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Direct *J*×*B* Drive of the molten Cathode Spot and its effect on the surface temperature in the Plasma Arc Cutting Torch

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1. Introduction

Plasma arc cutting (PAC) is known as a thermal cutting method [1]. A steel plate is cut by local heating on the arc plasma and then blows out molten steel by its ultra-high gas flow in the arc plasma. The PAC has several advantages of its fast cutting speed with low cost compared to other thermal cutting methods. In the PAC, rare metals (Hf) are used for the cathode, it is important to suppress this erosion. In order to suppress the Hafnium cathode erosion (melting point is 2504 K, boiling point is 4875 K), we studied the influence of axial magnetic field application on the Hf electrode surface temperature.

2. Experimental conditions

An axial ring-shaped permanent magnet (80 mT) was located outside of the torch and a center pipe was put inside of the torch to concentrate the magnetic field near the cathode surface. Fig.1 indicates a schematic diagram of the interaction between axial magnetic field and arc plasma near the cathode. Current has a radial component. Axial magnetic field is applied because it produces azimuthal $J\times B$ Lorentz force, which can lead to rotation of the arc plasma and the molten pool. We expected that the rotation of the hot molten cathode pool can flatten the peaked cathode temperature. In the present experiment, an arc current was set to 80 A. Dynamic behavior of the cathode molten pool was observed by a high speed RGB camera and the surface temperature of the molten pool was evaluated using RGB intensity ratio method [2].

3. Effect of axial magnetic field application on the arc plasma behavior and the Hf surface temperature

Fig.2 shows the high speed camera images of the molten pool on the Hf cathode for with/without external magnetic field. If there is no magnetic field application as indicated in Fig.2(a), the arc plasma is shrunk radially. On the other hand, application of axial magnetic field causes swirl motion of the arc plasma and the molten pool. The swirling motion of the molten pool is because of the $J\times B$ Lorentz force.

We evaluated the Hf electrode surface temperature using the RGB intensity ratio method. Fig.3 shows the Hf surface temperature with/without external magnetic field. As indicated here, the surface temperature is around 3750 K in the whole region. On the other hand, the magnetic field application reduces the surface temperature around 3600 K. From these results, the Hf surface was in molten state and rotating the molten pool could stir to be cooled, which might reduce the surface temperature. It would decrease the amount of the evaporation loss of the Hf cathode by 20% compared with the case of no magnetic field.

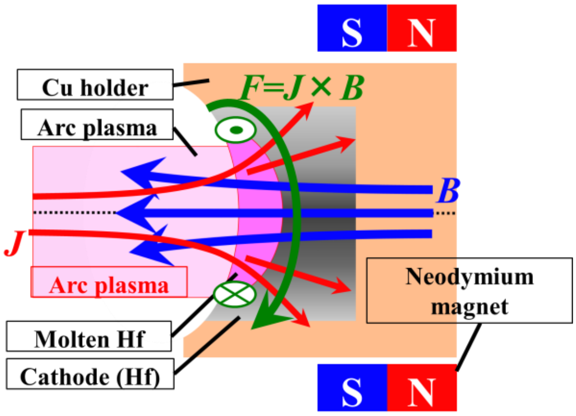

Fig.1 Principle of rotation of arc and molten pool.

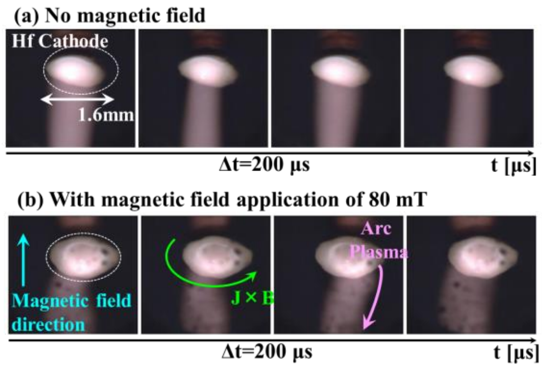

Fig.2 Observation on behaviors of the arc plasma and the molten pool using a high speed video camera

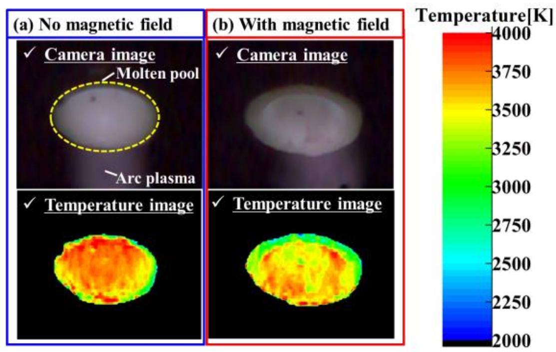

Fig.3 Camera image of Hf cathode (upper) and Hf surface temperature (lower) using a high speed video camera

References

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