

Multifluid Magnetohydrodynamic Modeling of Cathode Spot Dynamics

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A cathode spot is a small, highly localized region on the cathode surface in an electrical arc discharge where intense electron emission occurs, characterized by extremely high temperatures and current densities. These spots rapidly move across the cathode, sustaining the arc by continuous electron emission, while causing local melting and evaporation of the cathode material. Magnetic fields influence cathode spot motion and distribution through the Lorentz force, affecting arc stability, spot lifespan, and heat transfer patterns.

This study presents a comprehensive vacuum arc cathode spot model that couples full magnetohydrodynamics (MHD) with free surface dynamics, evaporation processes, and multifluid modeling of ionic and electronic species. By treating ions and electrons as separate interacting fluids, the model captures their distinct dynamics, including charge transport, diffusion, and recombination, which are crucial for accurately describing plasma behavior near the cathode. The effects of magnetic fields on cathode spot behavior will be presented and analyzed.

Key features include simulation of plasma formation, electromagnetic effects, and deformation and evaporation of the cathode surface, processes critical to spot stability and dynamics.

Preliminary results reveal the strong impact of surface evolution, evaporation, and multifluid interactions on the cathode spot's spatial and temporal development, emphasizing the essential role of MHD and detailed plasma chemistry in plasma/surface interactions.

Keywords: Magnetohydrodynamics, Cathode Spot, electric arc, Free Surface Dynamics, Evaporation, Plasma Modeling, Numerical Simulation