MODELING SPOTS ON COPPER AND COPPER-CHROMIUM CATHODES OF VACUUM ARCS*

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A variety of approaches have been developed in the literature towards modelling of cathode spots in vacuum arcs. These include space-resolved descriptions based on numerical solution of 1D or 2D partial differential equations, both stationary and non-stationary. However, the simplest model, namely, a stationary spot on an infinite planar cathode, has been studied mostly in the 0D approximation, where the spot is described only on the integral level. Some authors even presumed that due to thermal runaway steady-state solutions describing a stationary spot on an infinite planar vacuum arc cathode do not exist or are unstable. The lack of a mathematically accurate solution of the most basic problem of the theory of plasma-cathode interaction in vacuum arc discharges is unfortunate and detrimental to the theory.

The aim of this work is to obtain axially symmetric numerical solutions describing spots on cathodes of vacuum arcs and to investigate their stability. Also investigated will be the effect produced on these solutions by a granular structure of the cathode; a question which is of significant interest in connection with contacts of high-power vacuum circuit breakers. To this end, a self-consistent space-resolved numerical model of cathode spots in vacuum arcs is realized on the computational platform COMSOL Multiphysics. Distributions of temperature and electrostatic potential in the cathode body are calculated by means of the time-dependent heat conduction equation and the current continuity equation. Boundary conditions on the cathode surface are generated by means of a model simulating the near-cathode plasma layer.

Modelling results reveal a well-defined spot with a virtually constant temperature of the cathode surface, negligible current outside the spot, and a maximum of the density of energy flux from the plasma being positioned at the spot edge; features familiar from the general theory of stationary cathode arc spots and from modeling of spots on cathodes of high-pressure arcs. A spot on pure copper-cathode is stable if it operates at a fixed current. A spot is unstable due to thermal explosion or exponential decay if it operates at a fixed voltage, however it may be stabilized by a chromium grain.

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