Anode current density measurement of a non-transferred DC arc plasma generator

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Abstract: The current density on the anode surface of a non-transferred DC arc plasma generator was measured by using a self-designed electrostatic probe measurement system. The results show that when using pure argon as the working gas, the maximum current density was detected near the exit of anode throat, while for mixture working gas of argon/nitrogen, the maximum current density appeared at about 5mm downstream of the anode throat exit, and the maximum value increased with the increase of nitrogen gas flow rate.

Keywords: Anode surface current density, DC arc plasma, electrostatic probe.

1. Introduction

Thermal plasma generally refers to a high-temperature partially ionized gas, which is characterized by approximately equal heavy-particle and electron temperatures of about 10^4 K. It can be generated and maintained by methods such as arc discharge and inductively coupled discharge. DC arc plasma has been widely used in the field of material processing due to the characteristics of high temperature, high energy density, convenient operation and so on. Generally, the arc attachment to the anode surface of the plasma generator is constricted at an extremely high current density (average current density is up to 10^8 A/m^2 [1]), and temperature at the attachment spot is far higher than the melting or vaporization point of the electrode material, which leads to the electrode erosion and reduces the life time of the generator.

A special arc plasma generator was designed, and combined with suitable working parameters, diffused anode attachment in pure nitrogen arc was successfully achieved in our previous work [2]. In order to better understand the arc attachment behaviour on the anode surface of the designed plasma generator, in the present work, the current density on the anode surface was measured by using a self-designed electrostatic probe measurement system. Pure argon and mixtures of argon and nitrogen were used as the working gas.

2. Experimental details

DC arc Plasma was generated with pure argon and mixtures of argon and nitrogen as the working gas at a feeding rate of 7-25 slm and arc current of 80-100A. The plasma jet was injected into the atmosphere after leaving the generator nozzle.

The schematic diagram of the experimental setup is shown in Fig. 1. The anode of the generator has a flow-restrictor channel (anode throat) of 3mm in diameter and downstream expansion half-angle of 7°, with the purpose of creating a dispersed arc column by strong gasdynamic expansion effect. The electrostatic probe measurement system mainly includes four probes, a high precision ammeter and a reversing switch. The probe is made of 0.5mm platinum wire, and its side surface is coated with a titanium film to ensure that only front surface can receive electrons. A glass tube with an inner diameter of 0.6mm and an outer diameter of 0.8mm is sheathed outside the platinum wire for insulating the probe from the anode. There are four small holes of 0.8mm in diameter on the anode wall, and the positions are 0.8mm, 4.8mm, 8.8mm and 12.8mm from the exit of the anode throat. Four probes are fixed in the small holes by four fixtures as shown in Fig. 1, and the other end of the probes are connected to the anode of the generator through a reversing switch and an ammeter.

In order to prevent the surface contamination of the probe, the four probes were pulled put 5mm before measurement, the reversing switch was closed to the position of the probe to be measured, then the probe was moved to the inner wall of the anode through the fixture, and then recorded the ammeter value. By repeating the above process, the current density of 4 positions can be measured.

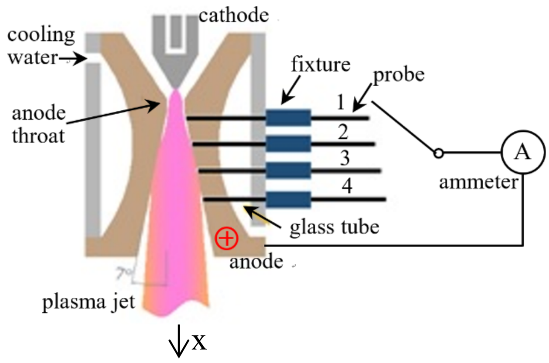

Fig. 1. Schematic diagram of the experimental setup.

3. Results and discussions

Fig. 2 shows the current density distribution along the axial distance of the plasma generator when pure argon is as the working gas, and horizontal coordinate “0” refers to the anode throat exit. It is seen that the maximum current density appears near the anode throat exit, and the current density is almost reduced to 0 when the distance is larger than 4.8mm. This indicates that the arc root is mainly attached to the exit of the anode throat.

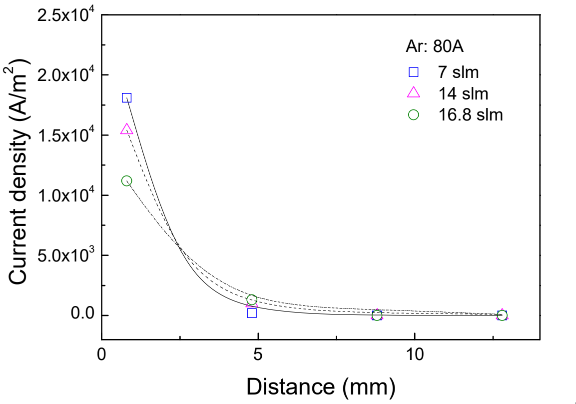

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Fig. 2 Current density distributions along the axial distance of the generator (0: the anode throat exit).

Fig.3 plots the distributions of the current density along the axial distance when mixtures of argon and nitrogen is as the working gas. It is clearly seen that the maximum current density appears at the distance of 5mm away from the anode nozzle exit, which is different from the pure argon gas, and the current density is nearly zero when the distance is greater than 12mm. It can be considered that the arc root attachment range is less than 12mm from the anode throat exit to the downstream, and mainly attached to the spot around 5mm from the throat exit. It can also be seen that as the increase of nitrogen gas flow rate, the current density near the throat exit decreases, while the current density increases significantly around the spot of 5 mm away from the throat exit, indicating that the arc root attachment moves toward the downstream under the action of aerodynamic forces. The movement of the arc root attachment to the downstream means that the arc column becomes longer, and thus the larger arc voltage. The maximum current density is about 1.5×10^5 A/mm^2, which is much smaller than that of the constricted arc root attachment of 10^8 A/mm^2. It may indicate that the arc root attachment is dispersed effectively.

According to the measured current density, the integrated current on the anode surface can be calculated. Fig. 4 shows the results when mixture gas of argon and nitrogen as the working gas, and it is seen that the calculated current differs greatly from the actual current. The reason maybe as follows: the distance between the probes is a bit large, and the position of the probe may not be where the maximum value of the arc root is attached; In the ideal measurement process, the end face of the probe is in the same plane as the inner wall surface of the anode. however, the end face processing condition, surface ablation, and measurement accuracy of the probe will bring some errors to the experiment. The present experiment can give some qualitative results.

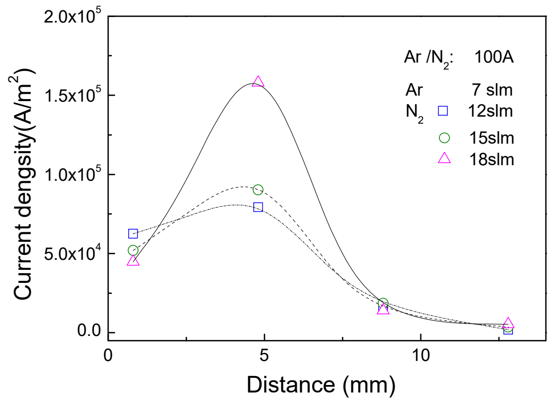

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Fig. 3 Current density distributions along the axial distance of the generator (0: the anode throat exit).

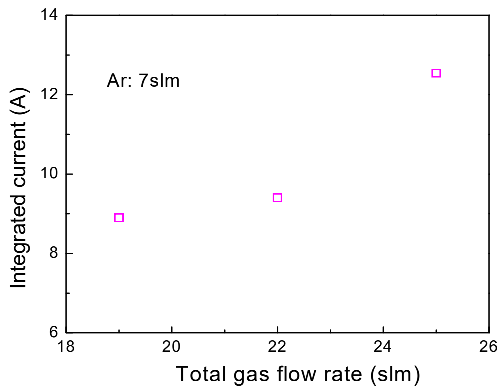

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Fig. 4 Variations of the integrated arc current as total gas flow rate.

4. Conclusions

Experimental results show that when using pure argon as the working gas, the maximum current density was detected near the exit of anode throat, while for mixture working gas of argon/nitrogen, the maximum current density appeared at about 5mm downstream of the anode throat exit, and the maximum value increased with the increase of nitrogen gas flow rate.

5. References

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