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Study on Suppressing Bead-Meandering of Pure Ar-MIG Arc Welding using External Magnetic Field

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1. Introduction

Currently, in gas metal arc (GMA) welding using a widely used electrode wire, a minimal percentage of O_2 is added to the shielding gas to protect the arc. The arc is stabilized by the formation of iron oxide, which easily emits electrons on the surface of the base metal to be welded by O_2. However, when O_2 is mixed into the molten metal, the toughness of the welded joint is lowered, which can be improved by reducing the mixing ratio of O_2 of the shield gas. In particular, using pure argon as the shielding gas (pure Ar-MIG arc welding) is desirable. However, bead-meandering is a challenge experienced in pure Ar-MIG welding. One of the causes is the phenomenon whereby the cathode spot on the base metal moves ahead of the molten pool in search of O_2 outside the shielding gas [1]. Conversely, research to improve welding strength and quality is underway, such as applying an external magnetic field to the current flowing in the molten pool or arc, and consequently generating an electromagnetic force. [2], [3] This study focuses on a method of suppressing the bead-meandering by controlling the cathode spot using an electromagnetic force, without having to change the electrode wire or the shielding gas. The direction of the external magnetic field was perpendicular to the welding direction, when both DC and AC external magnetic field were used. Bead-on-plate welding experiments were carried out by applying an external magnetic field and using pure Ar shielding gas. The effect of external magnetic field on arc stability, and bead shape was evaluated from the obtained results, and the effectiveness of pure Ar-MIG arc welding using external magnetic field was examined.

2. Bead-meandering suppression method using an external magnetic field

We propose two methods of bead meander suppression, one using a DC external magnetic field and the other using an AC external magnetic field. When a DC external magnetic field of magnetic flux density B_{DC} is applied perpendicularly to the arc of welding current I, electromagnetic force F_{DC} per unit length is generated in the outer product direction. The bead-meandering is suppressed by the force F_{DC} pressing the arc (cathode spot) backward. When an AC external magnetic field of amplitude B_{AC} and frequency f is applied perpendicularly to the arc of welding current I, electromagnetic force F_{AC} per unit length is generated in the outer product direction. This allows the arc to oscillate regularly at the frequency f as shown in Fig. 1. In Fig. 1, an AC external magnetic field is applied in the direction of welding progress and the arc is oscillated in a left-right direction by the electromagnetic force, although oscillation in a front-back direction is still possible.

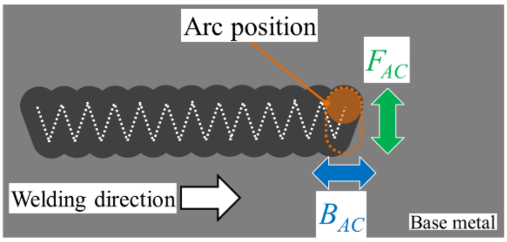

Fig. 1 Bead-meandering suppression by AC external magnetic field.

3. Welding experiment

As shown in Fig. 2, a small electromagnet capable of all-position welding was installed at the tip of the welding torch, and an external magnetic field was applied to conduct a bead-on-plate experiment.

To quantifiably evaluate the meandering of the obtained beads, we measured the bead widths at multiple points for one bead and obtained the average and standard deviation values. Under similar conditions for all experiments, three values of the bead width, standard deviation and average bead width each, were recorded and averaged. Table 1 shows the experimental conditions.

Fig. 2 Overview of the experimental apparatus.

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Table 1　Experimental conditions.

Base metal (thickness [mm])	SS400 (3.2)
Electrode wire (diameter [mm])	DS1A (1.2)
Shielding gas	100%Ar
Gas flow [L / min]	20
Welding speed v [m / min]	0.8
Welding current I [A]	300
DC magnetic flux density B [mT]	0.5, 1.0, 1.5
AC magnetic flux density root mean square value B_{RMS} [mT]	0.5, 1.0
AC magnetic flux density frequency f [Hz]	5, 10, 20, 50, 100

3.1 Experimental results

In the DC magnetic field, though there was a condition that could suppress the bead-meandering, the width of the bead narrowed in all conditions. In the AC magnetic field, bead-meandering could be suppressed under many conditions, even when the arc was oscillated in the front-back or, right-left directions. The bead width became narrower in front-back oscillation as well as in the DC magnetic field application, but became thicker than the bead without magnetic field application in right-left oscillation.
Fig. 3 and Fig. 4 compare the bead obtained by adding O_2 and the bead obtained by the proposed method when AC external magnetic field was applied. The black dot line is the value at the time of adding O_2. When front-back oscillation properties were B_{RMS} = 1.0 mT and f = 100 Hz, as shown in Fig. 3, the standard deviation of the bead width was much closer to that in the case of O_2 addition, and the bead-meandering could be effectively suppressed. However, as shown in Fig. 4, the average bead width was smaller and the bead became thinner. When left-right oscillation properties were B_{RMS} = 0.5 mT, f = 100 Hz, the bead width standard deviation was larger than the previous condition, and the bead-meandering suppression performance somewhat inferior. However, the average bead width was similar to that of the case of O_2 addition, and the bead width could be maintained. Fig. 5 shows the appearance of the beads with good meandering suppression. In the condition of front-back oscillation shown in Fig 5 (a), the bead-meandering was effectively suppressed, although the bead was thin. Additionally, the bead width was maintained under the condition of right-left oscillation in Fig 5 (b). Thus, the bead-meandering of pure Ar-MIG welding can be suppressed by external magnetic field.

4. Conclusion

A method for suppressing the bead-meandering of pure Ar-MIG arc welding using an external magnetic field was proposed. The effectiveness of the proposed method was verified by the bead on plate experiment by applying AC and DC external magnetic fields.

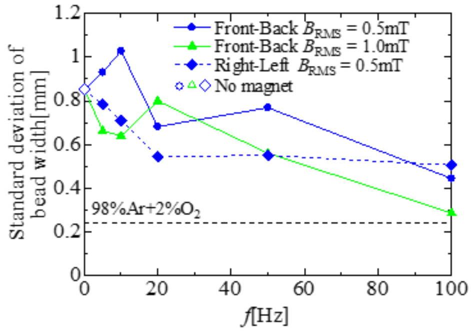

Fig. 3　Comparison of bead width standard deviation. (O_2 and AC magnetic field)

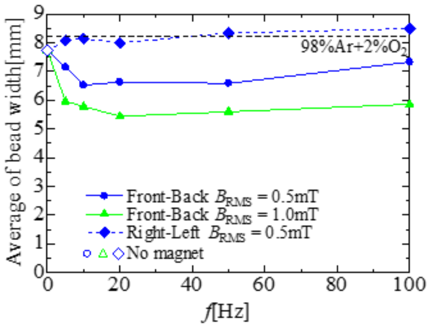

Fig. 4　Comparison of bead width average value. (O_2 and AC magnetic field)

(a) Conditions that suppressed bead-meandering the most. (AC front-back oscillation, B_{RMS} = 1.0mT, f = 100Hz)

(b) Conditions for suppressing bead-meandering while maintaining bead width. (AC right-left oscillation, B_{RMS} = 0.5mT, f = 100Hz)

Fig. 5　Bead appearance with good results.

References

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