Modelling current transfer to thermionic cathodes in a wide range of conditions

M. S. Benilov, M. D. Cunha, M. J. Faria

Departamento de Física, Universidade da Madeira, Largo do Município, 9000 Funchal, Portugal

1. Introduction

Different patterns of current transfer to thermionic cathodes and of its stability can occur under conditions of industrial interest. This work is concerned with studying these patterns in a wide range of conditions and with finding out in what conditions each pattern occurs and how a transition between different patterns happens.

2. Results and discussion

The modelling is performed by means of the model of nonlinear surface heating; e.g., review [1] and references therein. Tungsten cathodes of different shapes and with different temperatures of the cooling fluid are treated.

Three scenarios of changes of patterns of steady-state modes of current transfer to a thermionic arc cathode have been found: movement of the point of change of stability along a mode; bifurcation of modes of the same symmetry occurring at a certain combination of control parameters and accompanied by exchange of branches of the modes; junction of modes of the same symmetry which enters the considered range of arc currents from the region of very low currents.

The first scenario is at the origin of the change of stability of the high-temperature branch of the first axially symmetric spot mode which occurs in a transition from a cathode with a flat front surface to a cathode with a hemispherical front surface. The second and third scenarios are provoked by an increase in the curvature of the front surface of the cathode or in the cathode radius, or by a decrease in the cathode height or the cooling temperature, or by a protrusion on the front surface of the cathode. These scenarios result in a transition from the pattern with disconnected and stable diffuse and axially symmetric spot modes to a pattern with only one stable mode (mode 3) in a wide current range, which combines features of spot and diffuse modes at low and, respectively, high currents as can be seen in Fig.1.

A pattern with two distinct modes may be viewed as a manifestation of self-organization, while a pattern with one mode is governed by a non-uniformity of the current-collecting surface of the cathode. All the above-mentioned variations of control parameters contribute to the diffuse mode becoming less uniform along the front surface. Therefore, the above scenarios may be interpreted as a disappearance of self-organization due to an increasing non-uniformity of current-collecting surface.

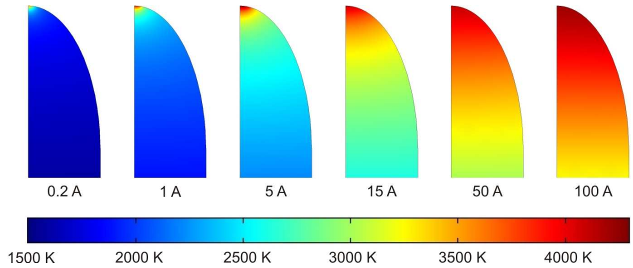

Fig.1 Distributions of the temperature inside a cathode with a spheroidal tip in the mode 3 at different arc currents. W cathode, Ar plasma, 1 bar, cathode radius 1 mm, height of the tip 2 mm, total cathode height 10 mm.

3. Comparison with the experiment

Modelling results provide explanation to some observations made in experiments with low-current arcs typical for high-intensity discharge lamps. In particular, the super spot mode observed in low-current arcs [2] may be explained as mode 3 of the present work attached to an elongated protrusion. There also is a reasonable agreement between the modelling and the experiment [3] on cathodes operating in the diffuse mode at high-current arcs. The modelling correctly describes trends observed in the experiment on spot mode in high-current arcs; however, the range of existence of the spot mode in the experiment exceeds that in the modelling. A further work is required, and this work should involve planning of experiments with account of modelling data.

The conclusions on existence under certain conditions of only one stable mode in a wide current range, which combines features of both spot and diffuse modes, and of a minimum of the dependence of the temperature of the hottest point of the cathode on the arc current, manifested by this mode, may have industrial importance and admit a relatively straightforward experimental verification.

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