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Development of KM-60 based orbit control propulsion subsystem for geostationary satellite

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Abstract

The paper contains the development results of an orbit-control electric jet propulsion subsystem intended for a geostationary satellite based on the EXPRESS-1000 family medium class platform. The subsystem is based on the newly-developed KM-60 thrusters featuring an increased specific pulse, and equipped with a Xenon storage tank made of composites, a small-sized Xenon feed unit, PPU and dedicated software. During the development stage, scientific and technical tasks were carried out to ensure thruster performance stability over the lifetime, to create a power processing system featuring increased output voltage, and a control unit operating through a multiplex data bus. As a result, a thruster subsystem significantly exceeding similar subsystems in main parameters was developed and implemented.

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Keywords: spacecraft, satellite, electric jet propulsion subsystem, thruster, flow control unit, Xenon feed unit, Xenon storage unit.;

1. Introduction

Plasma thrusters have been used in national satellites since 1971 [1]. Since 1982, 45 satellites made by JSC ISS were launched and commissioned. These satellites were equipped with electric jet propulsion subsystems [2]. Employment of such type of propulsion subsystems have made it possible to improve satellite efficiency as a whole due to reduction of the mass of fuelled propulsion subsystems achieved thanks to the high efficient performance of plasma thrusters versus chemical thrusters. All these subsystems were based on plasma thrusters of M-70 and SPT-100 types, with an accelerating voltage of 300 V [3] and equipment (storage and feed systems, power processing systems) manufactured to the technology level available at time of the propulsion subsystem creation. An analysis demonstrated that all these elements have essential resources both in terms of specific characteristics and mass. That is why on the cusp of 2000, a task was set to create updated elements of orbit-control electric jet propulsion subsystem for satellites, with

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the aim of further mass reduction. The relevance of this task was even enhanced with satellite life extension up to 15 years and more, the addition of new requirements for de-orbiting after satellite decommissioning, and satellite orbit raising to achieve the geostationary orbit. All these new requirements result in an increase of propellant volume required to generate the necessary total pulse and increase of propulsion subsystem mass. To make it reasonable, the JSC ISS set a task to develop a new thruster featuring an improved efficient performance, a newly developed PPU with improved output voltage and a lighter Xenon feed unit and Xenon storage unit made of composites. Such orbit-control propulsion subsystems were developed for medium-class satellites of 1000 to 1500 kg mass range (based on an EXPRESS-1000 platform) composing of a plasma thruster KM-60 (the Keldysh center), power processing unit - PPU (SPC POLYUS), Xenon storage unit - XSU (NIIMash), Xenon feed unit - XFU (JSC ISS), and on-board software – OBSW (JSC ISS). This paper contains brief data on the above-mentioned subsystem components, problems solved at the component development stage, a comparison versus the similar previous generation components, and an assessment of the effects achievable thanks to the new subsystem.

Such activities were continued, but with less intensity, at the Moscow Aviation Institute (MAI) only, and subsequently (since the end of 80-ies) – at the Research Institute of Applied Mechanics and Electrodynamics of MAI (RIAME MAI).

With the purpose to increase efficiency of the first-generation APPT and to start development of APPT of the second generation, the necessary investigations were made, which were aimed at the increase of specific thrust impulse and thrust efficiency. The greatest attention was paid to the improvement of processes inside the discharge chamber. In the pulsed thrusters, in which the discharge period is 10–20 μs, high losses were explained by a wide scatter of masses in velocities and by the local-temporal mismatching between the plasma density distribution and the accelerating three-dimensional electromagnetic forces. The discharge-accelerating chambers characterized by relatively good matching of above distributions were developed by MAI [2, 3]. Magnetic fields varying in time and space were tested by magnetic probes, and plasma density by spectroscopic methods. The APPT laboratory models with thrust efficiency of about 20-30 % were designed as a result.

1. Orbit control propulsion unit

An orbit control propulsion unit composes a thruster KM-60 and flow control unit (FCU). A thruster and FCU were developed and subjected to qualification tests by the Federal State Unitary Enterprise "Keldysh Research Center" ("Keldysh Center") [4]. The KM-60 prototype is a KM-45 thruster equipped with a similar magnetic system, discharge chamber, and cathodes; by the beginning of KM-60 development activities, the KM-45 had passed more than 1000 hours of life tests [5]. The Keldysh Center also manufactured flight model propulsion units. The KM-60 Thruster has an improved specific pulse (versus an analog thruster of M-70 type developed by the OKB FACKEL) exceeding 2000 *s* at BOL. The KM-60 peculiarity is a long-term operation with high specific pulse at relatively low power capacity. Implementation of such requirements was a complicated scientific and technical challenge requiring dramatic efforts linked to thruster development. The main parameters of the KM-60 based propulsion unit are summarized in the Table 1.

Table 1. Main propulsion unit parameters - thruster KM-60 and FCU

Main parameters of thruster KM-60		Main parameters of flow control unit (FCU)	
Thrust	42 *mN*	Propellant	Xenon
Discharge voltage	500 *V*	Input working pressure	$1.75 \cdot 10^5$ N/m^2
Discharge current	1.8 *A*	Electric valve supply voltage:	
Average specific pulse (over lifetime)	>1860 *s*	– On firing (from 0.1 to 1 *s*) – keeping mode	6.3 *V* 2.2 *V*
Total thrust pulse	>380 *kN·s*		
Current in magnet coil system (regulated)	1.5…2.5 *A*		