EXPERIMENTAL INVESTIGATION OF A GAS PROPELLANT CONSUMPTION OSCILLATION WHEN SELF-HEATED HOLLOW CATHODE IS STARTING FROM A COLD STATE

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Abstract

As was shown in [1] cathode start was with significant decreasing of researching chamber vacuum. The theoretical foundation of this effect was given in [3], and in [2] the erosion processes that connected with cathode start from cold state. It was shown that start erosion maximum (up to 70 %) could be described with decreasing of gas consumption when cathode starts. That is why experimental investigation of the process is described in this paper.

Facility

Vacuum system consists from stainless still chamber V=1,5 m^3, 2 turbo- molecular pumps with working capacity 2500 l/s each, 2 preevacuation pumps with working capacity 150 l/s each. Systems maximum vacuum was $2\cdot10^5$ Pa. Dynamic vacuum was not more than $3\cdot10^{-4}$ Pa.

For measurements the measurement-computing complex which consists from IBM PC/AT, "KAMAK", quick-operating analog-to-digital converter and connection blocks.

Operation of the complex was 80 ms and this was enough for carry out of experiments.

The self-heated hollow cathode M3.05 type was tested [4].

Methodic of gas consumption oscillation determination

It is obviously that vacuum chamber atoms quantity is defined by working capacity of high-vacuum pump, processes of adsorption-desorption in a chamber, gas consumption and flow in chamber. Equation of atoms quantity changing on a chamber could be written like:

$$\frac{dNc}{dt} = \dot{n}_{ca} + \dot{n}_f + \dot{n}_{ad} - \dot{n}_n \qquad (1)$$

where Nc – quantity of neutral particulars (NP) in a chamber;

$\dot{n}_{ca}$ - NP consumption through the cathodes diaphragm;

$\dot{n}_f$ - NP consumption of flow in chamber;

$\dot{n}_{ad}$ - NP consumption of adsorption-desorption;

$\dot{n}_n$ - NP consumption through the vacuum pump.

NP consumption through the cathodes diaphragm could be described by:

$$\dot{m}_{ca} = \dot{n}_{ca} \cdot m_a \qquad (2)$$

where m_a - mass of atom.

$\dot{m}_{ca}$ - gas consumption (Xe in our case).

NP consumption trough the vacuum pump could be connected with working capacity of vacuum system.

$$\dot{V}_n = \dot{m}_n \frac{R}{n_c \cdot k} \qquad (3)$$

where $\dot{V}_n$ - vacuum pump working capacity, l/s ;

$\dot{m}_n$ - vacuum pump working capacity, kg/s;

$\dot{n}_c$. NP concentration in vacuum chamber.

If change the $\dot{m}_n = \dot{n}_n \cdot m_a$ we will get rhe equation for NP consumption through a vacuum pump:

$$\dot{n}_n = \frac{n_c \cdot k}{m_a \cdot R} \cdot \dot{V}_n \qquad (4)$$

When volume of the chamber is known, NP quantity in it we can calculate like:

$$N_c = n \cdot V_v \qquad (5)$$

$$\frac{dn_c}{dt} = V_v \cdot \frac{dn}{dt} \qquad (6)$$

V_v - is the vacuum chamber volume;

In a first approximation we suppose sorption-desorption and flow in a chamber processes to be disregarded. So we could get from (1), (2), (4), (6) for gas consumption through the cathodes diaphragm:

$$\frac{dn}{dt} V_v = \frac{\dot{m}_{ca}}{\dot{m}_a} - n \cdot \frac{k \cdot \dot{V}_n}{\dot{m}_a \cdot R} \qquad (7)$$

or

$$\dot{m} = \dot{m}_a \cdot V_v \frac{dn}{dt} + n \cdot \frac{k \cdot \dot{V}_n}{R} \qquad (8)$$

Taking in to account linear characteristic of device scale in one measurement range limit we can write:

$$n = B \cdot u \qquad (9)$$

B – proportional coefficient;
u – device analog signal.
From (8) and (9) we have got:

$$\dot{m}_{ca} = \dot{m}_a \cdot V_v \cdot B \cdot \frac{du}{dt} + B \cdot u \cdot \frac{k \cdot \dot{V}_n}{R} \qquad (10)$$

For start gas consumption:

$$\dot{m}_{ca}^0 = B \cdot u_0 \cdot \frac{k \cdot \dot{V}_n}{R} \qquad (11)$$

From division of (10) and (11) we have expression for relative gas consumption determination:

$$\frac{\dot{m}_{ca}}{\dot{m}_{ca}^0} = \frac{\dot{m}_a \cdot R \cdot V_v}{k \cdot V_n} \cdot \frac{du/dt}{u_0} + \frac{u}{u_0} \qquad (12)$$

Experiments

The variant of experiment is shown in fig. 1. It is obvious that minimum of gas consumption was reached at about 11 sek. and reached 22,5 % from nominal value.

Reestablishment of the gas consumption up to 0,95 from nominal was in 30 sek.

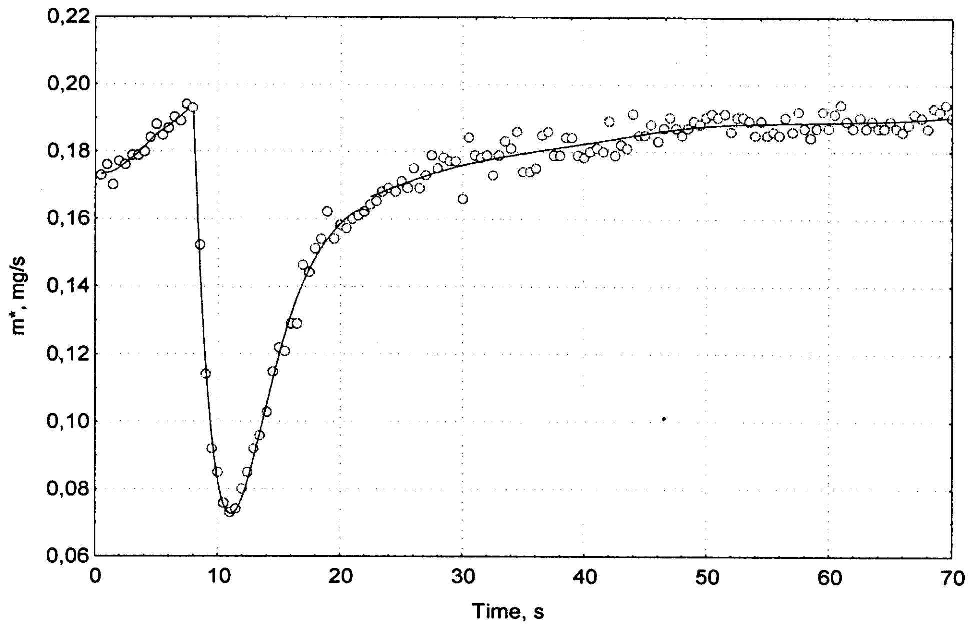

Fig. 1. Gas consumption oscillation in self-heated hollow cathode start.

Next research step was studying of gas consumption start value influence to time of gas consumption reestablishment. Main dependencies of plasma forming gas consumption from time with different start electric current are shown in in fig.2. Any significant influence absence is obvious.

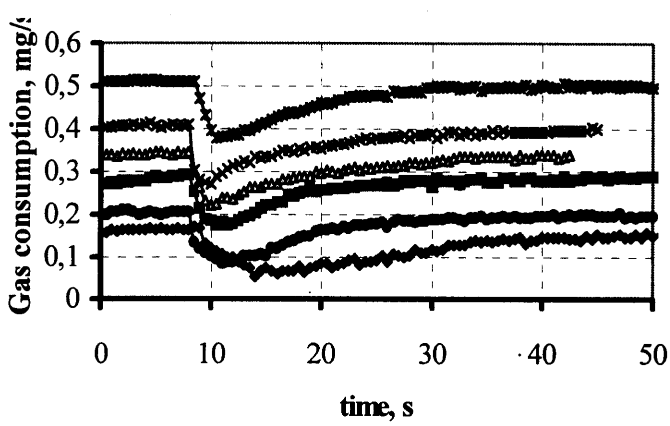

Fig. 2. Family of starts gas consumption oscillation.

Dependencies of cathode gas consumption reestablishment in fig. 3. from volume of hydro-resistance in tract of gas propellant supply. Decreasing of hydro-resistance allows increasing of time and vice-versa. Asymptotically behavior of the characteristic could be explained by supersonic flow in throttle. [2].

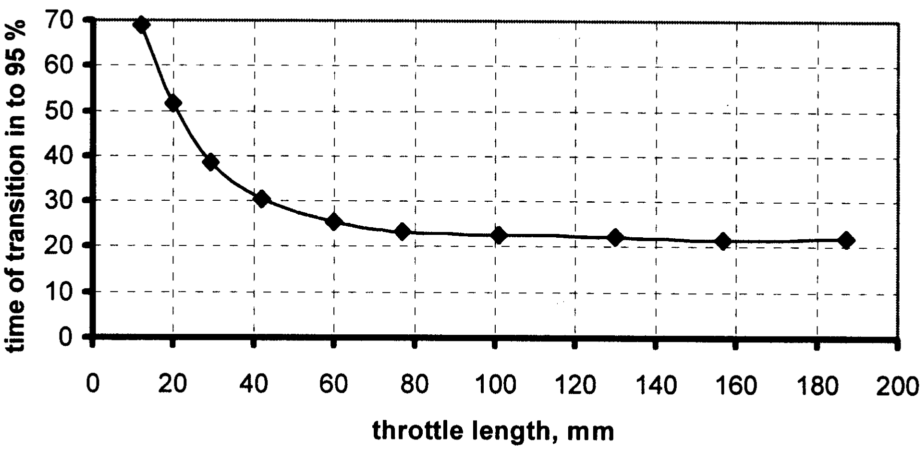

Fig. 3 Dependencies of cathode gas consumption reestablishment.

Conclusions

In the paper some gas-dynamic aspects of self-heated hollow cathode start were experimental researched.

1. Start value of a gas consumption not has significant influence to time of start.
2. Gas consumption was reached at about 11 sek. and reached 22,5 % from nominal value.
3. Reestablishment of the gas consumption up to 0,95 from nominal was in 30 sek.
4. Dependence of a cathode gas consumption reestablishment from volume of hydro-resistance has asymptotically behavior.

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