Two-Modes Operation of SPT of Second Generation

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A. I. Bugrova*, A.V.Desyatskov†, V.K.Kharchevnikov‡ and A.S.Lipatov§,
Moscow Institute of Radio-engineering, Electronics and Automatics, Moscow, Russia

and

S.Zurbach**
Snecma, Safran Group, Vernon, France

Abstract: In this paper different operation modes on discharge voltage and Xe flow rate for SPT MAG are studied. On the basis of integral VAC measurements conclusion can be done that there are two main modes of SPT MAG operation: mode with high specific pulse *I* and mode with high thrust *F*.

Nomenclature

U_d = discharge voltage
I_d = discharge current
$\dot{m}_a$ = anode mass flow rate
$\dot{m}_c$ = cathode mass flow rate
F = thrust generated by the source
I = specific pulse
η = source efficiency

Development and research of two stage thruster and it's modifications were carried out for characteristic improvement of existing classic SPT and also modern SPT like ATON.

The main advantage of two stage SPT MAG is that on the entrance into the second acceleration stage propellant is already fully ionized. Ions on the entrance of acceleration channel have low energy, so ion flow has little divergence angle. It gives a possibility to get practically mono energy ion flow in acceleration channel. Ion flow is focused, moved away form channel walls to prevent ion ruin.

The new two stage source SPT MAG has several distinctive features:

1. The possibility of using of different workings substances with high efficiency:

a) More cheap (Kr, Ar, N2) and so on in comparison with commonly used Xe;

b) Being in atmospheres of planets CO_2, CH_4, NH_3;

c) Vapors of metals (from light – Na, Mg, K, up to heavy – Hg, Pb, Br).

* Professor, Sub-faculty of Physics, bugrova@mirea.ru.
† Senior Researcher, Sub-faculty of Physics, bugrova@mirea.ru.
‡ Associate Professor, Sub-faculty of Physics, bugrova@mirea.ru.
§ Associate Professor, Sub-faculty of Physics, bugrova@mirea.ru.
** R&D Engineer, Space Engines Division, spephan.zurbach @snecma.fr

2. Reduced half-angle of flow divergence down to $\pm(8\div10)^0$.
3. Reduced noise level inside the working field of the channel.
4. High efficiency due to decrease of through electron current and the decrease of part of neutrals, ionized in the area of acceleration.
5. Increased life time due to the decrease of intensities of ions and electrons (anomalous) erosion.
6. Expanded working range in the mass flow rate and specific impulse.

These problems can be solved if the working substance ionization is full in the first stage and ions energy may be very little. So there is a possibility to get practically full propellant ionization and to avoid neutrals flow to acceleration channel. Ion flow on the acceleration channel entrance must be well formed and pushed off the channel walls. In case of bad focused ion beam or neutrals ionization in acceleration channel near wall conductivity increases due to excess or lack of electrons. So oscillation level increases in the channel.

One can see SPT MAG scheme in Fig.1.

Integral characteristics SPT MAG were studied for source with external dielectric channel diameter 113 mm with operating power up to 3000 W.

Calculated magnetic field geometry and magnetic coils 1-5 current density are shown in Fig.2.

There have been measured discharge VAC, the thrust generated by the source and using these values the specific pulse and source efficiency have been determined.

In the experiments the xenon mass flow rate through the anode $\dot{m}_a$ has been varied in the band (3,0-9,0)mg/s, the discharge voltage has been varied from the 300V up to 900V. The studied interval of the voltages U=(300÷900)V has corresponded to the range of the input powers W=(900÷3000)W. The xenon mass flow rate through the cathode has been kept constant and equal to $\dot{m}_c = 0{,}4 mg/s$.

The results of the measurements of the integral characteristics of the source SPT MAG are represented in the figs. 3-6.

The discharge volt-ampere characteristics of the source for the propellant mass flow rate through the anode ($\dot{m}_a$=3,0mg/s÷9,0mg/s) are represented on the fig.3. The magnetic field in every working point has been set close to the minimum of the discharge current value I_d and by the minimum of the discharge current oscillations. The topogram of the magnetic field strength has been remained practically the same throughout the total studied band of the mass flow rates and voltages. The discharge VACs have been vertical for the total the studied interval of $\dot{m}_a$ values, that characterized the high degree of the propellant ionization.

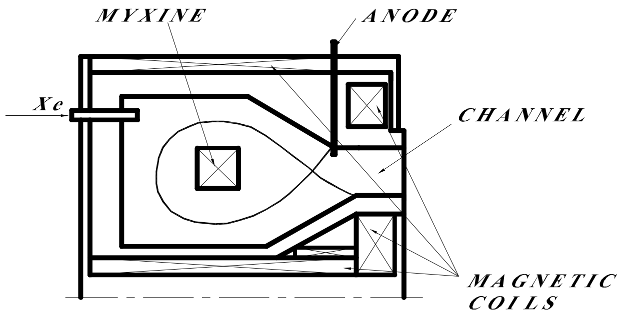

Figure 1. SPT MAG scheme.

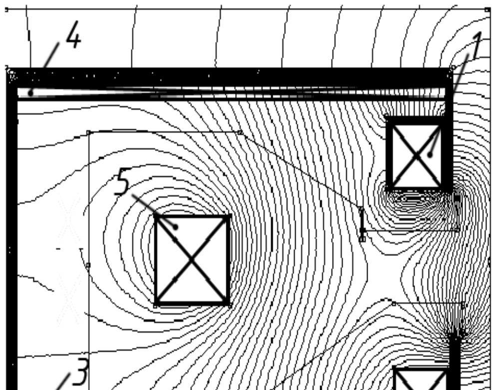

Figure 2. . Configuration of magnetic force lines in SPT MAG.
J1 = 1,5 10^6 A/M^2, J2 = 2,5 10^6 A/M^2,
J3 = 1,6 10^6 A/M^2, J4 = 1,6 10^6 A/M^2,
J5 = -3,5 10^6 A/M^2.

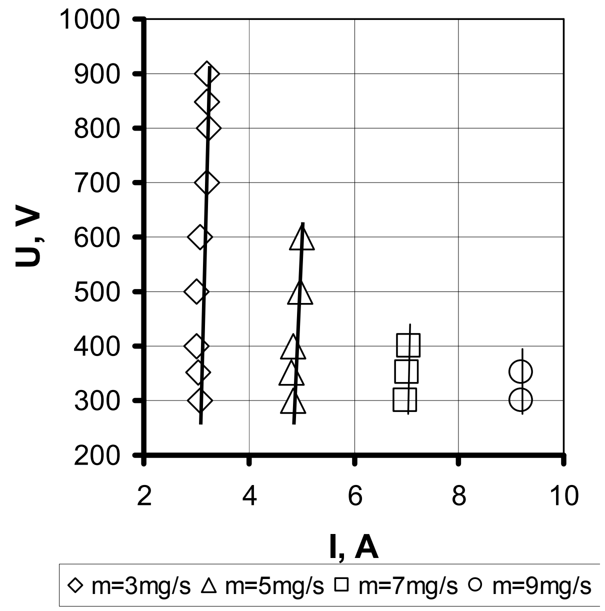

Figure 3. AC of discharge of source SPT MAG (Xe) under different mass flow rates.

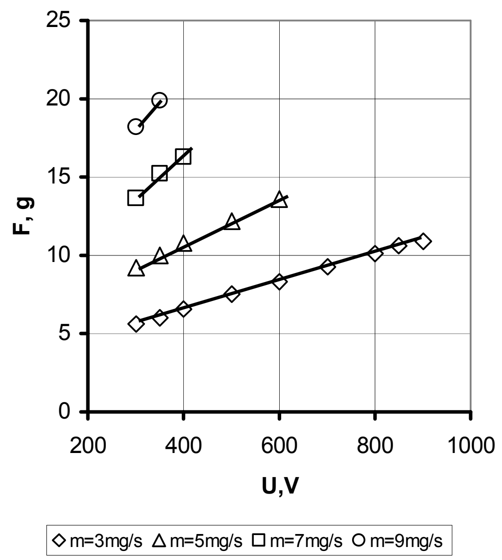

Figure 4. Thrust of source SPT MAG (Xe) under different mass flow rates

The discharge current oscillations level is very low, the value $\tilde{I}_d / I_d$ is in the band (1÷4)% except the mode $\dot{m}_a$=9,0mg/s, U=300V ($\tilde{I}_d / I_d$=9%). Throughout the total xenon mass flow rates band $\dot{m}_a$=3,0mg/s÷9,0mg/s and discharge voltage band U = (300÷900)V the channel insulators overheating has not observed.

The plots of the force, produced by the source, versus discharge voltage under the different mass flow rates are represented in the fig.4. It is seen from the figure, that the force value increases linearly with increase of the mass flow rate and the discharge voltage. The maximal value of the force reaches the value F=19,9g under the mode of the source operation: $\dot{m}_a$=9,0mg/s and U=350V (Fig.4).

The specific pulse behaves itself in full accordance with the change of the force (Fig.5).. The value of the specific pulse grows linearly with the voltage in the examined band of the discharge voltage and propellant mass flow rates. The maximal value of the specific pulse is reached at discharge voltage U = 900 V, anode mass flow rate $\dot{m}_a$=3,0mg/s and is P = 3650s.

The plots of the anode efficiency of the source versus discharge voltage under the different mass flow rates are presented in the fig.6. It is seen from the figure, that the source efficiency grows linearly with the voltage for all values of $\dot{m}_a$ and throughout the total voltage band U = (300÷900)V. The efficiency values reaches the magnitudes η=(66-67)%.

On the basis of integral characteristics research of two stage stationary plasma source SPT MAG conclusion may be done that there are two main modes of its operation:

- mode F with high thrust, existing under maximal propellant mass flow rates(7 – 9 mg/s) and discharge voltages U=(300 – 400)V values, for example, maximal thrust value F=19.9 g is reached at U=350 V and Xe mass flow rate $\dot{m}_a$=9 mg/s;

- mode I with high specific pulse, existing under minimal propellant mass flow rates $\dot{m}_a$ = (3 – 5) mg/s and high discharge voltages U=(600 – 900) V values, for example, the mode with maximum specific pulse I=3650 s realized at U=900 V and Xe mass flow rate $\dot{m}_a$=3 mg/s.

It is necessary to note, that, in contrast to one stage sources, SPT MAG in both modes (F and I) works with efficiency close to maximum one (η = 66-67 %).

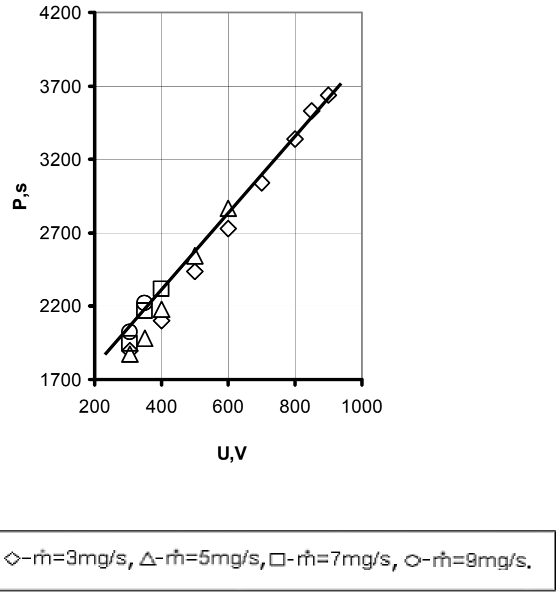

Figure 5. The specific impulse of the source SPT MAG (Xe) under different mass flow rates.

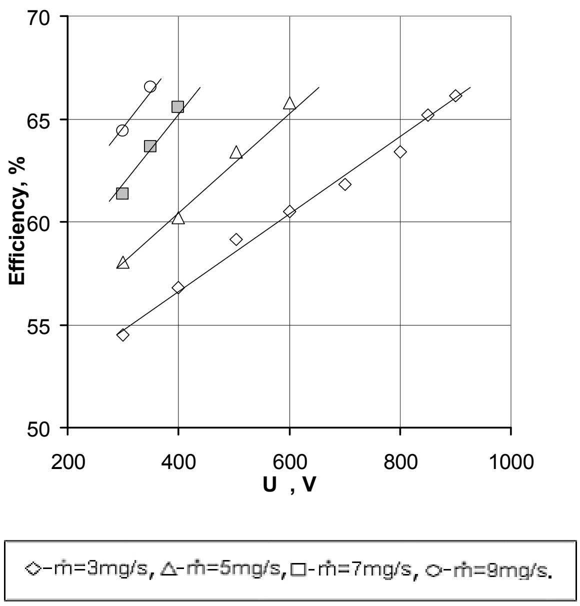

Figure 6 . The anode efficiency of the SPT MAG (Xe) under different mass flow rates.