Articles used

I. «Dynamics of Gliding Arc Climbing in a Unipolar Jacob's Ladder» by K. I. Almazov et al. 22 January 2020;

II. «Physical study of a gliding arc discharge» by F. Richard et al. 20 November 1995;

III. «Prospects of airflow control by a gliding arc in a static magnetic field» by N Balcon et al. 28 August 2008;

IV. «Numerical Calculations of the Properties of Axially Symmetric Arc Columns» by A.Wells March 1967.

1 Principal equations (I article)

1.1 Hand waving

I would like to write the energy equation: the rate of change of energy per unit volume. To do this, we look at heat exchange with the environment and at movement in an electromagnetic potential field.

In fact $E^2\sigma$ – specific energy density per unit time. We also have some heat exchange with the environment. The heat flux potential can be defined by

$$S = \int_0^T \varkappa \, dT, \tag{1.1}$$

So we characterize it as $\operatorname{div}\operatorname{grad} S = \nabla^2 S$, – specific heat exchange. Then

$$P = \sigma E^2 + \operatorname{div}\operatorname{grad} S.$$

We expect to see something like that.

1.2 According to the article

Taking into consideration only a small part of the arc, we define a set of axes (r, x) in cylindrical coordinates. **The energy equation** for a **steady arc** is

$$\rho U \frac{\partial h}{\partial x} + \rho V \frac{\partial h}{\partial r} = \frac{1}{r}\frac{\partial}{\partial r}\left[r \left(\frac{\mu}{P_r} + \frac{\rho \varepsilon_m}{P_{rt}} \right) \frac{\partial h}{\partial r} \right] + \sigma E^2, \tag{1.2}$$

and **the continuity equation** by

$$\operatorname{div} \boldsymbol{j}_m = \frac{1}{r}\frac{\partial}{\partial r}(r\rho V) + \frac{\partial}{\partial x}(\rho U) = 0, \tag{1.3}$$

where ρ is the density, U the axial velocity, V the radial velocity, h the specific enthalpy, μ the viscosity, ε_m the eddy diffusivity for momentum, P_{t} and P_{rt}

the Prandtl and turbulent Prandtl numbers, respectively, σ the electrical conductivity, and E the voltage gradient.

The heat flux potential can be defined by

$$S_{(T)} = \int_0^T \varkappa_{(T)}\, dT,$$

so that the **molecular diffusion term**

$$\frac{1}{r}\frac{\partial}{\partial r}\left[r\left(\frac{\mu}{P_r}\right)\frac{\partial h}{\partial r}\right] \equiv \nabla^2 S$$

in the energy equation can be replaced.

1.3 Assumptions

To describe the arc, we use a simplified model in which rough assumptions are made. These assumptions were used by Maecker and Frind to describe cylindrical arc behavior.

1. Flow is axially symmetrical.
2. Viscous dissipation and Lorentz forces can be neglected.
3. Radial pressure gradient is negligible compared to the static pressure.
4. Radiation is neglected.
5. Principal transfer of energy is produced by conduction and convection.

We consider two arc regions separately – **the plasma core**, also called plasma string, and **the outer flame** or weak ionized ring.

1.4 The plasma string model

Based on experimental results, although the arc is moving, the plasma channel can be considered to be **in a steady state with a constant radius**. Physical properties along the center line of the plasma string are assumed to be the same at every point on the line. As a result of the longitudinal convection affecting the arc, the form is assumed to be cylindrical.

Let us consider a small part of the plasma string which is assumed to be identical to any other section of the plasma arc.

The emission of light being the same all along the string, we assume

$$\frac{\partial h}{\partial x} = 0. \tag{1.4}$$

Turbulent effects and radial convection can be neglected for heat exchanges

$$V\frac{\partial h}{\partial r} = 0. \tag{1.5}$$

The energy equation is rewritten

$$0 = \frac{1}{r}\frac{\partial}{\partial r}\left[r\left(\frac{\mu}{P_r} + \underbrace{\frac{\rho\varepsilon_m}{P_{rt}}}_{0?}\right)\frac{\partial h}{\partial r}\right] + \sigma E^2, \tag{1.6}$$

rewriting in a different form,

$$\nabla^2 S + \sigma E^2 = 0, \tag{1.7}$$

which corresponds to the well known (авторами статьи) **Elenbaas–Heller equation**.

1.5 The arc core-outer flame transition

At the boundary of the arc core and the outer flame, the temperature profile in the plasma string is assumed to be invariable with a constant conducting radius r_c.

Convection is, therefore, the main cause of plasma string cooling. It constricts the arc as the difference in velocity between arc–core and the surrounding region increases. The constant plasma string radius is evidence of an equivalent constant convection effect expressed in terms of an axially symmetrical convection flow.

The convection term does not appear in the energy balance equation of the plasma string, but is implicitly taken into account in the input value of the electric field and power per unit of length deduced from experiments.

In the conductive inner part of the discharge, the electrical conductivity is given as a linear function of heat flux potential

$$\sigma = \beta(S - S_c), \tag{1.8}$$

where S_C is the heat flux potential for $\sigma = 0$ correspondings to the conduction radius r_c.

The conduction radius is

$$\boldsymbol{r}_c \sim \frac{1}{\sqrt{\beta}E}. \tag{1.9}$$

The power per unit of discharge length w is related to S_0 which corresponds to the axis heat flux potential ($r = 0$), on which the temperature is T_0, according to the following equation:

$$S_0 = \frac{w}{2\pi} + S_c.$$

2 Staged experiment (II articls)

Devices with a gliding arc are classified according to power supply regime as «**bipolar**» and **unipolar**». In the bipolar regime of power supply, sign-alternating sinusoidal voltage is applied to two electrodes of a device.

In this experiment and ours, we work with a Flyback transformer, so that the signal is rectified in the unipolar case.

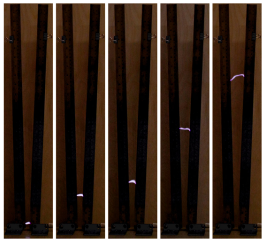

Рис. 1: Experiment for Article II.

It was founded, that it moves with a constant velocity on most of the path. Also, the the dependence of the arc rise speed on the angle between the electrodes was investigated.

3 Staged experiment (III articls)

A slightly more meaningful experiment was set up in the next article, it has yet to be analyzed.