24P023-O

Numerical Study on Effect of Gas Pressure and Cathode Diameter on Evaporation of Hafnium Cathode in a Plasma Cutting Arc

Nguyen Phi Long, Yasunori Tanaka, and Yoshihiko Uesugi

Division of Electrical Engineering and Computer Science,
Kanazawa University, Kakuma-machi, Kanazawa 920-1192, Japan

The effects of the gas pressure and cathode diameter in plasma cutting arc torch were investigated using a developed two-dimensional thermofluid model with considering hafnium cathode evaporation. The simulated results show that the temperature of the cathode surface is decreased at the center of cathode tip with increasing cathode diameter. On the other hand, increasing gas pressure elevates the surface cathode temperature in the range of 0.35 mm in radius of cathode tip. The net evaporation mass flux of hafnium cathode was predicted to be enhanced with increasing gas pressure and cathode diameter.

1. Introduction

The plasma arc cutting process is a widely used technique for cutting different metals with high speed and high accuracy in industrial fields. An arc plasma is established between the electrode in the plasma torch and a work-piece, which is molten by high-temperature from the arc plasma and heated by oxidation reactions [1]. To enhance the performance and the lifetime of plasma arc cutting device, understanding details of interactions between the electrode and the arc plasma under different operating conditions is necessary . This report numerically studied the effects of gas pressure and cathode diameter on temperature field and the net evaporated mass flux from hafnium (Hf) cathode in the plasma cutting arc torch.

2. Calculation model and boundary condition

Fig. 1 shows the arc model and calculation space used in this work. The copper electrode has a hafnium tip insert at the cathode center. Oxygen, which is used as the plasma gas, is supplied from the inlet by swirling gas flow. The length from the cathode tip surface to the nozzle exit is approximately 8 mm. The arc plasma is constricted by the copper nozzle with a nozzle outlet of 1.33 mm in diameter. The main simplifying assumptions on which the developed numerical models rely are as follows: steady state, axis-symmetric, laminar gas flow, local thermodynamic equilibrium, and optically thin plasma in a two dimensional space. This model solves not only the mass, momentum, energy conservation equation for plasma-gas, and mass conservation of Hf vapor evaporated from the cathode, but also the energy conservation equation of the electrode and the nozzle. The net mass flux from Hf cathode was predicted considering the evaporation flux estimated using the saturation vapor pressure and the redeposition flux. The SIMPLE method after Patankar [3] was used for the calculation scheme to solve the governing equations described in our previous report [2]. The swirl gas angle is fixed at 15 deg. The arc current of 100 A and gas flow rate of 20 slm are also fixed for different cathode diameters and gas pressures.

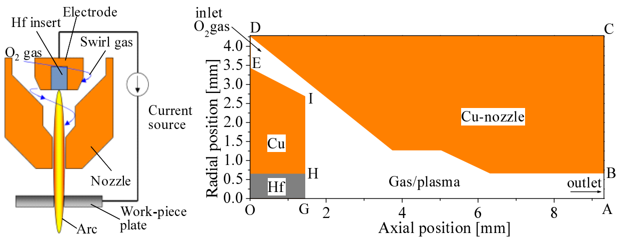

Fig. 1: Arc model and calculation space

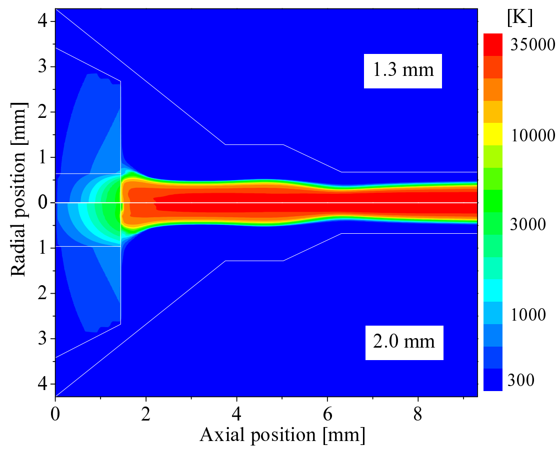

Fig. 2: Temperature distribution of arc plasma with cathode diameter of 1.3 mm and 2.0 mm

3. Calculation Results

3.1. Effect of cathode diameter

For purposes of studying the effects of cathode diameter on behavior of hafnium cathode evaporation, the cathode diameters are chosen with values of 1.3, 1.6, and 2.0 mm. The gas pressure is fixed at 0.8 MPa.

Fig. 2 shows the temperature distribution of arc plasma with cathode diameter of 1.3 mm and 2.0 mm. This figure demonstrates that the arc root near the cathode surface is expanded in the radial direction with a large cathode diameter and the maximum arc plasma

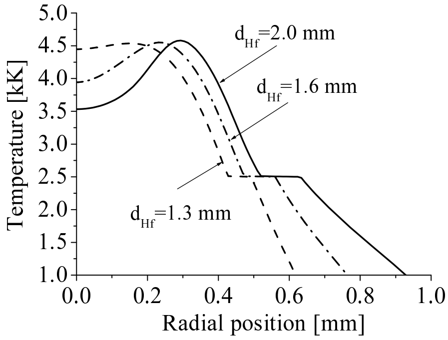

Fig. 3: Radial distribution of surface temperature of Hf cathode for different cathode diameters

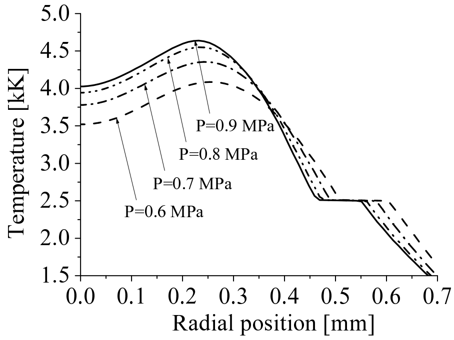

Fig. 5: Radial distribution of surface temperature of Hf cathode for different gas pressures

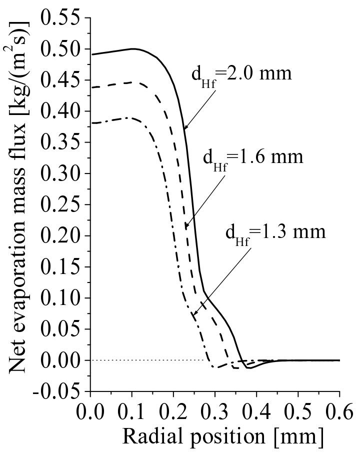

Fig. 4: Radial distribution of net evaporated mass flux from Hf cathode for different cathode diameters

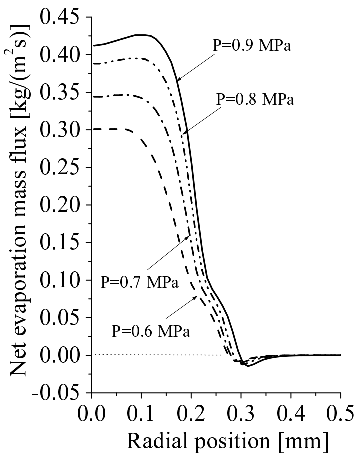

Fig. 6: Radial distribution of net evaporated mass flux from Hf cathode for different gas pressures

temperature reaches 33,000 K at the nozzle throat by constriction of the nozzle.

The radial distribution of the surface temperature of the Hf cathode for different cathode diameters is presented in Fig. 3. The temperature of the cathode surface is decreased markedly at the center of cathode tip with increasing cathode diameter. The reason is that the large cathode diameter allows a high density presence of hafnium evaporation on cathode surface and increases the convective heat transfer.

Fig. 4 shows the net evaporation mass flux from hafnium cathode tip for different cathode diameters. The net evaporation mass flux increases markedly and expands in radial direction with increasing cathode diameter. This is explained by the fact that an increased cathode diameter means a larger hafnium vapor in front of cathode tip expanding in radial direction. However, the negative net evaporation flux appears around the fringe of the arc, where the evaporated atoms return to the cathode surface.

3.2. Effect of gas pressure

The similar calculations were made to investigate the effect of gas pressure on Hf cathode evaporation. The gas pressures are chosen with values of 0.6, 0.7, 0.8, and 0.9 MPa. The cathode diameter is fixed at 1.6 mm. Fig. 5 presents the radial distribution of surface cathode temperature for different gas pressures. This figure shows that the surface cathode temperature in the range of 0.35 mm in radius increases with gas pressure. As gas pressure increases, the arc root skrinks, which allows a higher current density near the surface cathode tip, causing a high temperature of Hf cathode. Furthermore, the results from Fig. 6 indicated that the net evaporation mass flux from Hf cathode increases concomitantly with increasing gas pressure.

4. Conclusion

The numerical investigations of the influence of cathode diameter and gas pressure in plasma cutting arc torch are studied in this report. The calculation results show that the surface cathode temperature at the center of cathode tip decreases with an increasing cathode diameter and a decreasing gas pressure.

In addition, the net evaporation mass flux from hafnium cathode was enhanced with cathode diameter and gas pressure.

References

[1] V. A. Nemchinsky, and W. S. Severance,: *J. Phys. D: Appl. Phys.* 39 (2006) 423-428.

[2] N. P. Long, Y. Tanaka, Y. Uesugi, and Y. Yamaguchi: *Proc. 20th Int. Symp. on Plasma Chem., Philadelphia, USA* 2011.

[3] S. V. Patankar,: *Numerical Heat Transfer and fluid flow* (Hemisphere Publishing Corp. New York) 1980.