The Main Regularity of an Ignition in a SPT

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Abstract

The experimentally - analytical investigation is carried out with the purpose of resource increasing of selfheated hollow cathode - neutralizer (SHC) SPT and increase the reliability of SPT start.

The interrelation of voltage ignition value (U_{ig}), mass flow rate Xe ($m^{\bullet}$), distribution of value of magnetic induction (B) in the channel of experimental SPT structure M-70 type was investigated. For measurement of start-up fast processes the recording equipment similar to [1] was used, with a discretization of a signal 0.1 mks.

Is established, that: 1) at value B close 0, $U_{ig} < \varphi_i$ and (where φ_i - ionization energy of atom Xe); 2) there is a range of values B and $m^{\cdot\bullet}$, where U_{ig} ~1/B; 3) "voltage fall" between an anode and SHC, and also horse racings of a digit current is explained, found experimentally, at start SPT; 4) two versions of discharge development for two ranges of value B are possible.

Introduction

The application of SPT in correction and orientation spacecraft propulsion system puts forward the high requirements to dynamic characteristic of SPT. In case of using selfheated hollow cathode it is necessary to supply reliable SPT start. For this purpose the understanding of processes in a channel SPT during start-up is necessary

Experimental investigate of relation U_{ig} from value B and $m^{\bullet}$ by activity SHC in a mode with a high emissive capacity was made. The volt-ampere characteristic of development of discharge is gauged and some regularity are established. The mathematical model of process of an ignition is developed to explain observed effects. Using a technique like in [2], the calculations are a made more precisely.

1. Experimental research of the ignition process.

Experimental relation U_{ig} (B, $m^{\bullet}$) and also volt-ampere characteristic of discharge ignition (DI) in time are shown in a fig. 1,2. The analysis of these data allows to make the following conclusions: 1) (till a fig. 1) In condition when maximum value B < 1mTl then $U_{ig}<\varphi_i$ (where φ_i - the potential of ionization Xe). This effect is realized by electrons at the temperature of $T_e \approx 1$eV (temperature of electrons emitted from SHC) with energy more then φ_i ; 2) Exist a range of $m^{\cdot\bullet}$, where increasing of B lrads to a decrease U_{ig} ; 3) the voltage fall between the cathode and the anode (till a fig. 2) descends earlier, than there is a conforming increase of a discharge current (in a circuit SHC). This consequent of avalanche let of a negative charge of electrons in a circuit of an anode (from area of ionization for an anode apart of Larmor radius). The reset of this charge descends through SHC. On the basis of these submissions, following to a technique [2], the mathematical model of process DI in SPT was made.

2. Mathematical model of an ignition.

Under condition of SHC activity in a mode of high emission, the electronic current between the cathode and anode is limited by volume charge of electrons. Let's consider as an ignition conditioning, when the limitations on a current magnitude between an anode and cathode are removed.

We suppose, that distribution B(x) and concentration n(x) along a channel is described by formulas :

$$B(x) = B_m * \exp(-x * b / l)$$

$$n(x) = n_m * \exp(-(x - l) * N / l)$$

Where B_m and n_m - maximum ratings, l=0.03 m - stand of an anode, b=2, N=0.5. Following to a technique [2] we receive an electrical potential distributions $\varphi(x)$ and electrical field E(x) and density of an electronic current $j_{e0}(x)$:

$$E(x) = A_3 * U * (1 - \exp(-x * c / 3)),$$

$$\varphi(x) = A_3 * U * (x + 3 / c * (\exp(-x * c / 3) - 1)),$$

$$j_{e0} = \frac{(U^3 * n_m \sigma_{cm} * A_3 * \varepsilon_0 * 2 * m)}{(B_m^3 * \exp(N) * 3 * q)} \qquad (1),$$

Where: $A_3 = (l + 3 / l * (\exp(-l * c / 3) - 1))^{-1}$, $c = (3 * b + N) / l$, $\sigma_{cт}$ =1.2*e^{-19} m^2 cross-section of an elastic electron-atom collision Xe, q and m - charge and mass of electron, U - voltage between the cathode and anode, ε_0=8.85*10^{-12} Kl/m constant.

Supposing, that the initial velocity of ions Vi is equivalent to thermal speed of atoms Xe, following [2], we receive the condition of an ignition in the form of:

$$\ln(K) = \frac{5 * b * m * A_3 * U}{l * B_m^2} *$$

$$* (\exp(2 * b) * K^{-2/5} - \exp(b) * K^{-1/5}) \qquad (2),$$

Where: $$K = \frac{(l - 3/c)^6 * B_m^8}{U_з^5 * F * \exp(5 * b)},$$

$$F = \frac{n_m^2 * \sigma_{cm} * c * m^4 * 2 * l}{\exp(N) * q^4 * V_i} * \beta_{uXe},$$ $\beta_{иXe}$- speed of Xe atoms ionization. The calculation by (2) is shown on fig. 3. The deviation of calculation from experimental data for range B from 0 up to 12 mTl - outcome that becomes possible ionization in dense flow of atoms taking off from an anode, whereas the ionization in all volume of near anode area was esteemed. Let's consider ionization in dense flow of atoms.

We suppose, that the atom concentration distribution in dense flow is satisfactorily described by relation

$$n(x) = n_m * 1.1 * 10e^3 * \exp\left(\frac{x - l_c}{l_c} * N\right),$$

Where: length of considered area of a spray l_c=4.5 mm, N=7.

Density of an electron current j_{e0} (x) =const along channel is determined by the previous expression. The analysis similar to above, leads to the following relation for the ignition condition:

$$l_c = \frac{1}{\left(\frac{U_з^3}{B_m^4} * 2 * n_m^2 * D - \frac{b}{l_c * \exp(0.5)}\right) * \exp(0.5)}$$

(3),

where: b=0.5,

$$D = \frac{c * \exp(N) * \sigma_{cm} * \beta_{uXe}}{l_c^2 * V_i * N * (5.6 * l_c - 3/c)^3} * const,$$

$$c = (3 * b + N)/l_c$$

The calculation by (3) is shown in a fig. 3. At tendency of value B to zero , the minimum voltage U_{ig} (≈1 V) should supply a injection of ions from a channel. The criterion of transition from a mode of ionization in dense flow of atoms to a volume ionization in niaranode area of a channel is the ratio of a Debye radius of shielding and expansion l_c of considered area. Owes will be executed disparity

$$\frac{r_D}{l_c} \geq 1 \qquad (4)$$

I.e. bearing in limits l_c ions should compensat a space charge of electrons and so to supply increasing density of an electron current in limits l_c, in the initial moment. Determining r_D with the count of the obtained ratio:

$$r_D = \frac{B_m^{2.5}}{U_з^{2.5} * n} * const .$$

The border calculated by (4), where the constant value is determined by experiment data, is shown in a fig. 3.

Conclusions

The results of researches are the follows:

1) The processes resulting to the ignition, start near to the anode, apart of Larmor radius of an electron. This explain the subsequent voltage fall between an anode and cathode;
2) At value B about 0 the ignition is possible at $U_{ig} < \varphi_i$;
3) U_{ig} proportional to the B, however, exist the range B and $m^{\bullet}$, where U_{ig} proportional 1/B;
4)For two ranges of value B exist two different spatial domains (for an anode), where Xe are ionized intensive at an ignition.

References

1. S.A.Lobov, A.V.Loyan Physic-mathematics model of a self-heated hollow cathode electric discharge evolution/ IEPC-99-127, p.714
2. Kim V. The analysis of ignition laws of the basic discharge in SPT. / Plasma Sources and Accelerators. Ukraine. Kharkov:KhAi, v.3, 1978, p.22

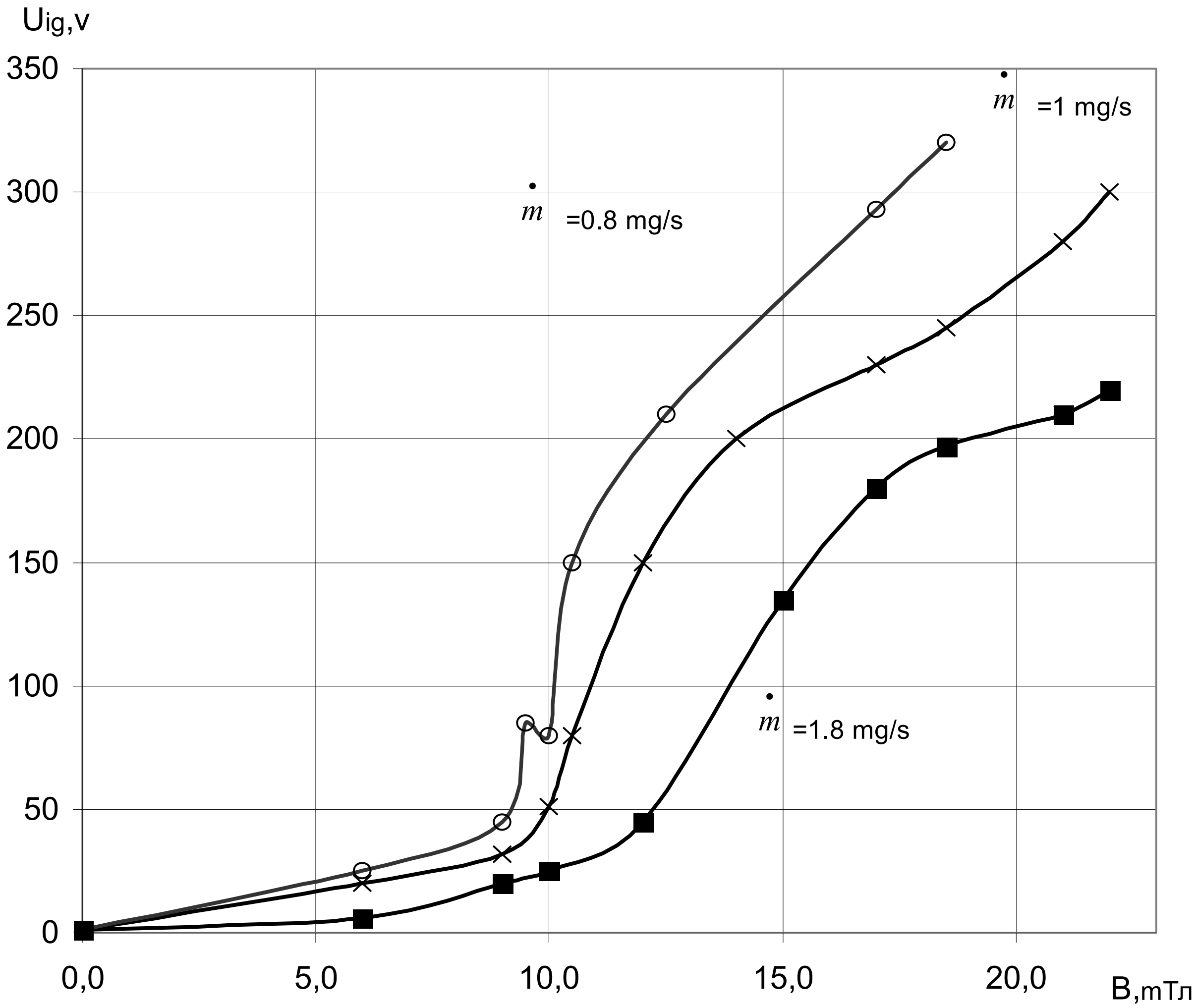

Fig.1 The experimental dependence of ignition voltage from magnetic induction and mass flow rate (at the cut of channel).

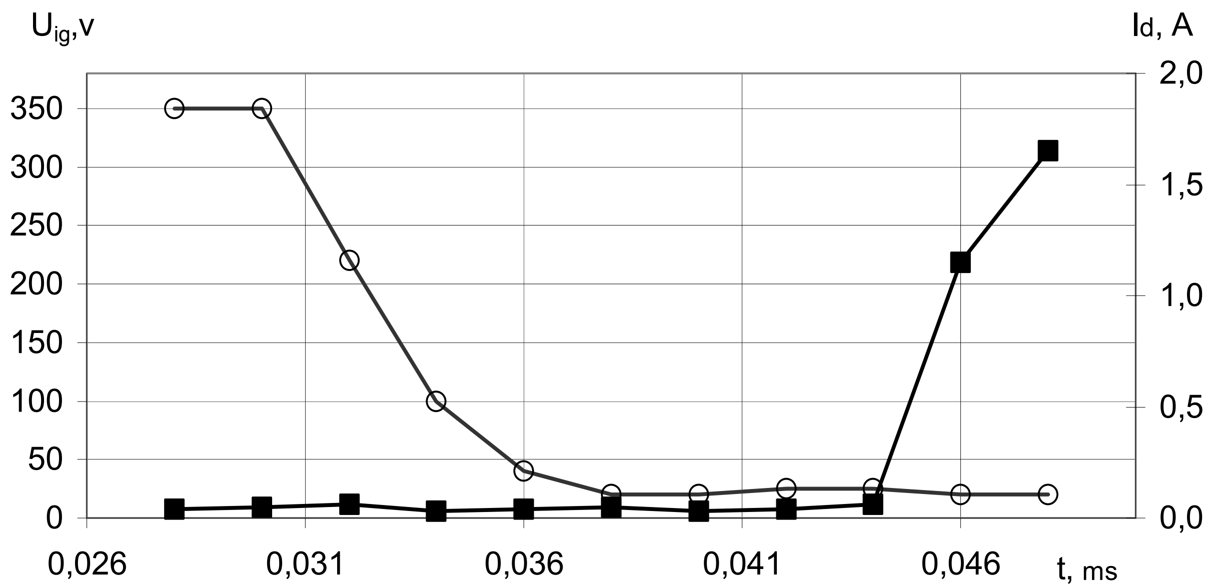

Fig.2 volt-ampere characteristic discharge ignition (DI) in time for B=15 mTl (at the cut of the channel) and m=2 mg/s.

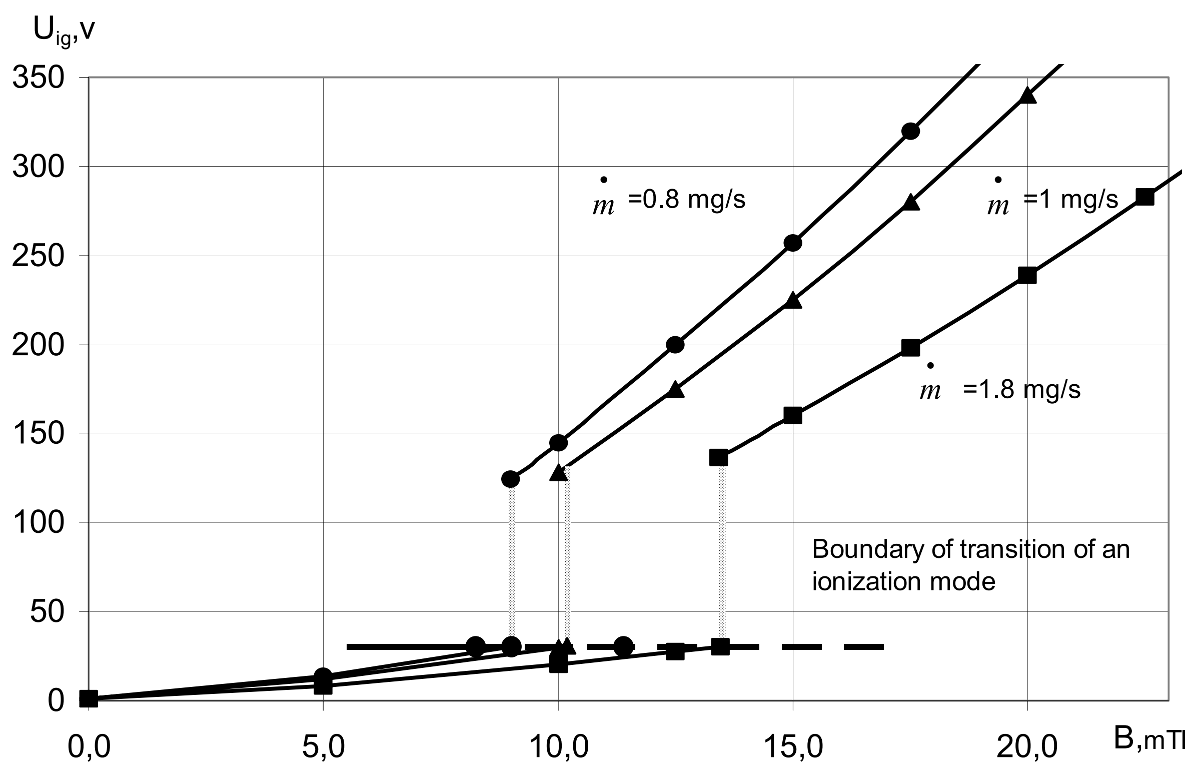

Fig.3 The calculated dependence of ignition voltage from magnetic induction and mass flow rate (at the cut of channel).