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Numerical simulation of the flow structure of the heavy particles in SPT.

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Abstract.

The method of numerical simulation of the moving of heavy particles in the SPT channel of any geometry used. It is based on Monte Carlo method for ionization processes and for scattering on the walls. After ionization the ions move in electric fields taken from experiment or modelled. The ionization processes is drawn using an experimental data on electron temperature and concentration fields in channel and plume. The output results of this method could be the distributions of ions over velocities and energies at any chosen crossection and any variable averaged over these distributions. Mean velocity in the plume, for example, presents the thrust per unity of propellant debit. Such calculations have been carried out for SPT ATON geometry and gave a resonable results on the distributions and thrust. The influence of the potential of the walls relative to volume potential on the thruster performance is studied. Assuming the neutral particle flying into channel from outlet we can simulate the influence of the background gas entrainment on the thrust. The calculations have shown that if 1 mg/s of Xe mass flow goes usual way (from the gas-distributor) it originates 1.9 g of the thrust as if it goes from outlet the trust originated is .48 g. So if one want to evaluate a critical pressure of background gas one should take into account that effectivness of backward mass flow is only .22 of effectivness of direct mass flow.

1. Introduction.

One of the main difficultes for them who works with SPT now is that they have no a good theory of such a sistem, the theory which could with resonable accuracy to predict the main features of the thruster operating if some set of input parameters is given. The point is that the accurately formulated problem assumes the solving a sistem of kinetic equations for sistem of three (as minimum) types of particles moving and interacting in very ingomogeneous fields and having (electrons and heavy particles) very different time and space scales. As far as now we don't know how to solve this problem in full formulation we decided to test some approaching problem which we could to compute in appropriate calculating time and which could to describe some main features of investigated sistem. This approach uses as input data experimental or model electric, electron temperature and electron concentration fields and keeps track of the fate of single heavy particle entering into the thruster channel and experiencing ionization, scattering on the walls and moving in these fields. As it is found that if to test not larger than 1000 particles drawing by Monte Carlo method their fate in the above-mentioned processes it is possible to obtain rather reliable results on the plume form and on the distribution functions of the output particles.

2. Brief description of the method

Detailed description of this method one can find in [1]. Here we mark some features.

The calculation process included the following steps. The initial velosities were drawn according to Maxwell distribution with temperature 700 K. Then atom moved freely scattering on the walls only. Moment of ionization was drawn by the constant crossection method[2] and after double or single ionization the particle moved forsed by electric field. The single ion could be ionized once more up to double ion. Higher ionizations were not considered. The ion scattered on the wall became neutral atom with the unit probability (it is not the method limitation but are used in presented calculations) and moved from the wall in arbitrary direction. Here we assumed the energy conservation after scattering on the wall but one can consider any losses.

3. Objectives, results and discussions.

We have used our method for two problems. One of them is as follows. The experimental electric field used in our calculations in [1] have such a feature that there was slight potential increment (~2-5 V) towards channel walls near them (since it happend to be very few ions penetrate into this layers through 2-5 volts barrier we do not consider here potential behavior in Debye layers which space scale is of order of .01-.1 mm in the SPT channel conditions , our scales have order of 1 mm). As it was mentioned in [1] the calculations with this potential gave a good agreement with thrust experiment (in the limits of 10% mistake), the picture of the plume was very similar to that in experiment. Here we wanted to check the role of mentioned above increment. We have used now the same potential excluding the increment. Really we change the potential only near the walls reducing it there by 2-5 V. The results was as follows. If in experimental field with increment on the walls the trust was 1.9 G per mg/s of Xe debit in the fields without increment it have been 1.8 G per mg/s of Xe. So 5% of thrust decreasing give 10% decreasing of efficiency (which proportional to square of thrust) or 6 % of absolute value of efficiency. Here we do not take into account the losses connected with increasing scatterings of the ions on the walls (losses on new ionization) so the real decreasing of the efficiency should be larger. The pictures of the flow from the thruster in both cases are shown on Fig 1. One can see there

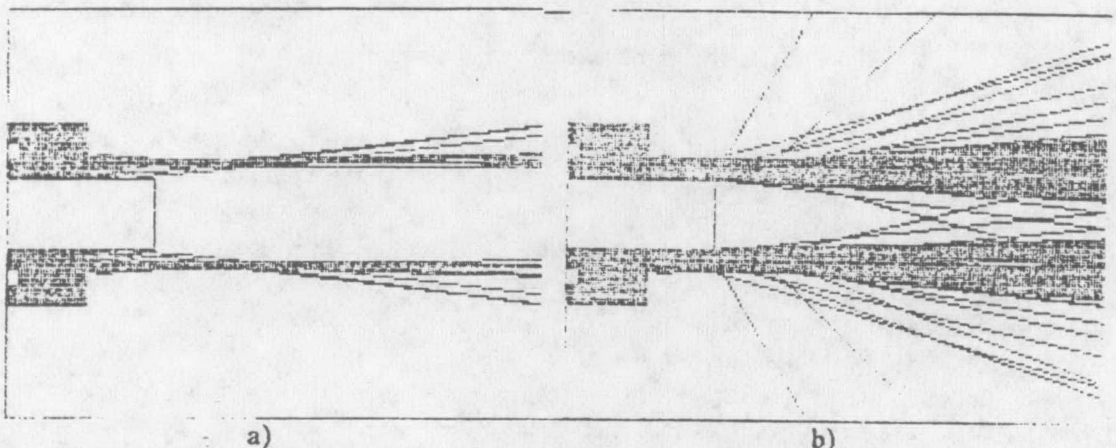

Fig.1. The calculated plume shape in two different potentials.
a) experimental potential with increment on the walls;
b) modified potential without increment.

increasing of plume divergence if potential increment towards the walls disappears.

The second objective of presented work was to understand how the background gas can influence on the thruster perfomance. To do it we consider the atom entering to thruster channel from its exit and moving in the same fields as entering is normal, from gas-distributor. The conditions are as follows. The neutral particle appeared in the region in front of exit at random point not further than 5 cm from exit. The particle velosity was distributed by the Maxwell with temperature 300 K and directed randomly in the angle at which exit was seen. The calculations have shown that only ~1% of the particles reached the thruster buffer zone. At Fig. 2 one can see the example of several trajectories of the particles flying into the channel from the exit.

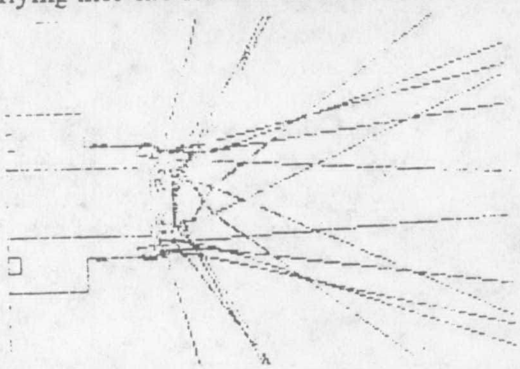

Fig.2. The tragectories of entrained particles.

In the total the thrust originated by the particles entering from thruster exit equal to .48 G per 1 mg/s of Xe mass flow. So we can correct an evaluation of the critical facility pressure which presented in paper of T.Randolf et al.[3]. They obtain the value $5 \bullet 10^{-4}$ Torr supposing that the entrained mass has the same influence on the thrust perfomance as injected propellant. We think that their evaluation appears to be too overrestricting and could be enlarged by the factor 4 (1.9/.48). So founded on our calculation we propose the critical pressure to be equal to $2 \bullet 10^{-4}$ Torr.

4. Conclusions.

Based on the calculations we can mark that just very small variations of the wall potential in SPT may lead to sufficient deterioration of its performance.

The influence of the background gas is weakened by small penetration of gas particls into the accelerating field because of its ionization near the thruster exit.

Acknowledgment.

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