INVESTIGATION OF THE STATIONARY PLASMA THRUSTER SCALE IMPACT ON THE ELECTRIC FILTER PARAMETER CHOICE

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Abstract

As it is well known, there are intensive enough oscillations in a discharge circuit during the stationary plasma thruster (SPT) prolonged operation. These oscillations could have a negative impact on the thruster performance and power processing unit (PPU) operation. Therefore a so-called "filter" is typically included in the discharge circuit between thruster and the main power supply source. Filter parameters are chosen after their optimization for the definite thruster and PPU for this thruster.

And it is interesting to know how the "filter" schemes and parameters are to be changed for the thrusters of different sizes. Therefore the special study has been fulfilled consisting of the optimum "filter" parameter determination for thruster of different sizes for the "filter" scheme similar to that one for the SPT-100 case. According to this scheme there is relatively small inductance, included in between discharge power supply source plus output and SPT anode. The key moment is an existence of capacitance $C_f \sim 1\mu F$ included in between anode and cathode and reducing significantly the level of discharge voltage oscillations. There was also an additional inductance simulating an impact of magnetization coils included in a discharge circuit. Varing all these parameters it was possible to study their values impact on the oscillation intensity and performance.

Obtained results show that optimum filter parameters does not depend too much on the thruster scale.

There was found also that under definite C_f values an increase of the discharge voltage oscillations is appeared which could be interpreted as a resonant condition for the counter including capacitor C_f and thruster.

Introduction

As it is well known [1, 2] plasma in the so-called stationary plasma thrusters is characterized by instabilities of at least several types. These instabilities could have negative impact on the power processing unit (PPU) operation. The electric circuit feeding the discharge in SPT could have an impact on thruster operation and performance. So, it is necessary to optimize the SPT – power supply source (PSS) joint operation. Typically for this purpose the special matching unit (MU) is used.

One of the first tasks of MU was to reduce the level of discharge voltage oscillations which amplitude is increased at the beginning of thruster prolonged operation [3]. Therefore MU was called as a "filter".

Interaction of thruster, MU and PSS is more complicated. Therefore it is interesting to study their joint operation under different MU parameters and thrusters of different sizes. Such study was fulfilled at Research Institute of Applied Mechanics and Electrodynamics (RIAME) of Moscow Aviation Institute within the frames of INTAS 96-2276 project. Obtained results are represented in a report.

1. Methodology of study

To study the SPT-MU-PSS joint operation there were used SPT-50, SPT-70 and PPS-1350 laboratory models available at RIAME.

To maintain SPT discharge there was used powerful PSS (PS1 in Fig. 1) allowing to vary discharge voltage and current in a wide enough range and MU "filter" of standard scheme consisted of inductance L_a (see Fig. 1) at the PPU output and capacitance C_f shunting the SPT discharge between anode and cathode [4].

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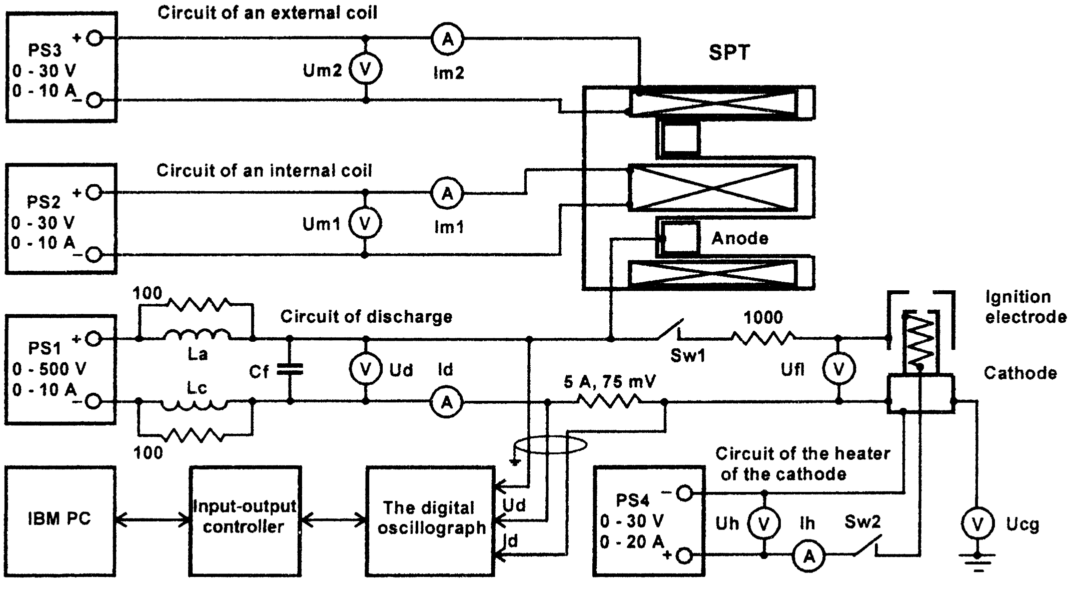


Fig. 1. Registration scheme

There was used also an additional inductance L_c simulating the magnetization coil inductance while they are included into discharge circuit.

L_a, C_f, L_c values were variable in a wide enough ranges and it was possible to study their impact on the oscillation intensity and thruster performance level.

To control the oscillation intensity in a thruster discharge counter there was used the oscilloscope allowing to register discharge voltage and discharge current signals. It was connected with PC able to realize the signal spectral analysis.

Thruster models were fired inside vacuum chamber of 2 m in diameter and 6 m in length. The dynamic pressure did not exceed $1{,}5\cdot10^{-4}$ Torr during test of all the mentioned models. There were measured the discharge voltage, discharge current, mass flow rates through the accelerating channel and cathode, thrust. So, it was possible to determine oscillation intensity and performance data at the same time.

2. Result of experiments

Obtained results show that the discharge voltage and discharge current oscillation amplitude dependences on the MU parameters are similar for thrusters of different sizes, namely:

- General trend is decrease of the discharge voltage oscillation amplitude with increase of C_f value (Fig. 2), but there some particularities under $C_f \approx (0{,}1\ldots0{,}5)\mu F$, namely: there is observed the definite discharge voltage oscillation amplitude maximum under $C_f \approx 0{,}1\mu F$ and L_a=(0,175-0,525) mHn and under $C_f \approx 0{,}25\mu F$ and $L_a \approx L_c \approx 0$ for SPT-50 under C_f=0,1μF, L_a=0,175mHn and L_a=0,35mHn,

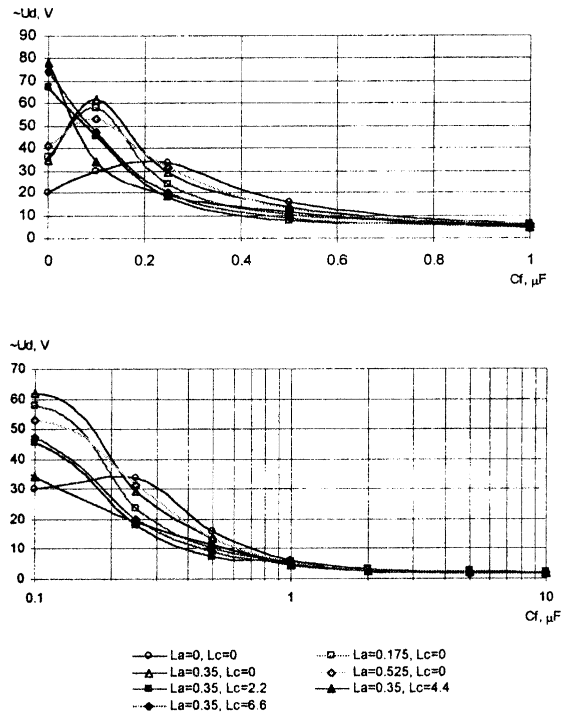


Fig. 2. Discharge voltage oscillation amplitude versus C_f values for SPT-50 model (Operation mode: $\dot{m}_a$ = 1.77mg/s, U_d=298V, I_d=2.17A)

L_c=6,6mHn for SPT-70 (Fig. 3), under C_f =0,1μF, L_a=(0,175-0,35) mHn for PSS-1350 (Fig. 4).

- General trend of inductance L_a+L_c increase is reduction of the discharge current amplitudes (Fig. 5-

7), but there are also some particularities showing that "filter" impact on the PSS-MU-SPT joint operation is complicated enough. For example for SPT-70 in a some cases (see Fig. 5) the amplitude for $L_a \approx 0,175$ mHn is higher than for $L_a \approx 0,35$ mHn under $C_f \approx 0,1\,\mu F$.

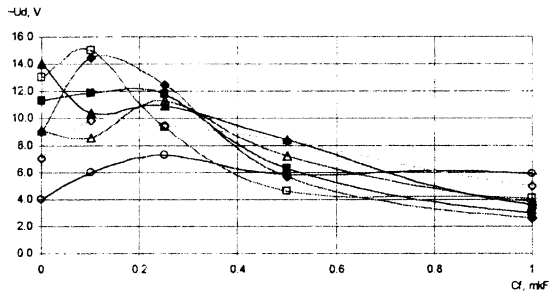


Fig. 3. Discharge voltage oscillation amplitude versus for SPT-70 model. (Operation mode: $\dot{m}_a = 2.15$mg/s, U_d=300V, I_d=2.19A)

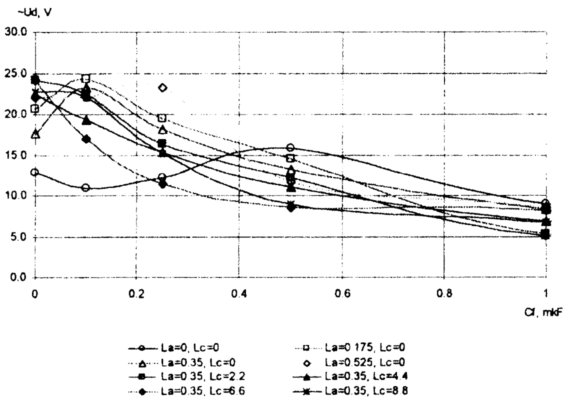
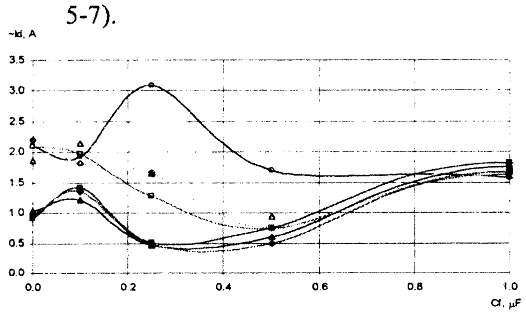


Fig. 4. Discharge voltage oscillation amplitude versus for SPT-1350 model. (Operation mode: $\dot{m}_a = 3.88$mg/s, U_d=350V, I_d=3.8A)

- For values of $L_a+L_c \geq 2,2$ mHn the character of U_d and Id oscillation amplitudes dependencies becomes almost identical for different thrusters and there are observed the local maximum of the discharge current amplitude at $C_f \approx 1\,\mu F$ and its local minimums at C_f=(0,25-0,5) μF and $C_f \approx$(2-3)μF (see Fig. 5-7).



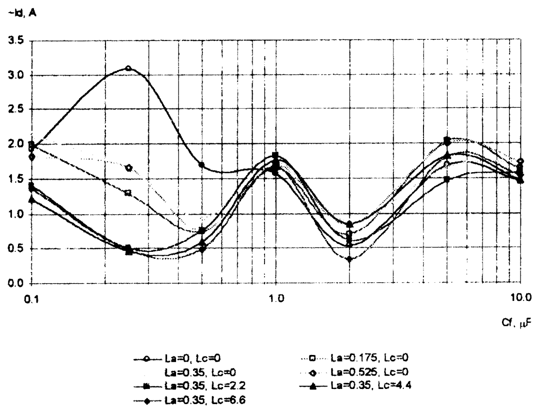


Fig. 5. Discharge voltage oscillation amplitude versus C_f values for SPT-50 model. (Operation mode: $\dot{m}_a = 1.77$mg/s, U_d=298V, I_d=2.17A)

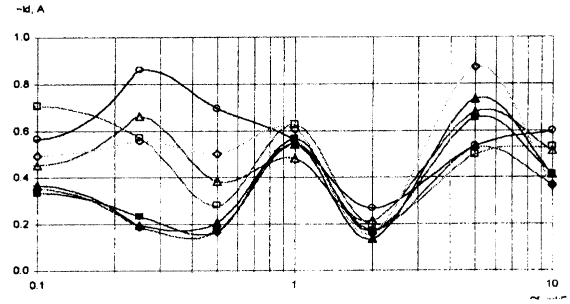


Fig. 6. Discharge current oscillation amplitude versus for SPT-70 model. (Operation mode: $\dot{m}_a = 2.15$mg/s, U_d=300V, I_d=2.19A)

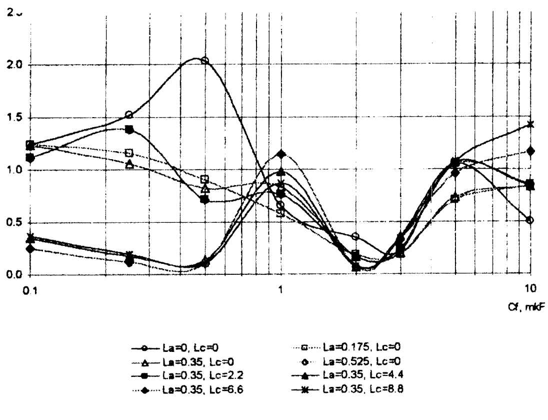


Fig. 7. Discharge current oscillation amplitude versus for SPT-1350 model. (Operation mode: $\dot{m}_a = 3.88$mg/s, U_d=350V, I_d=3.8A)

- Discharge voltage and current traces character is changed while filter parameters are changed. Respectively there is changed the amplitude-frequency oscillation characteristics (Fig. 8-9).

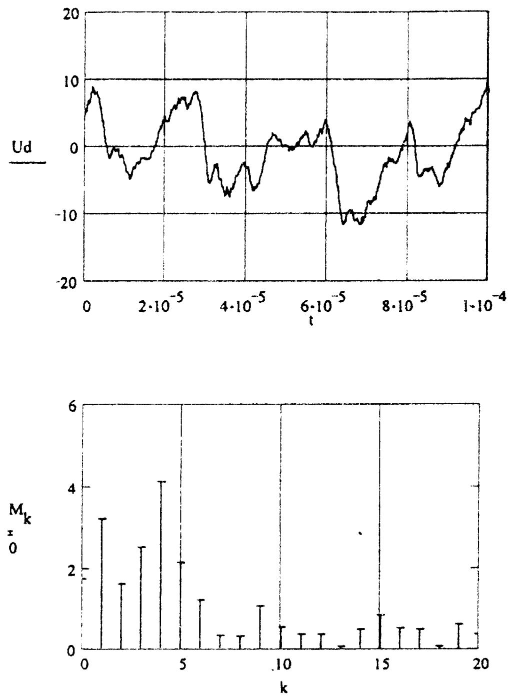


Fig. 8. Discharge voltage trace and its spectrum for SPT-50 under L_a=0.35, L_c=1,C_f=1.0.
(Operation mode: $\dot{m}_a$ = 1.77mg/s, U_d=298V, I_d=2.17A)

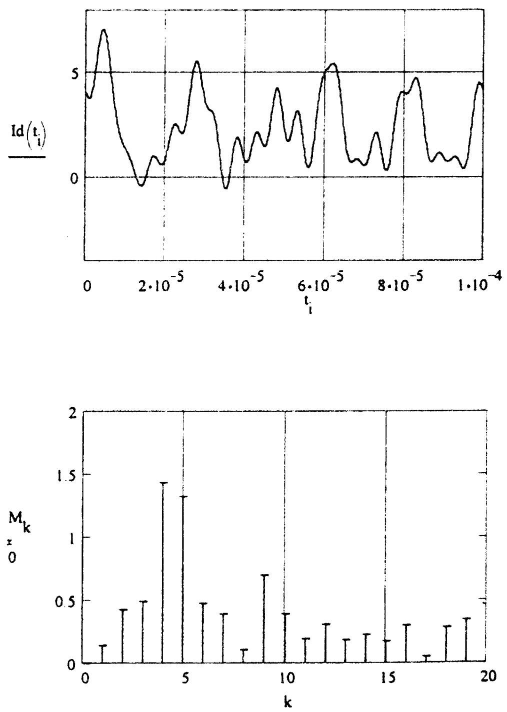


Fig. 9. Discharge current trace and its spectrum for SPT-50 under L_a=0.35, L_c=1,C_f=1.0.
(Operation mode: $\dot{m}_a$ = 1.77mg/s, U_d=298V, I_d=2.17A)

Typically there are at least several modes of oscillations with different frequences and amplitudes exist in a spectrum. But for the mentioned specific cases C_f≈(0,1-0,25)μF with discharge voltage oscillation amplitude maximum signal becomes almost monochromatic (Fig. 10-11).

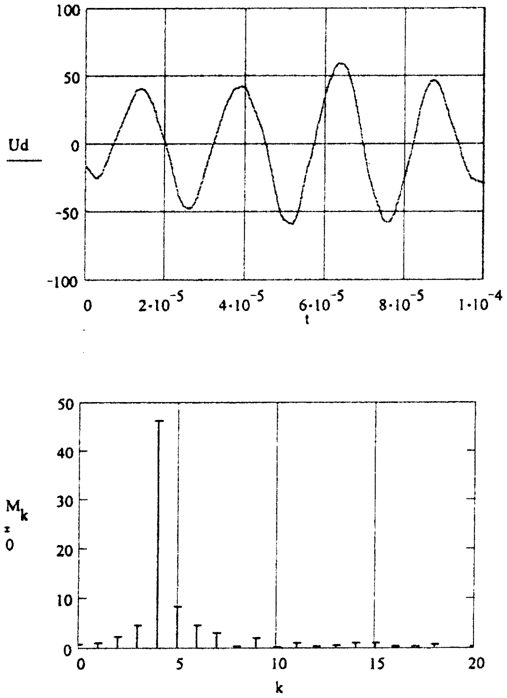


Fig. 10. Discharge voltage trace and its spectrum for SPT-50 under L_a=0, L_c=0, C_f=0.25.
(Operation mode: $\dot{m}_a$ = 1.77mg/s, U_d=301V, I_d=2.18A)

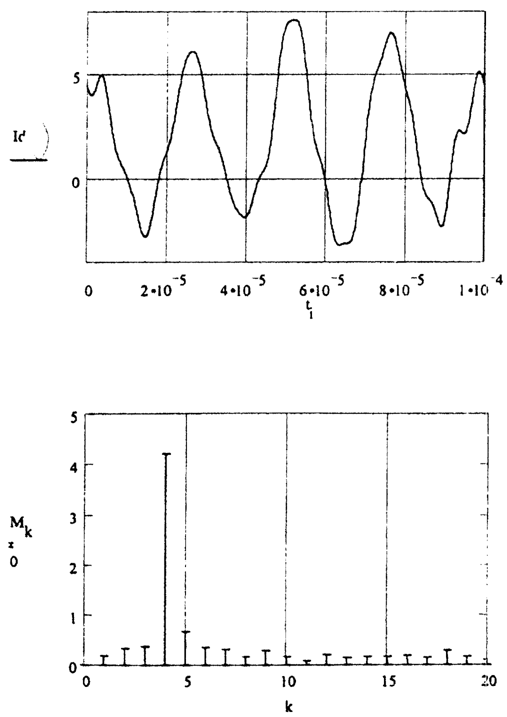


Fig. 11. Discharge current trace and its spectrum for SPT-50 under L_a=0, L_c=0, C_f=0.25.
(Operation mode: $\dot{m}_a$ = 1.77mg/s, U_d=301V, I_d=2.18A)

- There is no direct correlation between oscillation intensity and thrust efficiency (Fig. 12-14). For example η_T could have its maximum under MU parameters ensuring $\tilde{U}_d$ amplitude maximum (see Fig. 2 and Fig. 12) or under moderate $\tilde{U}_d$ or $\tilde{I}_d$ amplitude values (see Fig. 4, 7, 14).

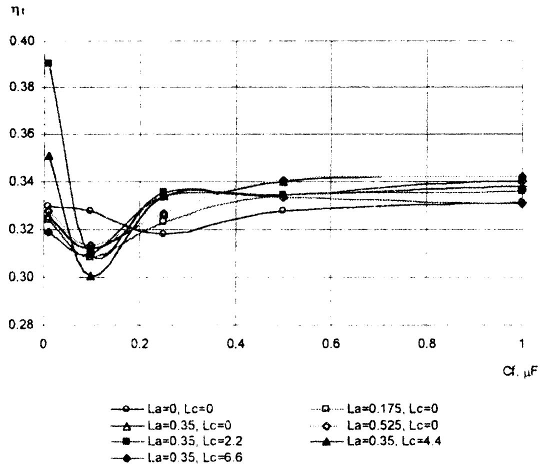


Fig. 12. Thrust efficiency versus C_f values for SPT-50.
(Operation mode: $\dot{m}_a$ = 1.77mg/s, U_d=298V, I_d=2.17A)

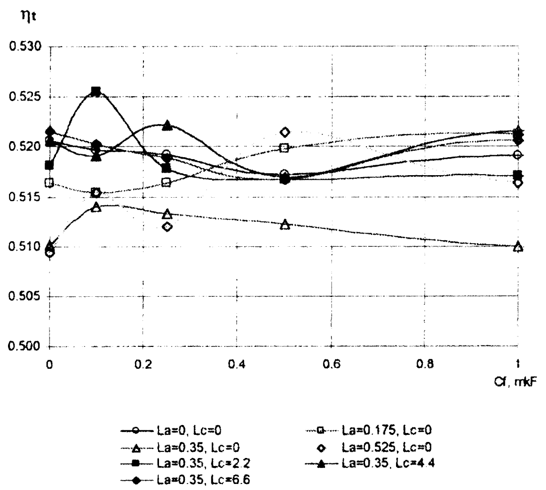


Fig. 13. Thrust efficiency versus C_f values for SPT-70.
(Operation mode: $\dot{m}_a$ = 2.15mg/s, U_d=300V, I_d=2.19A)

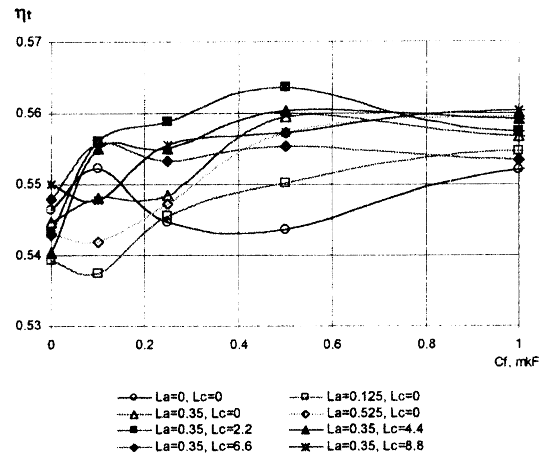


Fig. 14. Thrust efficiency versus C_f values for SPT-1350.(Operation mode: $\dot{m}_a$ = 3.88mg/s, U_d=350V, I_d=3.8A)

Thus obtained data show that the MU parameters does not change significantly with the thruster size variation. Moreover there are some general trends of their impact on the joint SPT-MU-PSS operation are to be taken into account to optimize MU parameters. Surely, it is necessary to choose the MU parameters taking into account complex of thruster output parameters.

Conclusion

Obtained data show that the matching unit impact on the discharge voltage and current oscillation intensity has some general trends for thrusters of different sizes to be taken into account during SPT-matching unit - PPU joint operation optimization.

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