EVALUATION OF ION THRUSTER BEAM NEUTRALIZATION

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Abstract

A Xenon Ion Engine Subsystem (hereafter called IES) is now under development for north-south station-keeping of Engineering Test Satellite VI (hereafter called ETS-VI) .

ETS-VI, which is to be launched in 1993, is a three-axis stabilized satellite with a mission life of 10 years.

In order to evaluate and confirm the ion thruster (TRS) life, several life tests have been conducting. In the latest TRS life test at Tsukuba Space Center ion thruster test chamber, unbalance of the neutralizing current was observed between simultaneously operated thrusters. These phenomena may affect on the neutralizer life and satellite electromagnetic interference (EMI) design.

By the direct measurement of neutralizing current, it is proved that the quantity of the neutralizer emission current strongly relates to the space chamber potential (beam target potential) and the ratio of unbalance depends strongly on the Xe mass flow rate supplied to the each neutralizer. It is seemed that these phenomena are caused by the subtle difference of the neutralizer electron emission characteristics.

As shown in another paper on Mass Flow Controller (IEPC-91-109) , mass flow rate to the neutralizer is controllable by the ground command. Therefore, it is proved that neutralizing current can be controled to reduce these unbalance phenomena in accordance with the monitored practical neutralizing electron current and mass flow rate to the neutralizer.

Introduction

Ion Engine System (hereafter called IES) for Engineering Test Satellite VI (hereafter called ETS-VI) is under development successfully.

The system block diagram and its specification are summarized in the Figure 1 and Table 1, respectively.

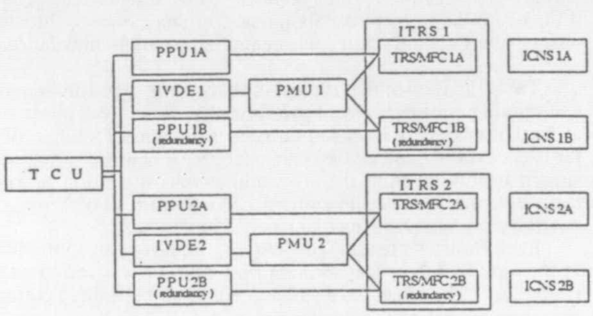

Fig.1SystemBlockDiagram
Note:TCU,IVDEand PMU have a full redundancy in one unit

Table1 The Main Parameters of the Ion Engine System

Thrust Method	Electric Propulsion with an Electron-bonbardment Xenon Ion Engin
Operation Configurations	Two Thrusters are operated Simultaneously to perform north-South Station Keeping
Individual Thruster's Output	23.3mN
Combined Thruster's Output	40.3mN (with two thrusters canted in 30 degrees)
Specific Impulse	Individual thruster : more than 2906sec Combined thruster : more than 2516 sec
Power Comsumpsion	1570 W (average value with 2 thrusters' beam extraction)
Weight	95 kg
Propellant Weight	41 kg (for 10-year mission of 2-ton satellite)
Total Operation Time	6500 Hours (Design Value for 10-year mission)
Total Number of Firing	2920 cycles (Design Value for 10-year mission)

After the evaluation of the engineering model test results (each component level tests, IES level tests and ETS-VI satellite system tests) and some modification of the design, its development status is now on the protoflight model (hereafter called PFM) or prototype model (hereafter called PM) fabrication and test evaluation / verification phase.

Performance tests and environmental tests, such as thermal vacuum, sinusoidal vibration, random vibration, and acoustic tests, were performed for each component, using PFM and PM. Afterward, subsystem (IES) interface matching test and performance test are to be carried out.

Results obtained during these tests are fairly satisfactory and the interface matching of IES among each IES component and in the ETS-VI satellite system are to be confirmed.

Concurrently, using two development model (DM) thrusters and four engineering model (EM) thrusters, life tests of ion thruster for ETS-VI has been conducted. These life-tests have started after the over 9,000 hours successive operation of the bread-board model (BBM) thruster .

As of July 1991, approximately, 5660 hours and 7160 hours successive operations for 2 DM thrusters and 2630 hours, 2680 hours, 3070 hours and 1960 hours ON/OFF operations for 4 EM thrusters have completed. These life-test data show that thruster operation and its performance are stable during these tests period.

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Life Test Configuration

The life tests are carried out with 2 DM thrusters and 4 EM thrusters in order to verify the TRS operating life. Required total operating life (beam extraction time) and ON / OFF cycles of ETS-VI TRS are 6,500 hours and 2,920 cycles, respectively.

DM / EM life tests are conducted in the new ion thruster test space chamber at NASDA Tsukuba Space Center. Figure 2 shows the schematic diagram of this ion test space chamber. In this space chamber, life tests of 2 DM thrusters and 4 EM thrusters are carrying on at the test conditions summarized as belows.

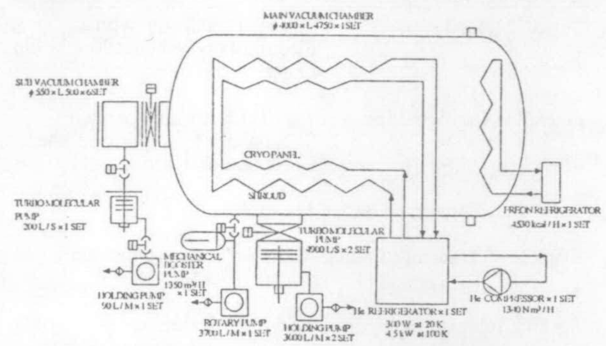

Fig.2 Schematic Diagram of Ion Engine Test Facility

Life test Configuration

Main Chamber Dimensions	ɸ4000 x L4750, mm
Subchamber Dimensions	ɸ 550 x L500, mm
Pressure Condition	less than 4.0 x 10^{-4} Pa (3 x 10^{-6}Torr) simultaneous operation of 5 thrusters at nominal point
Beam Target Temperature	less than -50°C
Operating Condition	DM:Successive Operation at nominal point EM:ON / OFF Cycle Operation at nominal point ON time: 3 Hours OFF time: 1 to 3Hous

In this facility, two or more thrusters can be operated simultaneously. From the aspect of several thrusters' simultaneous operation, this operating configuration simulate the flight configuration, under which two thrusters are to be operated in order to generate synthetic thrust vector for NSSK.

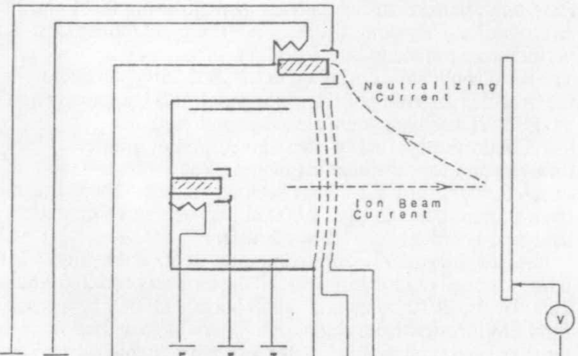

Fig.3 Electrical Configuration of TRS and Its Facililies

Figure 3 shows the electrical configuration of thruster operation for one thruster. As is shown in this figure, ion beam current was showered to the ion beam target (large-area floating electrode) and the showered ion beam piles up the potential of ion beam target . This piled up potential of the ion beam target extract the neutralizing current from the neutralizer. On the contrary, the neutralizing current showered to the ion beam target prevent the increase of the target's potential. Therefore, the target's potential and the neutralizing current was settled to some value.

As for the flight configuration, the potential difference was created by the satellite potential sinking compared with the surrounding potential, and this potential difference extract the neutralizing current. Therefore, the neutralizing current extraction mechanism of the test facility is a good simulation of the flight configuration.

Unbalance of Neutralizing Current

According to the neutralizing current generation mechanism described in the last section, if some numbers of thrusters are operated simultaneously, the potential difference between the thruster ground and surroundings was determined by the relation with the total amount of all the operated thruster's neutralizing current because all thrusters are grounded to the same potential and the ion beam target potential is also common for all thrusters. This configuration is common both for the test configuration and flight one.

Table2 Summary of the Unbalancing Phenomena of Beam Neutralization (using EM#2 and 4)

Mass Flow Rate for Neutralizer, SCCM		Neutralizer Keeper Voltage: Vnk, V		Neutralizing Current : In, A		Main Beam Current : Ib, mA		Target Potential :
EM #4	EM #2	EM #4	EM #2	EM #4	EM #2	EM #4	EM #2	Vt, V
1.0	1.0	12.7	15.1	0.4	0.38	479	477	23.0
0.8	0.8	12.1	15.3	0.4	0.36	480	475	23.3
0.6	0.6	12.7	15.0	0.35	0.40	479	476	23.7
0.4	0.4	14.6	13.9	0.16	0.60	479	478	29.5
0.5	0.5	13.9	13.9	0.21	0.52	479	476	28.0
0.6	0.5	12.8	15.0	0.35	0.40	479	476	23.7
0.6	0.4	11.5	16.6	0.53	0.30	479	476	29.1
0.6	0.8	12.6	15.0	0.38	0.38	478	476	23.8
0.6	1.0	12.7	14.6	0.33	0.40	477	478	23.8
0.5	0.4	11.6	15.7	0.63	0.20	478	477	29.4

Under the condition of multi-thruster operation, neutralizing current of each thruster is not required to be the same. Therefore, if the neutralizing current emission performance of each thruster differs, there should occur some neutralizing current unbalance.

Table 2 shows the typical unbalancing phenomena of neutralizing current between two thrusters, which was observed at Tsukuba Space Center ion thruster test chamber, when two thrusters (EM #2 and EM #4) are operated at nominal point. As shown in this table, at the simultaneous operation of two thrusters, the sum of the emitted current from two thrusters' neutralizers amounts to approximately 750~800 mA.

Each thruster's neutralizing current is, however, not equal in the case that the nominal mass flow rate Xe was fed to each neutralizer. Therefore, the distribution ratio of the emitted current from two neutralizers is unbalanced.

Figure 4 shows the schematic of these unbalance. As shown in this figure, when the electron emission characteristics of the TRS #2 neutralizer is better than those of the TRS #1 neutralizer, unbalance of the neutralizing current is cancelled by the current flown through the satellite structure body via both thrusters' Power Processing Units (PPU #1 and #2) bonding point.

In the case of nominal mass flow rate : 0.4 SCCM (standard cubic centimeter per minute) to each neutralizer, unbalancing quantity of the emitted current from each neutralizer is approximately 58 %. Moreover, these phenomena are not affected by the thruster's start up sequence, such as the timing difference of the each thruster's ion beam exhaustion.