THERMAL INSTABILITY IN NON-UNIFORMITIES ON THE SURFACE OF CATHODES OF VACUUM ARCS*

Mikhail S. Benilov and Mário D. Cunha
Departamento de Física, CCCEE, Universidade da Madeira, Largo do Município, 9000 Funchal, Portugal

Werner Hartmann and Norbert Wenzel
Siemens AG, Corporate Technology, Günther-Scharowsky-Strasse 1, 91058 Erlangen, Germany

Instability stemming from the strong dependence of electron emission current on the local surface temperature plays an important role in current transfer to hot cathodes of arc discharges. In the case of vacuum arcs, this instability may lead to microexplosions on cathode surface even if the surface is planar. This work is concerned with numerical simulation of effect produced by surface non-uniformities, which always exist on cathodes of vacuum arc devices. Simulations have been performed in the framework of a self-consistent space-resolved numerical model of cathode spots in vacuum arcs developed on the basis of the COMSOL Multiphysics software. Spots operating at fixed voltage, which is a situation typical of high-power circuit breakers, have been considered in the following cases: spots on hemispherical protrusions in a Cu cathode, spots on spherical Cr grains embedded in a Cu matrix, and spots on spherical Cu grains embedded in a Cr matrix. It is found that the effect is non-trivial. For example, in the case of hemispherical protrusions of different radii R on a Cu cathode, thermal instability develops faster than in planar cathodes if the radius of the protrusion exceeds 6 μm or is below 5 μm, although the difference is not very significant, up to about the factor of 4. In the intermediate range 5 μm $\lesssim R \lesssim$ 6 μm, the instability develops slower than in planar cathodes; and if the attachment area coincides with the surface of the protrusion, which happens for $R \approx 5.5$ μm, then the instability may even not develop or lead to a stable steady state rather than to thermal explosion. In all the cases, the explosion time is of the order of 1 μs or higher. One can conclude that the development of the thermal instability is affected by effects originating in motion of the molten metal. The conclusion that surface non-uniformities similar in size to steady-state arc attachments can suppress the development of thermal instability and thus prevent thermal explosions, while being theoretically interesting, does not mean that arc attachments to these non-uniformities may exist for a long time, since the non-uniformities will anyway be destroyed by melting. However, this conclusion may be helpful for analysis of results of simulations of temporal evolution of cathode attachments of vacuum arcs with account of motion of the molten metal.

---

* The work at Universidade da Madeira was supported by FCT through the projects PTDC/FIS-PLA/2708/2012 and PEst-OE/MAT/UI0219/2014 and by Siemens AG.