RESEARCH OF PERFORMANCE OF SMALL THRUST THRUSTERS WITH A CLOSED DRIFT OF ELECTRONS

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ABSTRACT

The basic characteristics and the parameters of electrical propulsion thrusters for application on small space vehicles are presented in the report. As base thrusters for the decision of a problem of orbit parameters correction the electrical propulsion thrusters with closed drift of electrons - stationary plasma thruster and thruster with an anode layer are considered. Application of existing electrical propulsion thrusters (SPT-70, SPT-100) in a mode of small thrust results in significant decrease of efficiency of their work. Results of experimental researches of various variants of the engine with an anode layer are presented. These thrusters differ by the sizes, peculiarities of a design, size of input power and mass flow rate of working substance. In the report is shown, that one of the important units of the electrical propulsion thruster, determining an overall performance of the thruster with closed drift of electrons, is the hollow cathode - neutralizator. The traditional designs of cathodes - neutralizators at the level of the mass flow rate of working substance at a size 0,01 mg/sec work anstable, with small efficiency, that results in decrease of reliability of the electrical propulsion engine module work. Parameters of cathodes - neutralisers, working on composite working substances, are presented which have shown a high overall performance in a required range of sizes of a discharge current and mass flow rate of working substance.

INTRODUCTION

The modern tendency of development, tests and operation of spacecraft for many European countries, including Ukraine, consists in all greater application of the small satellites (mass about 1000 Kg). These satellites solve specific problems, are equipped by small number of devices and have limited size of electrical power onboard. Distinctive peculiarity of such satellites is an opportunity of launching them at launching on the orbit the heavier satellites or launching of the several small satellites simultaneously by one rocket - carrier. Thus cost of launching of the small satellite on a necessary orbit much decreases.

At development of the small satellites there is the problem of the propulsion engine unit creation with high efficiency, ensuring the parameters of orbit correction. It is known [Ref. 1], that the most perspective propulsion engine units with a small thruster for application on the small satellites are installations on the basis of thrusters with closed drift of electrons - stationary plasma engine (SPT) and thruster with an anode layer (TAL). At the moment the versions of these electrical propulsion thrusters - SPT-70 and SPT-100 have passed all-round experimental research and during of a number of years are used on space vehicles. However the level of the input power capacity of these electrical propulsion thrusters is rather high (1.0 - 1.5 kW), that causes significant difficulties of application of these thrusters on the small satellites. The attempts of their use in modes of small draft have shown, that the overall performance thus is much reduced. Thus, requirement to parameters of engines for the orbit correction of the small satellites it is possible to formulate as follows: input power - 100 - 300 W, thrust - 5 - 15 mN, lifetime - $(1\text{-}3)\cdot 10^3$ hours.

1. RESULTS OF EXPERIMENTAL RESEARCHES OF THE THRUSTERS WITH AN ANODI LAYER WITH SMALL THRUST

In Dnepropetrovsk State University were developed and laboratory tests the engines with an anode layer of various updating and level of input power (D-24, D-30, D-50) have passed. The results of experimental researches are presented in Tables 1 - 3. Received results show, that each of considered thruster can ensure a required level of the thrust at a level being available onboard the small satellite of electrical power. The thrusters of a smaller diameter (D-24, D-30) have higher operating ratio of working substance, but at an identical level of input power are more heat-stressed, that reduces a resource of their work.

The comparative analysis, spent on the basis of received experimental data on TAL and results of research SPT of small diameters, received in Moscow Aviation Institute [Ref. 1], has shown, that the thrusters with an anode layer have the smaller cost of the trust and greater thrust's efficiency. Hence, the application of such thrusters for the decision of the orbit correction problems for the small satellites is perspective.

2. PROBLEM OF DEVELOPMENT OF THE CATHODE BLOCK FOR ELECTRICAL PROPULSION THRUSTERS WITH A SMALL THRUST

The problem of development of electrical propulsion thrusters with a small thrust (about 10 mN) does not consist only in determination of the anode block size and optimisation of its characteristics. The requirements to parameters of cathode unit, following from the traditional approach (the mass flow rate through the cathode does not exceed 10 % from size of the general mass flow rate), form the rather rigid requirements to modes of the cathode operating (Id = 0.2 - 1 A, mc = 0.01 - 0.05 mg/sec, ηg = Id/mc = 100 - 150 A/ (mg/sec), N (10 - 20 W).

The traditional designs of the cathode units in a required range of the discharge currents work unstable, there is the uncontrollable transition from a plume mode to a spot mode, that causes the unstable working of the thrust [Ref. 2]. The maintenance of stable work of the hollow cathode in a range of digit currents Id = 0.2 ..1 A is rather problematic, since in the given working range transition to a mode of the decaying discharge and failure of a working mode is rather probable. Therefore for engines with an anode layer with a small thrust a design of cathode unit on the basis of the cathode with the internal discharge [Ref. 3] was used which stable discharge in a required range of the discharge current provides. Criterion of an overall performance of the cathode block is size of gas efficiency, which should be not lower 100 A/ (mg/sec).

The experimental research of the hollow cathode with the internal discharge have confirmed an opportunity of achievement of required parameters. Thus a design of the ampoule cathode was used. The hollow cathode worked on composition working substances (activator + gas). The size of the mass flow rate through the cathode made 10^{-4} - 10^{-2} mg/sec. As the activator salts of alkaline metals were used. Probably the construction of the ampoule cathode block, working only on salts of alkaline metals without use of gas. The results of experimental researches of the cathode block ampoule type are presented on Fig. 1 and Fig. 2, where voltage-current characteristics of hollow cathode working for the anode are presented and the voltage - mass flow rate characteristics of the hollow cathode by its work in structure of the thruster (D-32).

3. CONCLUSIONS

In result of spent researches the whole line of thrusters with an anode layer of small thrust (D-24, D-30, D-50) with ampoule construction of the hollow cathode - neutraliser, which have the size of the thrust in a range 5-15 mN, were developed. However, for the decision of each particular problem of space application of the electrical propulsion engine module the detailed analysis of an anode - cathode unit for realisation of optimum modes of its operation is necessary.

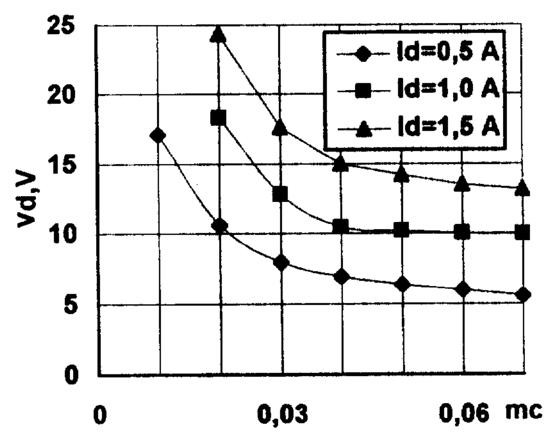

Figure 1. Voltage-current characteristics of the hollow cathode.

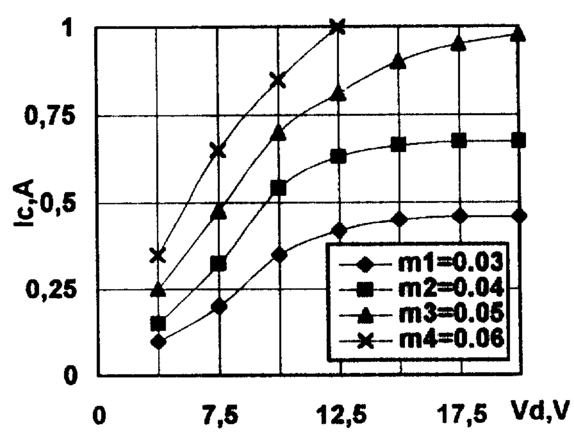

Figure 2. The voltage - mass flow rate characteristics of the hollow cathode.

4. REFERENCE

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2. Philip C.M. "A study of hollow cathode discharge characteristics", AIAA Paper № 70-1087, 1970.

3. Khitko A.V., Maslyany N.V. "Experimental investigation of caesium orificed hollow cathode with internal discharge", 3rd Russian-German Conference on Electric Propulsion Engines and their Technical Applications, Stuttgart, Germany, 1994.

Table 1. Results of the thruster with anode layer D-24 experimental investigation

m	Vd	Id	P	N	J	η
mg/sec	V	A	mN	W	m/sec	%
1.00	85	1.10	2.00	93.5	2000	2
1.00	105	1.55	4.90	162.8	4500	6
1.00	130	1.70	6.90	221	7000	11
1.00	170	1.80	8.80	306	9000	13

Table 2. Results of the thruster with anode layer D-30 experimental investigation

m	Vd	Id	P	N	J	η
mg/sec	V	A	mN	W	m/sec	%
0.4	85	0.55	2.45	46.8	6250	17
0.4	100	0.55	2.94	55.5	7500	20
0.4	120	0.55	3.63	66.0	9250	26
0.4	135	0.55	4.02	74.3	10250	28
0.4	150	0.60	4.32	90.0	11000	27
0.4	165	0.60	4.61	99.0	11750	28
0.4	180	0.60	5.40	108.0	13750	35
0.4	200	0.65	6.38	130.0	16250	41
0.4	215	0.65	6.77	139.0	17250	43
0.7	82	1.00	5.40	82.0	7857	26
0.7	105	1.00	7.06	105.0	10285	35
0.7	125	1.00	8.04	125.0	11714	38
0.7	140	1.00	8.83	140.0	12857	41
0.7	150	1.00	8.54	150.0	12428	36
0.7	160	1.00	9.03	160.0	13142	38
0.7	180	1.00	9.32	180.0	13571	36
0.7	185	1.00	9.81	185.0	14285	39
0.7	200	1.00	10.3	200.0	15000	39
1.0	95	1.30	6.87	123.5	7000	20
1.0	115	1.35	8.34	155.3	8500	23
1.0	118	1.40	8.04	165.2	8000	19
1.0	120	1.40	8.34	168.0	8500	22
1.0	125	1.45	8.54	181.3	8700	21
1.0	130	1.35	9.32	175.5	9500	26
1.0	140	1.35	10.3	189.0	10500	29
1.0	143	1.30	10.3	185.9	10500	30
1.0	155	1.25	11.3	193.8	11500	34

Table 3. Results of the thruster with anode layer D-50 experimental investigation

m	Vd	Id	P	N	J	η
mg/sec	V	A	mN	W	m/sec	%
1.6	90	1.5	9.8	135	5937	21
1.6	130	1.5	13.7	195	8750	31