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Numerical Simulation of Dynamic Arc Root Attachment in a Three-Dimensional Transferred Arc Plasma Device

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A key aspect of the operation of conventional non-transferred direct current (dc) plasma torches is the instability of the arc inside the nozzle. The axial displacement of the arc root at anode brings about a variation in the length of the arc column and, therefore, in enthalpy input to the gas, consequently, inhomogeneity in the plasma jet issuing from the plasma torch. The fluctuating mode of arc with restrike (or restrike mode) is characterized by a movement of the anode arc root in the direction of the superimposed flow followed by a sudden restrike upstream of nozzle between the cathode column and the anode [1]. A better control of these effects requires improved understanding of the arc attachment behavior and mechanism at the anode.

Dynamic simulation of arc root movement along anode surface in a direct current (DC) transferred arc plasma device is performed through a fully nonequilibrium model with appropriate boundary conditions to investigate phenomena of the arc root motion and characteristics of restrike processes. A chemical kinetic model which considers the ground-state argon atoms, excited argon 4s state, atomic ions, molecular ions and electrons is used in this simulation to describe the chemical nonequilibrium characteristics of arc attachment behavior around the anode [2].

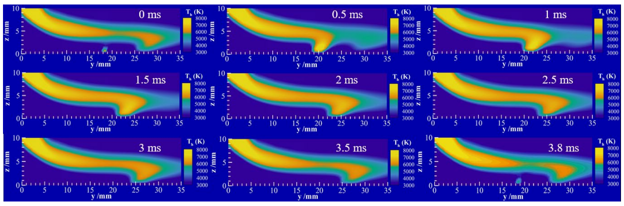

Fig.1 Heavy particles temperature distribution in the anode region of the transferred arc plasma device for one cycle of arc root movement with time interval of 0.5 ms

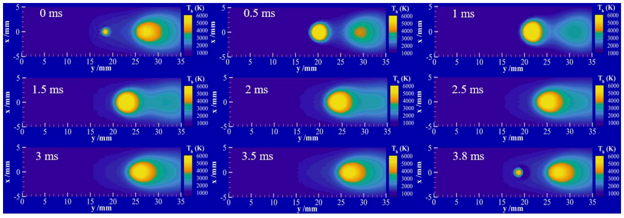

Fig. 2 Top view of heavy particles temperature distribution at z=1 mm for one period of arc root movement with time interval of 0.5 ms

Figure 1 shows the pattern of periodic change of the arc near the anode region with arc current of 30 A, working gas flow rate of 5 slpm and lateral gas flow rate of 16 slpm. At 0.5 ms, the arc is attached at a position 20 mm away from the lateral gas inlet. Then, the arc attachment position gradually moves to the right, that is, downstream, under the action of the lateral gas aerodynamic force and the arc is gradually elongated. At 3.8 ms, the arc root moved to the far right of the calculation domain at about 28 mm, the temperature of the arc column gradually decreased and finally disappeared. At the same time, at the location of 18 mm, a new arc spot appeared on the anode surface. The arc spot where the new arc is attached gradually increases, and the current passing through it also gradually increases. At 0.5 ms, it forms a new arc attachment. The corresponding top view of heavy particles temperature distributions 1 mm above the anode surface is shown in Fig. 2. The bright spot in the figure, is very close to the arc spot on the anode, represents the location where the arc is attached. As the arc moves to the right under drag force, the upstream arc spot gradually strengthens, while the downstream arc spot gradually weakens.

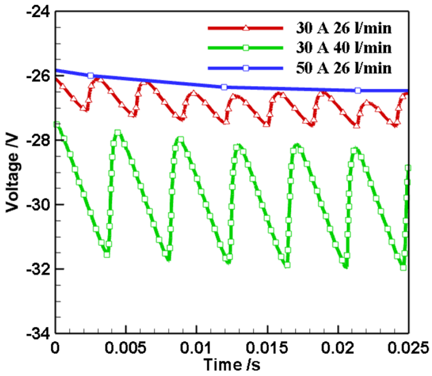

Fig. 3 Time evolution of predicted arc voltage.

Figure 3 shows the predicted results of the fluctuation of arc voltage under different gas flow rates and working currents. It can be seen that the arc attachment position is basically unchanged with low flow rate of lateral gas, indicating that the aerodynamic force is balanced with the Lorentz force, but as the flow rate of the lateral gas increases, the attachment position moving to the right side, the arc voltage fluctuates in a saw-tooth shape which is often observed in experiments.

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