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Vacuum arc erosion behavior in hybrid DC interruption

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Vacuum arc erosion has an important impact on the performance of hybrid DC circuit breaker. An inherent property of the vacuum arc is the generation of microparticles. This paper focused on the dynamics of microparticle and erosion behavior in high-current vacuum arc. The arc was sustained with AC 110 Hz between two butt CuCr alloy contacts with a diameter of 10 mm. An *in situ* microparticle diagnostic system suitable for vacuum arcs was developed.

Aiming at the problem of low signal-to-noise ratio of microparticle images in high-current vacuum arcs, a high-resolution analysis of microparticle images based on Gaussian pyramid interpolation technology and non-sharpening masking method was proposed. On this basis, using the characteristic that the eigenvalues of the Hesse matrix only respond to the spot-like structure, a spot-enhanced filtering function suitable for 2D images is proposed, which can be used to obtain the boundary of microparticles accurately. Finally, the Otsu algorithm was used to complete the reconstruction of the microparticle images. Besides, aiming at the problems existing in microparticle volume statistical algorithm, a metal particle matching strategy based on direction-oriented cross-correlation algorithm was proposed, which reduces the false matching between microparticles.

Based on the diagnostic system, three sources of microparticles were observed and the corresponding motion characteristics were obtained by our method. The influence of current, Cr content, electrode gap and opening speed was investigated in this paper. The results indicate that when the peak current is not greater than 5 kA, the ability of CuCr alloy cathodes to produce microparticles decreases with the increase of Cr content. When the peak current is not less than 6 kA, the CuCr30 cathode has the strongest ability to suppress microparticle production among the three tested materials.

High-voltage trigger equipment and specially designed cathode structure were used to investigate the influence of electrode gap on vacuum arc erosion characteristics quantitatively. The experimental results show that when the electrode gap is 3mm, the cathode microparticle ablation is the most serious due to its highest cathode surface temperature. By contrast, the influence of electrode gap on the cathode erosion characteristics was obtained by using a specially designed anode structure which was used to avoid the interaction between anode spot and cathode surface. The results indicate that the observed cathode microparticles in this study are almost entirely attributable to the interaction between the anode spot and cathode surface.

Besides, the influence of opening speed was investigated within the range of 0.65m/s to 3.42m/s. The results show that when the opening speed is 1.15m/s, the ablation of the cathode is the most serious. When the opening speed is not less than 1.88m/s, the opening speed has little effect in the ablation of the cathode. In addition, the erosion characteristics under the action of external transverse magnetic field were also studied, revealing the effects of magnetic field strength on the erosion amount, as well as the speed and diameter of the ablated microparticles.

The results presented add to the understanding of microparticle behavior in high-current vacuum arcs. They will assist in improving the design of vacuum arc electrodes, particularly by allowing appropriate material selection for specific short-circuit currents and appropriate opening speed for specific breaking condition, with the ultimate goal of minimizing the production of microparticles.

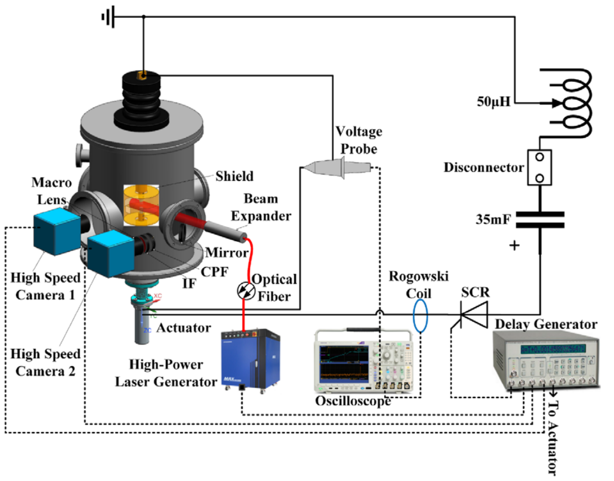

Figure 1. Schematic diagram of the experimental setup used for electrode erosion behavior in vacuum arcs.

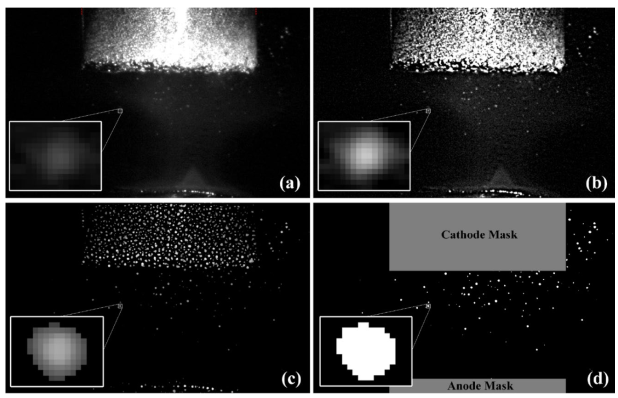

Figure 2. (a) An image of microparticles in a vacuum arc. (b) Sharpened image of (a) obtained by unsharp masking algorithm. (c) Blob enhanced image of (b) obtained by improved blob enhancement filter. (d) Binarized image of image (a).