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Influence of magnet configurations on magnetic controlled TIG arc welding[†]

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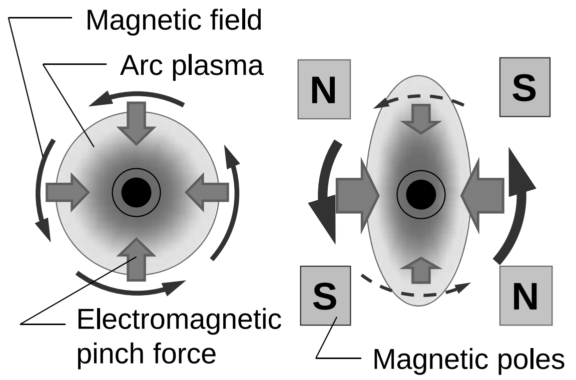
KEY WORDS: (Magnetic control) (Permanent magnet) (Arc plasma) (Weld penetration) (3D analysis)

1. Introduction

Arc plasma is affected by external magnetic forces. From this view point, conventional studies have been conducted on controlling the arc plasma by magnetic force for effective welding [1-4]. We focused on the cusp type of magnetic field, which changes the cross section of the arc plasma from a circular to an elliptical shape. In the previous study, the cusp magnetic field suggested by Maruo et al. was given by solenoid coils [4]. On the other hand, we made the magnetic field by permanent magnets. Its characteristics are small device size and no other power source. We have applied this magnetic control to TIG arc welding and evaluated its performance experimentally and theoretically. It was confirmed experimentally that the permanent magnets installed in the TIG torch can make an arc plasma with an elliptical shaped cross section. As a result, bead on plate welding with the magnetized TIG arc provided sound weld beads and the limit of welding speed without a weld imperfection was expanded [5, 6]. Our previous results show that arc shape control by permanent magnets is useful.

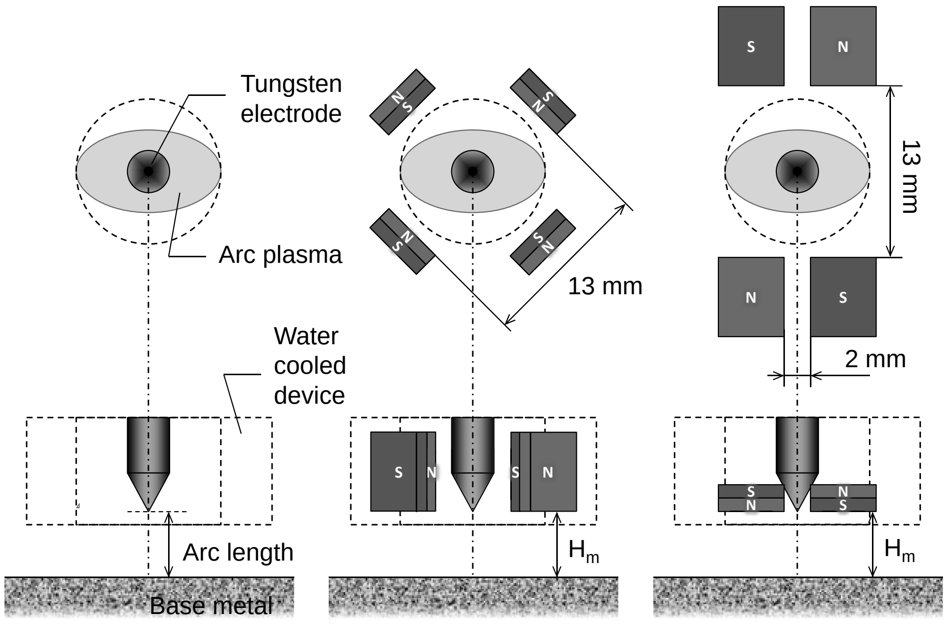
2. The Aim of This Study

Figure 1 shows the principle of the elliptical arc shape generated by the cusp type magnetic field. A conventional TIG arc plasma is illustrated in Fig. 1 (a). The cross section of the arc plasma is circular. In contrast, the magnetized arc plasma by the cusp type magnetic field, which is composed of four magnetic poles, is shown in Fig. 1 (b). The magnetic fields of the arc and the external magnets are in the same direction in the right and left areas, and reversed in the top and bottom areas. Therefore, the field produces alternative electromagnetic pinch forces, and changes the cross



(a) Conventional TIG arc **(b)** Magnetized TIG arc

Fig. 1 Principle of elliptical arc shape by cusp type magnetic field



(a) Without magnets **(b)** Type A **(c)** Type B

Fig. 2 Experimental condition of magnet configurations

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section of the arc plasma from a circular to an elliptical shape. For example, **Fig. 2** (b) is one of actual alignment of magnets providing a cusp type of magnetic field. In order to provide the cusp type magnetic field, an arrangement of magnets' position like that is required. Therefore, we can consider different configurations of magnet positions. In this paper, the influence of the magnetic field varying with the arrangement of magnets is investigated experimentally.

3. Experimental setup

We performed TIG arc welding with the cusp type magnetic field experimentally. Four permanent magnets are placed inside the water cooled device to prevent the magnets from heating as shown in schematic Fig. 2. This device is inserted into the nozzle of the TIG torch. The base metal is stainless steel plate. Other experimental conditions are tabulated in **Table 1**. To investigate the influence of magnet configurations, we made two types of magnet configurations where the magnetized direction is different from each other. Furthermore, the distance between the magnets and the base metal (= Hm) is a factor that determines the relationship of the magnetic field and the arc plasma. This is also investigated by changing this value from 5 mm to 3 mm.

4. Results and Discussions

The experimental results are summarized in **Fig. 3**. The crater shape comparison shows that the elliptical effect and the sensitivity to magnets' positions of type A seem to be higher than that of type B. The comparison of weld penetration under the 10 cm/min bead on plate welding also shows differences. Narrower bead width and higher D/W are obtained due to the magnetic control. In the case of type B, the penetration becomes deeper compared with the conventional arc. This implies that the magnetic control also changes the flow inside the weld penetration.

5. Conclusions

In this study, we applied the cusp type magnetic control to TIG arc welding with permanent magnets and investigated the influence of the magnet configurations. We made two types of magnet configuration where the magnetized direction is different from each other. As a result of magnetic control, narrower bead width, deeper penetration, higher aspect ratio of weld penetration and change of the flow inside the weld penetration were obtained. However, their effects depend on the magnets configuration. One type affects the arc plasma much more than the molten pool, resulting higher elliptical effect. Another type has the advantage in controlling the weld penetration such as deeper penetration.

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Table 1 Experimental conditions

TIG arc condition	Base metal: SUS304 Welding speed: 0, 10 cm/min
Arc length: 5 mm Current: 150 A Shielding gas: Ar, 15 ℓ/min Electrode diameter: 3.2 mm Electrode vertex angle: 60 º	**Magnets condition** Size: 5x6x2 mm³ Surface magnetic flux: 300 mT Height (= "H_m" in Fig. 2): 3, 5 mm

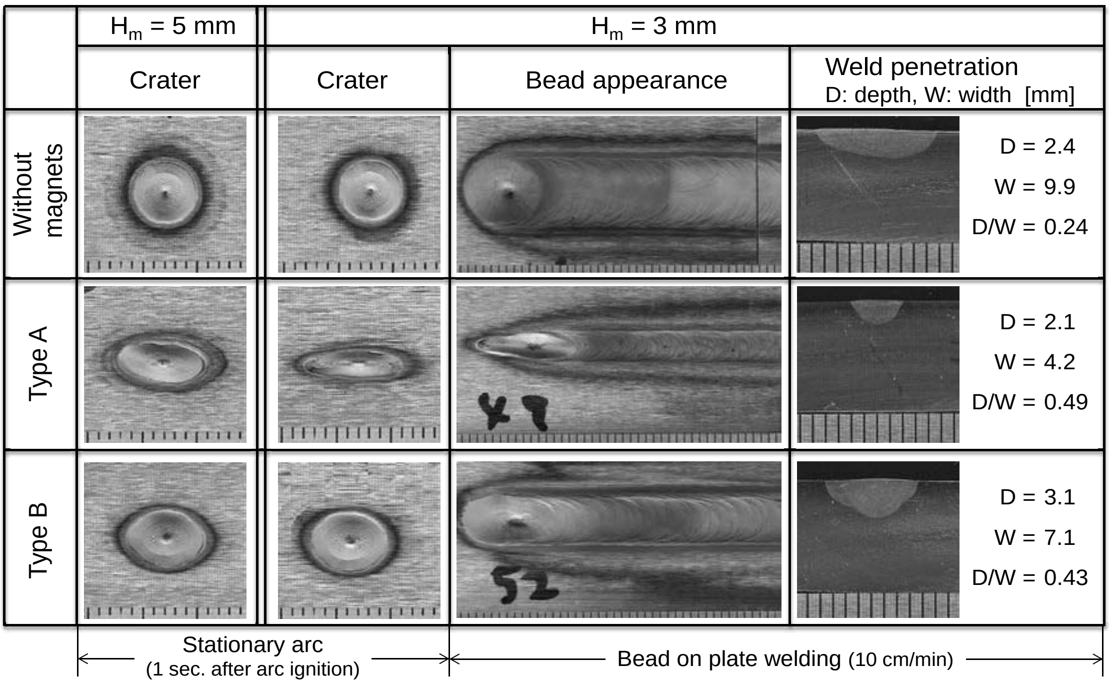

Fig. 3 Influence of magnet configurations on TIG arc welding