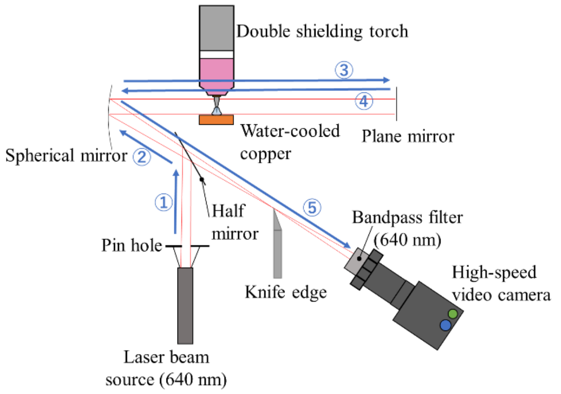

Fig. 3. Schematic illustration of experimental setup for schlieren method.

Table 1. Welding conditions.

Welding current	80 A
Inner gas	Pure Ar
Inner gas flow rate	5 L/min
Inner nozzle diameter	3 mm
Outer gas	Pure CO_2, 80%Ar+20%CO_2, Pure Ar
Outer gas flow rate	15 L/min
Outer nozzle diameter	13 mm
Electrode material	W-2 wt.%La_2O_3
Electrode diameter	2.4 mm
Electrode tip angle	45 deg.
Arc length	3 mm
Extension length	3, 5, 7 mm
Base metal	Water-cooled copper
Polarity	Electrode negative

3. Results and Discussion

Figure 4. shows the oxygen concentration on the base metal surface when the outer gas was set to the gases shown in the figure. The horizontal axis of this figure shows the radial distance from the central axis of the electrode. The shielding effect was confirmed in the radial direction with oxygen concentrations close to 0 from 3 mm to 9 mm in the radial direction when each gas was used. On the other hand, when 80%Ar+20%CO_2 gas and carbon dioxide were used as the outer gas, an increase in oxygen concentration was measured near the central axis of the electrode. Besides, Fig. 5. shows the oxygen concentration on the base metal surface when the extension length was set to 3, 5, and 7 mm. When the extension length was long, oxygen concentration near the central axis of the electrode increased. These increases in oxygen concentration suggested that carbon dioxide in the outer gas was transported to the central axis of the electrode.

Finally, Fig. 6. shows the result of gas flow visualization by the schlieren method when carbon dioxide gas was applied as the outer gas. As shown in region A of this figure, vortexes formed near the electrode were observed. It was implied that carbon dioxide in the outer gas was transported to the vicinity of the central axis of the electrode.

From these results, it was revealed that the vortex generated near the electrode transported the outer gas to the vicinity of the central axis of the electrode, and carbon dioxide in the outer gas dissociated in arc plasma as temperature increased. Eventually, oxygen concentration on the base metal surface increased by oxygen dissociated from carbon dioxide.

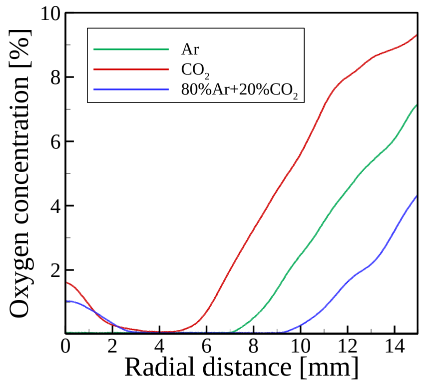

Fig. 4. Oxygen concentration on the base metal surface for each outer gas.

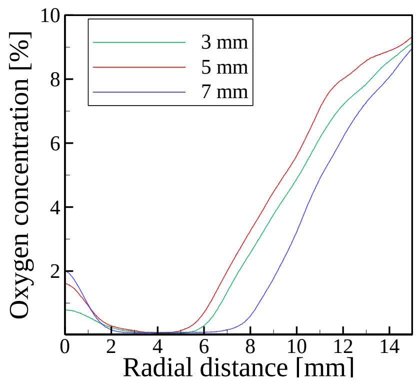

Fig. 5. Oxygen concentration on the base metal surface for each extension length.

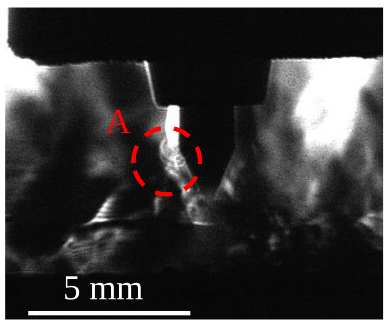

Fig. 6. Schlieren image when carbon dioxide gas was used as outer gas.

4. References

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