THE INFLUENCE OF STATIONARY PLASMA THRUSTER FACTORS ON FUNCTIONAL PARAMETERS OF NEUTRALIZER CATHODE

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An experimental working off the electric propulsion thrusters (EPT) units including the determination of life-time descriptions is doing with the use of simplified discharge devices. EPT ion beam are simulated by metallic anode.

Appropriation of such attempt is adjusted by simplicity and lower cost of trials, as well as by possibility of independent variation of regime parameters of cathode in wide range of values. Cathode descriptions, which are obtained in diode scheme of trials, are directly used during the decision of question on usability of cathode in EPT. Nobody can suggest that such attempt now is completely reasonable and adjusted by experience. Cathode life-time trials in EPT have done for limited number of cathode design, single examples and, as a rule, for single work regime. There are no analogues results on diode scheme for cathodes, which are checked in EPT, and vice versa.

The cathode work like SPT cathode unit is connected with influence of additional thruster factors because of main thruster work processes and difference in electrode system geometry. We can call the next most evident difference between the cathode work in EPT and in diode scheme.

1. Discharge gap geometry.
2. The condition of cathode cooling.
3. The change of neutral atoms density in cathode area because of the gas flow through the EPT.
4. The presence of magnetic field in discharge area.
5. The presence of high energy ions.
6. Modulations of plasma potential and density because of oscillations in ionization and acceleration zones in EPT.

Tests organization

The researches were directed on the determination of the complex action of thruster factors on the cathode unit descriptions. High emission gas discharge hollow cathode (HEGHC) of KhAI-2 type was used in experiments. BP 5/BP 20 thermo-couples were used for temperature measuring in active zone.

Cathode unit, thruster, plate and ring anodes, thermo-throttle, cathode hollow pressure sensor, electric probes were mounted on the experimental unit, which provides the change of mutual positions of discharge device elements and motion of probes in axial and radial directions comparatively the cathodes. Cathode and discharge circuit parameters researches were made in following versions as for compositions and elements mutual positions:

1. SPT M-100 with lateral cathode position.
2. SPT M-100 with central cathode position.
3. SPT M-50 with lateral cathode position.
4. Cathode unit with plate anode (Mo).
5. Cathode unit with ring anode.
6. SPT M-100 with lateral KhAI-2 cathode position without carter and heat screens unit.

Researches were occupying the next parameters area:

1. 1..6 A of discharge current.
2. 0.1…1 mg/s of mass flow through the cathode.
3. 1…5 mg/s of mass flow through the EPT anode.

HEGHC autonomous work with plate and ring anodes

To select the influence of each similar to "thruster" factors on cathode descriptions the trials were made for cathodes in diode discharge devices.

While cathode operations with plate molybdenum anode the Volt-Ampere descriptions (VAD) and cathode temperature dependence on the current were measured for cathode mass flow 0.3 mg/s and 0.6 mg/s and for cathode-anode distances 25 mm, 34 mm, 40 mm (fig. 1, 2). The temperature dependence on current is practically constant during the considerable change of discharge voltage in current range 1..2 A (fig. 2). Discharge gap more similar to central cathode position in SPT simulation by ring anode had given almost the same result – discharge voltage change with the constant temperature-current dependence with the fixed mass flow (fig 3, 4).

The xenon supply during the work with plate and ring anodes were done through the additional pipe. So the influence of anode mass flow influence on the cathode descriptions were simulated.

Mass flow into discharge area provides the discharge voltage decrease, especially for currents of 1…3 A (fig. 3). Relative voltage decrease is more for the work with ring anode. For plate anode the voltage is sufficiently lower for distances of 40mm and 34 mm between the cathode and anode. Cathode trials together with SPT M-50 had shown that VAD of discharge on SPT anode (without magnetic field) qualitatively is in accordance to VAD for the work on plate and ring anodes, and SPT anode mass flow acts on the discharge equally to mass flow through the additional pipe for the work with plate and ring anodes. The temperature dependence on discharge current and on cathode mass flow was constant also in this mode.

For selection of SPT magnetic field influence on cathode area the plate anode was situated on the distance of 35…40 mm together with SPT M-50. SPT solenoid switching-on did not practically result into discharge descriptions. Thruster magnetic system directly does not change cathode area descriptions for cathode positions, which are typical for SPT.

We can conclude from trials results with plate, ring and SPT anodes that it is not practically reasonable to simulate geometry and gas distribution in discharge area. Stationary cathode work on thruster anode is in enough accordance to it’s work on the plate anode. This conclusion as for SPT M-100 work was used further for simplifying of comparative trials and permitted to go from the comparison of cathode work in diode and in thruster schemes to comparison of cathode work on thruster anode with and without magnetic field. These regimes further are named like “diode” and “thruster” ones.

HEGHC work with SPT M-100 while lateral and central positions

The results of cathode temperature regime research during the work in SPT M-100 show that the change from lateral to central cathode position result into temperature regime change. This change can be described like some temperature smoothing via cathode surface. Temperature maximum value here is not sufficiently changed.

For the constant mutual position of the cathode and thruster the change from “thruster” regime to “diode” one and back not result into temperature change with the same current values, however the voltage in discharge gap is changed almost in order. The absence of sufficient difference in cathode work in “anode” and “thruster” regimes is adjusted by the result of cathode hollow pressure measurement.

Thus as a result of emission unit temperature measurement, cathode hollow pressure measurement one can conclude that the change in external discharge column with constant discharge current and mass flow do not practically bring to processes change inside cathode hollow.

Probe measurements in cathode area

Probe measurements were done in cathode area during the work with SPT M-70 and SPT M-100 with lateral cathode position. As a result of these measurement one can outline the sufficient re-distribution of plasma parameters on the 1..10 mm distance from cathode unit while change from “diode” regime to “thruster” one.

The series of probe measurements were done directly near the cathode orifice plate to determine the character of plasma parameters change while the coming from “diode” to “thruster” regime. The emission unit KhAI-2 without carter, heat screens and heater unit was used. The measurement here were done on the distance of 1.5…6 mm from the cathode orifice plate. The most sufficient results for electron density and temperature are show on fig. 5, 6.

It is possible to outline after probe measurements that the change character while coming from “diode” to “thruster” regime is different in different zones of cathode area. “Thruster” factors action is larger on the distance of 3…6 mm from the cathode

If the mass flow decrease this area comes closely to cathode. As for the nature of description one can note that electron density on the distance of 1.5…3 mm from the cathode while coming to "thruster" regime with mass flow more than 0.5 mg/s practically does not change. Electron density on the distance of 3…10 mm from the cathode decrease comparatively with "diode" regime, which can be explained by influence of thruster electric field on this zone and by development of ionization in the plasma column between the cathode and the thruster. Electron temperature and plasma potential decrease, which is found by probe measurement, adjust this explanation.

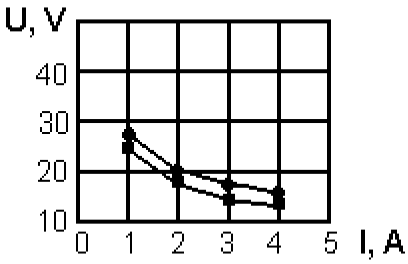
Thus we can consider the work conditions of cathode orifice plate like sufficiently different while the cathode operation in thruster even in the case of independence of the processes inside the hollow on the plasma distribution in external column.

Conclusion

One can conclude after these researches results that the parameters, which determine the cathode life-time, – emitter temperature, hollow pressure – are changed insufficiently in "thruster" regime comparatively with "diode" regime inside diode devices, which are usually used while the trials and experimental tuning of EPT cathodes.

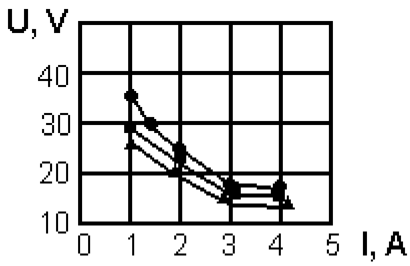
It is difficult to make the numerical estimations using the present results. Qualitatively one must note the change of temperature regime while coming from lateral cathode position to central one as well as the plasma parameters change in the cathode area while coming from "diode" to "thruster" regime. Sufficient errors in probe measurement do not permit to use these results for ultimate conclusion about cathode orifice plate area work conditions, and moreover – for numerical estimations.

It is necessary to do the complex trials with the measurements of cathode temperature regime, hollow pressure, plasma parameters inside hollow and external column, erosion description by spectral and weight methods – for obtaining the ultimate conclusions as for cathode operation conditions change in thruster comparatively with the diode schemes conditions.



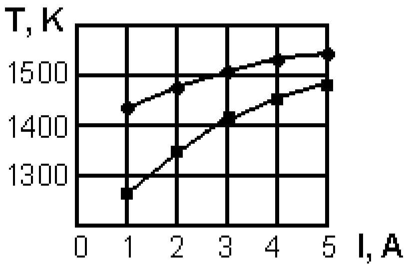
● - $\dot{m}_c$ =0.3 mg/s; ■ - $\dot{m}_c$ =0.6 mg/s;
$l_{c\text{-}a}$ = 25 mm.

Fig. 1. Volt-Ampere description with plate anode.



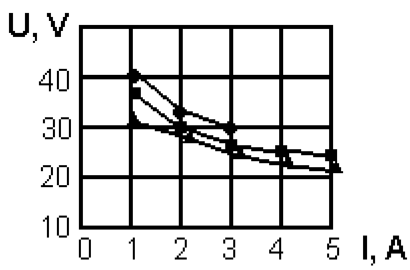
● - $l_{c\text{-}a}$ =40 mm; ■ - $l_{c\text{-}a}$ =34 mm; ▲ - $l_{c\text{-}a}$ =40 mm;
$\dot{m}_c$ =0.3 mg/s.

Fig. 2. Volt-Ampere description with plate anode.



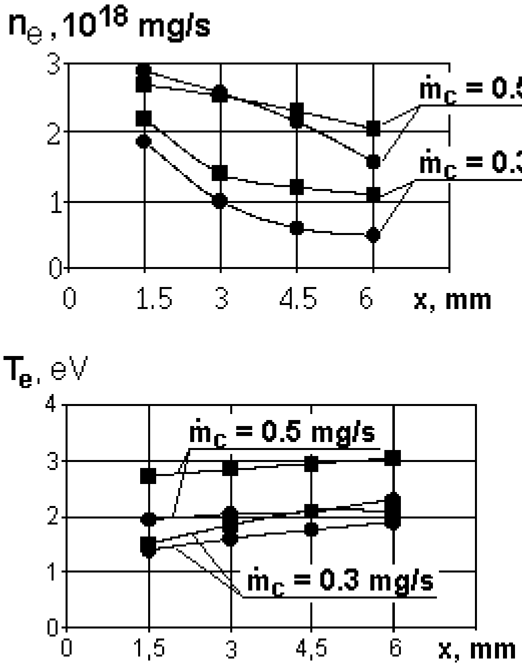
● - $\dot{m}_c$ =0.3 mg/s; ■ - $\dot{m}_c$ =0.6 mg/s;

Fig. 3. Cathode temperature dependence on the current.



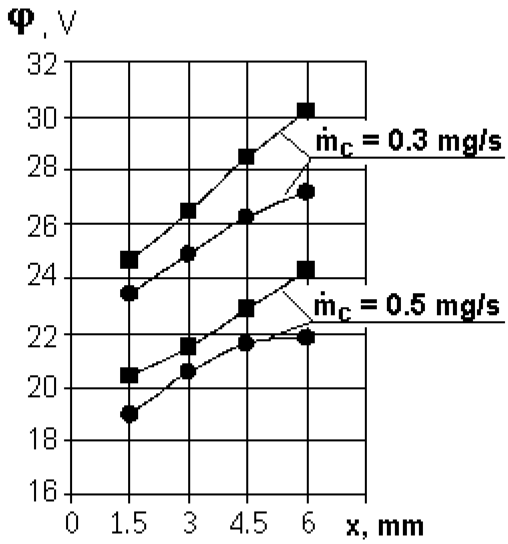
● - $\dot{m}_{add}$ =0; ■ - $\dot{m}_{add}$ =0.85 mg/s;
▲ - $\dot{m}_{add}$ =1.2 mg/s
$\dot{m}_c$ =0.33 mg/s; r_a=25 mm

Fig. 4. Volt-Ampere description with ring anode and mass flow through additional pipe.



■ - “diode” regime, U=34 V, I=3 A;
● - “thruster” regime, U=250V, I=3 A, $\dot{m}_a$ =2 mg/s.

Fig. 5. Electron density and temperature distribution.



■ - “diode” regime, U=34 V, I=3 A;
● - “thruster” regime, U=250V, I=3 A, $\dot{m}_a$ =2 mg/s.

Fig. 6. Plasma potential distribution.