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Crater evolution and droplet generation in vacuum arcs during the cathode spot development

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Abstract: Electrical breakdowns and cathode spot initiation are important phenomena in applications used for components with high voltage assemblies. During the cathode spot formation, dense and hot plasma is produced that generates an intense heat flux towards to the cathode surface. As result the cathode melts. Under the plasma-surface interaction, droplets and craters are formed. The arbitrary geometry of the crater rim and remnants of the surface droplets in the form of tips, stimulate new breakdown processes, changing the character of electrical field distribution and generates hardening processes of the material. This causes a technological challenge. Therefore the dynamics of the cathode heating and cathode phase transition under high pressure spot plasma is an issue for understanding of the processes leading to breakdown under high electric fields for various applications that require the maintaining of such fields.
The present work presents a physical and mathematical model including the heat flux that takes in account the ion kinetic and potential energy, cathode heat conduction, the plasma pressure due to hot ionized and neutral particles, metal melting, convection and liquid flow. The plasma spot characteristics obtained from a previously developed spot theory [1] were used in order to formulation the requested boundary conditions. Specifics of the time-scale that relate to controlling the shape of the craters as well as of it re-solidification were considered.
Using Finite Element modeling we investigate effects controlling the complicate geometry and flow of the liquids as well as elasto-plastic response. Plasma effects are simulated using non-trivial boundary conditions. Initial results regarding crater characteristics and their dependence on plasma spot parameters are presented. Results can help link crater population statistics to that obtained in experiments and help explain plasma parameters in these experiments.

[1] I.I. Beilis, “Cathode Spot Development on a Bulk Cathode in a Vacuum Arc”, IEEE Trans. Plasma Sci., Vol.41, N8, Part II, 2013, (pp. 1979-1986)

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Modelling and Simulations

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