3rd Asia-Pacific Conference on Plasma Physics, 4-8,11.2019, Hefei, China

Chemical non-equilibrium simulation of arc attachment on anode of a high-intensity transferred arc

Hai-Xing Wang[1], Su-Rong Sun[1], Jin-Yue Geng[2], Tao-Zhu[1], Chong Niu[1], Jiang-Hong Sun[1]
[1] School of Astronautics, Beihang University, [2] Beijing Institute of Control Engineering
e-mail (speaker):whx@buaa.edu.cn

Direct current (DC) arcs have been widely used for welding, cutting, plasma spraying etc., for several decades [1]. For these applications, integrity and lifetime of the anode are of great concern in many arc plasma devices. The ablation of the anode surface often caused by the unfavorable arc-anode attachment may substantially reduce the lifetime of the anode due to the fact that anode is frequently subject to extremely high heat transfer rates. Therefore, the investigation of arc attachment mode on the anode continues to attract considerable attention in the thermal plasma research community.

The purpose of this study is to provide a better understanding of the chemical nonequilibrium effects on arc anode attachment of DC transferred arc through a numerical investigation. Departures from thermal and chemical equilibrium in plasma are studied by two-dimensional simulations using a two-temperature multicomponent fluid-dynamic model with chemical and excited-state kinetics. Electrons, ions, and ground-state atoms and excited atoms are considered as separate chemical species in the plasma mixture. The plasma flow in electric arc has very high gradients of species concentrations and temperatures, particularly near the electrodes and arc fringes. Hence, the self-consistent effective binary diffusion coefficient (SCEBDC) approximation is used to treat the species diffusion.

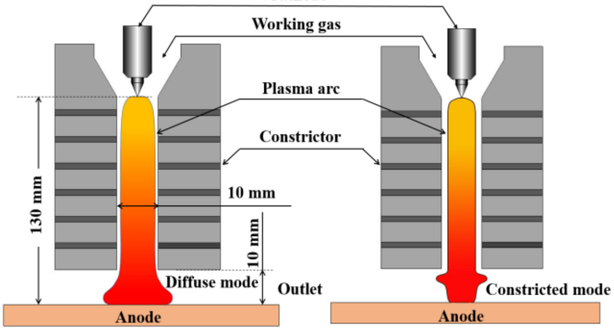

Fig. 1 Anode attachments of wall stabilized arcs

As shown in Fig. 1, the model used in this study is based on a wall-stabilized rotationally symmetric arc attaching to a plane cooled anode perpendicular to the axis of the arc. In this kind of device, the stability and axisymmetry of the arc column are ensured by using a coaxial and segmented water-cooled tube to constrict arc. This arc arrangement allows unobstructed viewing of the entire anode region. The experimental results showed that the diffusion and constricted arc attachment can be obtained by adjusting the arc current, electrode spacing, gas flow rate and the shape of cathode tip.

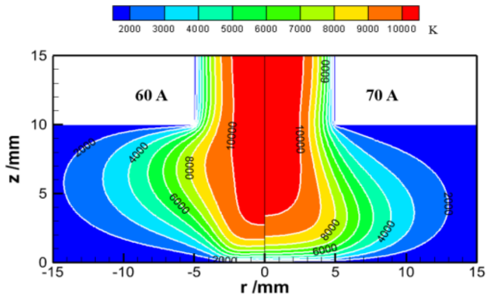

Fig. 2 Comparison of the computed heavy species temperature distributions

In this study, the constricted and diffusive arc attachment at the anode can be self-consistently obtained for the cases with the same mass flow rate of 0.14 slpm, while the different arc current of 60 A and 70 A, respectively. It is shown that compared to the diffusive arc attachment, the current contours significantly constricts at the anode surface for the constricted arc attachment. The reason for this shrinkage of arc current is due to the low temperature and low electric conductivity in the vicinity of the anode. For the constricted arc attachment, cooling effects of the inflow of low temperature gas entrained from the arc surrounding along the anode surface intensify this processes which lead to the significant constriction of current density distribution.

The results show that for constricted arc attachment mode, the ionization is dominant production processes of electron at the arc center, while for diffuse arc attachment mode both the convection and ionization play important roles on the electron number density distribution near the anode surface. The direction of convection transport of electrons for two arc attachment modes are opposite in the vicinity of the anode which is due to the fact that the flow induced by the cathode jet in this region is oppsite to the flow induced by the anode jet

Acknowledgment
This work was supported by the National Natural Science Foundation of China (Grant Nos. 11735004, 11575019) and the National Postdoctoral Program for Innovative Talents (BX20180029)

References

[1] Wang H X, He Q S, Murphy A B, Zhu T, Wei F Z (2017). Plasma Chemistry and Plasma Processing 37: 877–895.
[2] Wang H X, Sun S R, Sun W P (2015). Plasma Chemistry and Plasma Processing. 35: 543–564