Some remarks about published data concerning the SPT-100 jet parameters distribution

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Abstract

Russian success in usage of the SPT-type electric-rocket thrusters for different space missions and SPT-100 exploitation at the geosynchronous satellites[1] are the reasons of the great interest to these type of thrusters among the firms, designing space crafts either in Russia or abroad. Nowadays lots of works analysing the possibilities of the SPT-100 usage for some space platforms are appeared. In this case an optimal integration of the electrical thrusters' on board of the spacecraft is very important when a new spacecraft is developed. It is practically impossible to do without thruster jet investigation. It is especially actual for SPT in which calculation of the ion flows direction gives only approximate results. The methodological bases for thruster jet investigation, some results of experimental data analysis are represented in this report. The refinement data about SPT-100 jet parameters are also represented.

Introduction

Analysis of the electric propulsion jets influence to the surfaces of the spacecraft's elements is very important at the stage of satellite designing. MAI experience in this scientific field has been transformed into some software packages. For design investigations concerning the thrusters integration on board the spacecraft the software packages TURBO DESIGN and ISP 1.0 are successfully used[2,3]. As the initial data for the calculations with the help of this packages it is necessary to set the distribution of the local parameters in the jet. At first for SPT-100 we used the most complete experimental data, represented in work[4]. But detailed calculations about the software verification with mentioned data, which we carried out, gave some unexpected results. The results that we obtained had the great divergence with the experimental data about the jet action[10]. At the same time the analogues calculations for the SPT-70 and the same power level SPT models[5] jet parameters had good agreement to the experiment. These distincts forced authors to doubt in the data[4] reliability and to carry out the additional investigations concerning the sufficiency of the measurement methods and determining the real data of the local parameters distributions in the SPT-100 jet. We took into account as ourselves experimental data as another ones [6,9].

1. Problems concerning the SPT jet investigations

As usual the SPT jet are examined under different test facility conditions: vacuum chambers' sizes and configuration are significantly various in different laboratories and chambers pressure during the tests are also varied. Method of measuring in every laboratory depends on scientific traditions in it. Probes structure and sizes, distances at which they are located relatively the thruster's cut and their motion manner (linear or circular) is very individual. A probe dislocation also is not unified and depends in majority of cases on chamber size and test facility's peculiarities.

Let's examine the main methods for SPT jet investigation. For completed description of the SPT jet it is necessary to have ion current density and ion energy distributions as a dependence of the jet divergence. It is evident that it is possible to obtain the main complete information if electrostatic probes are used. In this case the trajectory of probe motion should be so that data recalculation onto round diagram has minimum error. The simplest way is the circular probe motion at a distance under which the thruster's channel can be represented as a material point (7-10 calibres).

Plate electrostatic probes are mainly used in such types of investigations. Such probe permits to obtain the spectrum of charged particles by the method of deceleration in the layer of volume charge, surrounding the probe. This type of probe has some disadvantages which are limited its usage. The disadvantages are the following:

- plate electrostatic probe does not permit to obtain separately ion and electron characteristics;
- it is difficult to determine the value of probe collecting surface, because of the volumetric charge layer formed around probe;

- it is impossible to determine the real current saturation to the probe, so it is difficult to process the performances;
- there is probe surface emission influence on to measurement results;
- under great probe potential the surrounding plasma are disturbed significantly.

We think that for jet investigation the multy-electrodes probes or so-called retarding potential analysers (RPA) are the most perspective. With the help of these devices it is possible to obtain high accurate data about either current density or ion energies. For such investigations either double or triple-electrode probes can be used. Double –electrode probe consists of grid and collector. High negative potential is applied onto grid and it stops electrons. Ions move freely to the collector; plasma break is occurring. Positive potential decelerated ions onto collector. Varying collector potential, one can registered the retarding curve. Only ions, energy which is greater than retarding potential difference, can reach the collector. With the help of it is possible to estimate ion density in plasma. There are some disadvantages of double-electrode probe:

- high potential of electron cutting grid is the reason of great disturbances in plasma;
- photo- and secondary-electron emission are suppressed not sufficiently.

Partly it is possible to overcome such disadvantages with the help of triple-electrode probe, which has additional grid, screening probe elements from plasma. In this case the electric field from probe's electrodes does not penetrate out of the external grid and parameters of surrounding plasma are not spoiled. As a result a probe-collecting surface practically is not changed and retarding curve has good saturation.

Our experience concerning RPA usage shows that it is reasonable to use the scheme with ion flow deceleration instead of collector onto additional grid (see fig.1). In this case one is able to develop probe structure of significantly small sizes and to obtain satisfactory (close to theoretical ones) form of retarding curve (see fig.2) in the area of great potential values. In order to determine base plasma potential it is possible to use the potential of screen grid or probe body, but more acceptable data one can obtain using heating probe method. For example, it is possible to use the method developed by MAI jointly with Michigan University[6]. It is also reasonable to use collimating probes, which permits to determine flow parameters dependence from angle more correct. In our structures we used diaphragms made of dielectric materials and it decreases probe influence on surrounding plasma layers.

It is necessary to point out separately the problem how to choose RPA elements parameters. Calculations concerning grid parameters choosing according recommendations[7] for SPT jet show that it is possible to use a grid with cell size about 0.2 mm with wire diameter 0.4 mm as a screen grid. In this case its transparency will be 0.7-0.75. Electron cutting grid should have smaller structure, so we use cell size 0.056 mm and wire diameter 0.026 mm. Its transparency is 0.444. Retarding grid has following parameters: cell – 0.226 mm, wire – 0.112 mm, transparency ~ 0.5. Distance between grids and collector are about 0.5-1 mm, diaphragm aperture is 7 mm in diameter. RPA with such elements parameters having cross diameter 30 mm were developed by MAI department "Spacecraft Electric Propulsion and Powerplants" and have been used by several organisations[6,8], demonstrating stabile performances. We used it for control measurements when we investigated the SPT jet.

2. Experimental data analysis

So, as it was mentioned here above, we had some questions, concerning reliability of data published in the work[4]. Analysing this work in details we found out that the data represented in it badly correlated either between each other or with the experimental data obtained in various organisations[6,9]. Processing data, represented in work[4], we found out that the integral of ions energetic spectres does not coincide with measured ion currents (the divergence was from dozens up to thousands times, depending on the angle between probe and beam axis). Data about ions current angular distribution in work[4] divergence with other measurements[6,9], re-calculated to the analogues measurements conditions.

In order to analyse the experimental data authors developed method based on generally accepted regularities[7]. As a criteria of it acceptability is the comparison of the thrust calculated with ion density and energy angular distribution and its experimental value. This method usage for processing of various powers SPT models testing in our department gives the satisfactory results. The verification has always been done processing the experimental data for SPT-100, represented in the work[6]. Here we also obtained good correlation between calculation and experiment. Then we took the initial experimental data about SPT-100 jet parameters at a distance 1 m with the probe effective collection area 0.25 cm^2, the same which were used in the work[4] as initial data and processed them with the help of developed method. Obtained results with account of the potential difference between cathode and plasma ΔUc~ 20 V are represented in fig. 3-7 (we give the same diagrams as in the work[4]). This data have good agreement with data presented in works[6,9] and processed on the same test conditions. Its further usage (SPT-100 plume ISP 1.0 software processing see fig.8) in the calculations concerning the jet interaction with the surfaces had good convergence with the experimental data[10]. This fact permitted us to make the conclusion, that the experimental data, used as the initial ones in work[4] are correct and under the proper processing can be included in the data base as for existing as for developing software.

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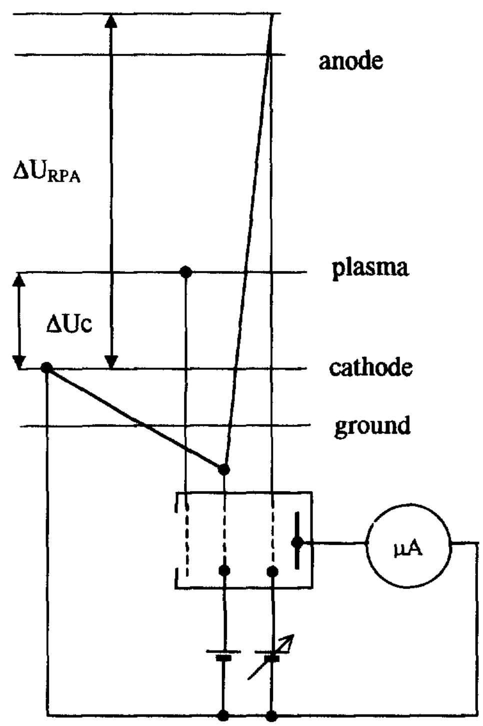

Fig.1

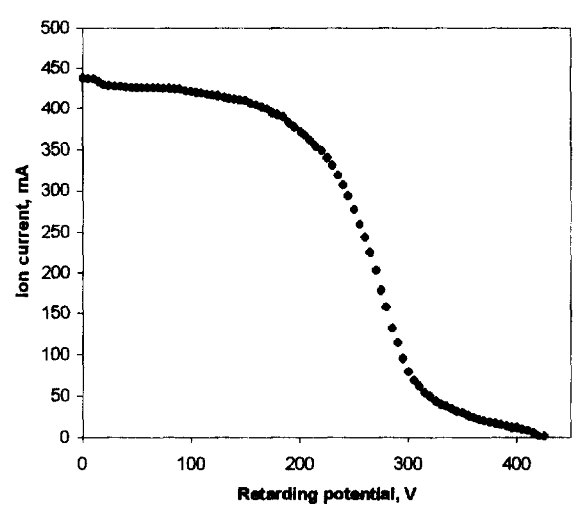

Fig.2

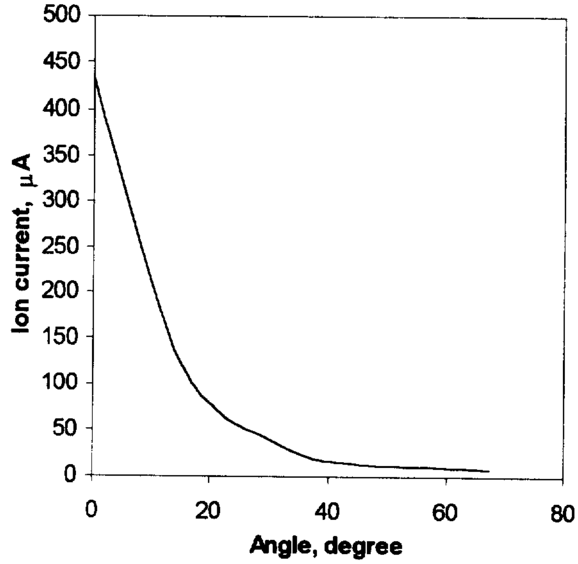

Fig.3

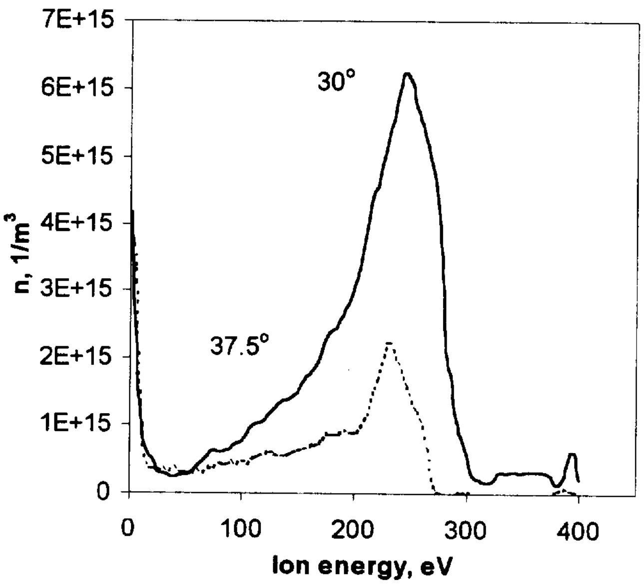

Fig.5

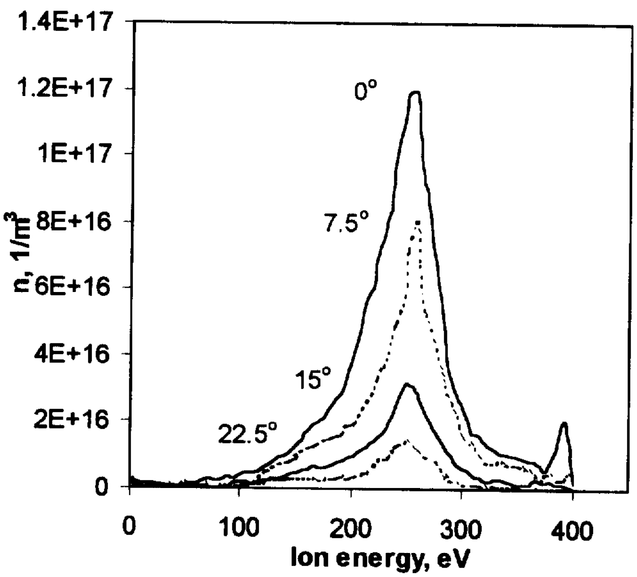

Fig.4

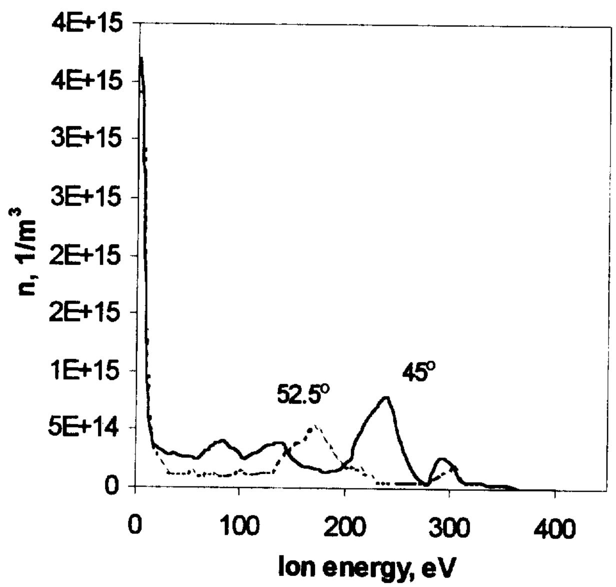

Fig.6

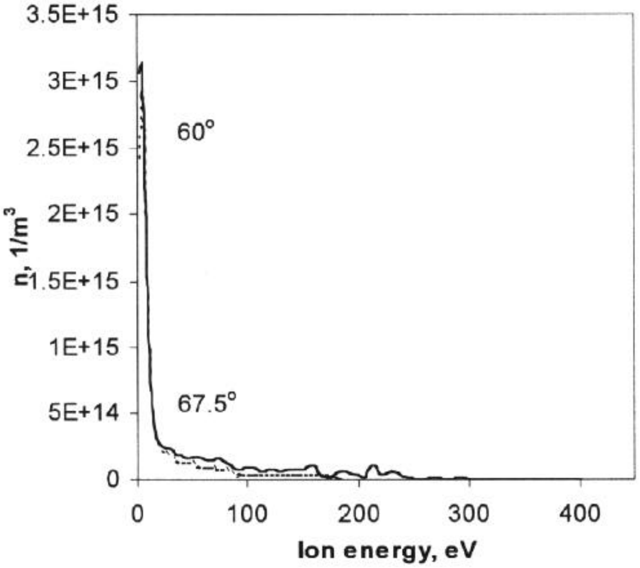
3.5E+15
3E+15
2.5E+15
2E+15
1.5E+15
1E+15
5E+14
0
n, 1/m3
60°
67.5°
0
100
200
300
400
Ion energy, eV

Fig.7

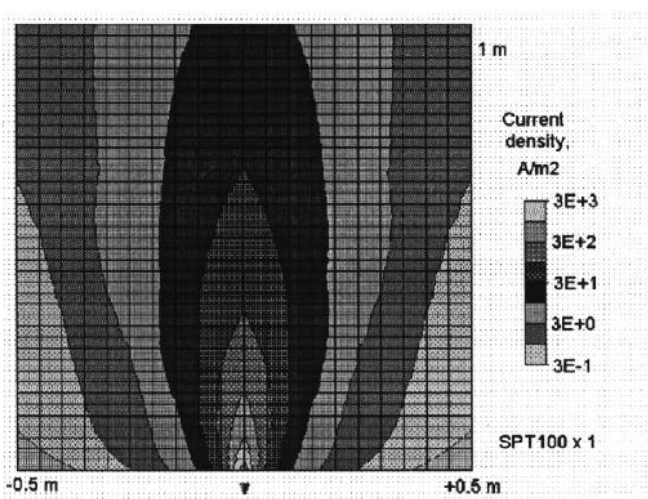
1 m
Current density, A/m2
3E+3
3E+2
3E+1
3E+0
3E-1
SPT100 x 1
-0.5 m
+0.5 m

Fig.8