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RECENT FRENCH RESULTS OF SMALL HALL EFFECT THRUSTERS INVESTIGATIONS IN COLLABORATION WITH THE NATIONAL AEROSPACE UNIVERSITY IN KHARKOV

The significance of using and investigation of Hall effect thrusters is described in this paper. The progress in development of HET all over the world and activities of Ukraine and France on this field are given. The small HET SPT-20M was manufactured at the National Aerospace University "KhAI". An optical method was proposed to analyze the plasma plume of the SPT-20M. In two ground tests facilities, (Kharkov and Orléans), the SPT-20M has been tested. A new small Hall Effect Thruster PPI using permanent magnets instead of magnetic coils has been recently manufactured in France. The recent tests of PPI was performed in vacuum chambers at the laboratories GREMI and ICARE in Orléans on three succesive prototypes.

Key words: *electric propulsion, Hall effect thruster, optical emission spectroscopy.*

Introduction

Electric propulsion for satellites set in geostationary orbit and probes for planetary exploration is now well recognized as the most attractive device because of its performances in specific impulse, level of thrust, low-propellant consumption, time of life (qualification tests are up to 10,000 hours), possibility of several thousand successive ignitions with an absence of degradation of the intensity of the thrust, in low divergence of the jet propulsion and storage capability of xenon (propellant chosen because of its low first ionization potential level and lack of toxicity).

For many years Ukraine and France have initiated programs of research and development with the objectives of research on physical phenomena of Hall effect thrusters, development and operation onboard spacecrafts.

In Ukraine, this activity has resulted in the development of Hall effect thrusters used in space and recently in the study, manufacturing, testing and improving the series of SPT-20M.

In Europe, this activity led to the launching of satellites Stentor (CNES / DGA) lost due to launcher failure ArianeV (Dec.11, 2002), the ESA probe Smart-1 inserted with success in a lunar orbit on Sept.15, 2003, the development of a series of Hall thruster by the Snecma company: ATON, PPS100, PPSX000, PPS5000 and the creation of a research group to coordinate the theoretical, numerical and experimental studies conducted in 15 French laboratories (CNRS and Universities).

Research conducted around the world cover a wide power range from a few tens of W (a miniaturized HET was developed by MIT – 50 W, 1600, 3 minutes) to a few tens of kilowatts (NASA-457M thruster, a high power 50 kW was developed by the Gleen Research Center – GRC). Today, there is a renewed interest of space agencies and companies for small engines - the first flight of HET thruster was tested by the USSR by the launch of Meteor meteorologic satellite in 1971 and the first EDB HET thrusters "Fakel" was of the types SPT-60 (1971,1974,1976) and SPT-50 (1977,1978).

Research results

1. Ukrainian Hall effect thruster SPT-20M

The National Aerospace University "KhAI" in Kharkov has defined, manufactured tested and improved a set of successive SPT-20M Hall effect thrusters (see: [1 – 3]. SPT-20M is a low power thruster requiring an electric input power lower than 100 W (in the range 30 – 100 W), using xenon with a mass flow of 0.1 – 0.35 mg/s and with a plasma discharge voltage

between 220 V and 310 V. The annular chamber consists of two chambers with successive diameters (diameter of the outer ceramics: 23 mm, diameter of the inner ceramics: 15 mm). The model M6 delivers a thrust from 2 mN to 4 mN with an global efficiency between 25% and 40%.

In parallel of campaigns carried out in the vacuum chamber of KhAI, other tests were performed in a vacuum chamber at the GREMI laboratory (University of Orléans, France) by Optical emission spectroscopy (O.E.S.) and by Retarded Probe Analyser (R.P.A). A mini-spectrometer HR2000 (380 – 830 nm, resolution: 2 nm) and a spectrometer ACTON 750 i (ROPERS Scientifics) (750 focal length, CCD camera, resolution lower than 0.10 nm) image the plasma plume. The study is focussed on the spectral lines of Al I (396.152 nm), XeI (828.01 nm) and XeII (484.433 nm).

Fig. 1. SPT-20M: plasma plume of model M6 (in the KhAI vacuum chamber)

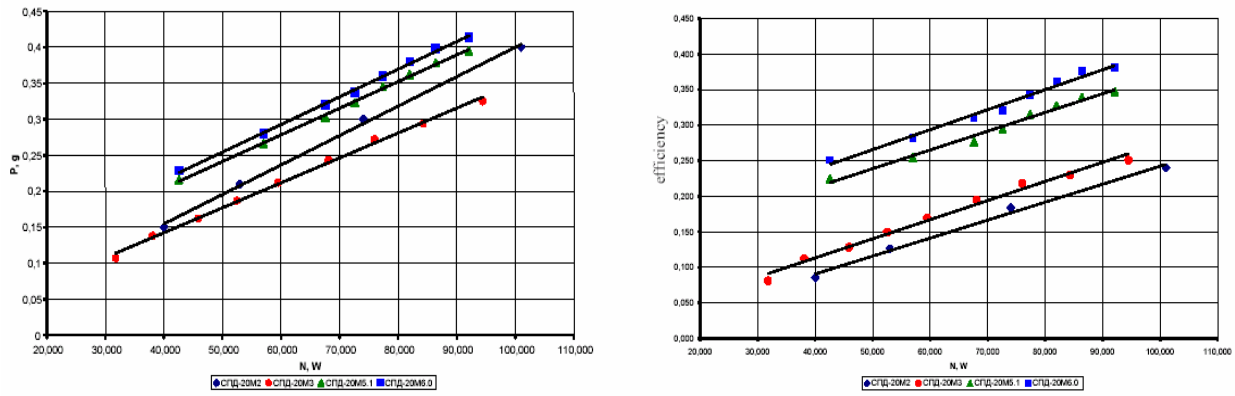

Fig. 2. Thrust and efficiency vs. power consumption for the SPT-20M series

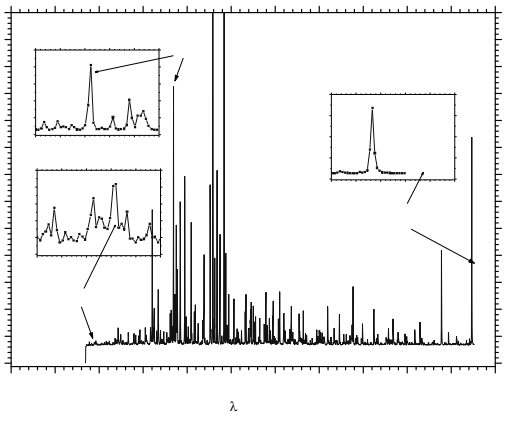

Fig. 3. Spectra emitted for a mass flow of 0.25mg/s, a coil current of 1.7A and a discharge voltage of 280V (HR2000 and ACTON 750i spectrometers)

The different spectra are used to analyse the behaviour of the plasma plume as a function of the operating conditions and to estimate the erosion rate by the use of the actinometry method.

Small French Innovative Propulseur (PPI)

A new small Hall Effect Thruster (HET) using permanent magnets instead of magnetic coils has been recently manufactured [10]. The new configuration does not need magnetic screens as in classical HET; it includes annular magnets, which lead to a very high azimutal homogeneity of the radial magnetic field ($\Delta B/B < 0.1\%$). Xenon propellant (0.55 mg/s) is dispersed into the channel through a porous ceramic set in the bottom of an annular chamber (internal radius 11.7 mm, external radius 16.7 mm). The magnetic field is obtained by parallel cylindrical SmCo magnets set in external and internal annular rings. The recent tests performed in vacuum chambers at the laboratories GREMI and ICARE in Orléans on three succesive prototypes (B = 500,250,200 G) show – after improvements of the thermal circuit – a stable, reproducible and broad working range (50 – 200 W).

The efficiency of the PPI thruster is 20% for a discharge voltage of 250 V and a xenon mass flow rate of 0.8 mg/s (electric power: 160W).

Fig. 4. PPI thruster and run in the vacuum chamber of the laboratory GREMI

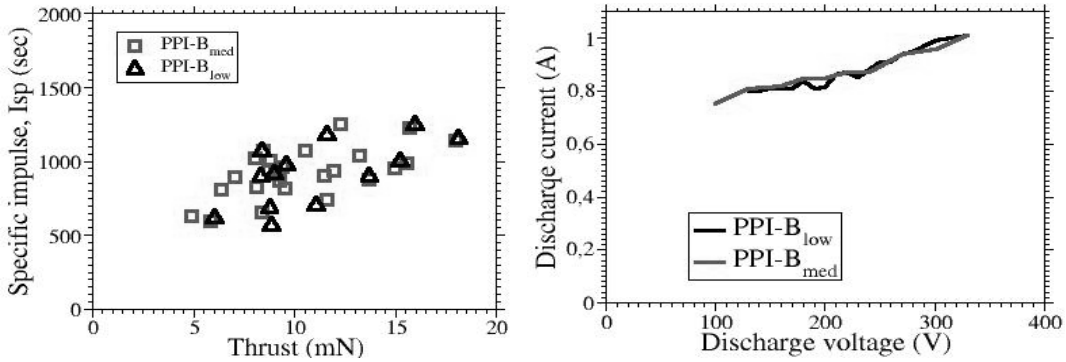

Fig. 5. Discharge current versus discharge voltage, and specific impulse versus thrust for two magnetic fields

Conclusion

At the National Aerospace University "KhAI was defined, manufactured tested and improved a set of successive SPT-20M HETs requiring an electric input power lower than 100W. The model SPT-20M6 delivers a thrust from up to 4mN with an global efficiency up to 38%. In parallel of campaigns carried out in the vacuum chamber of KhAI, other tests were performed in a vacuum chamber at the GREMI laboratory by O.E.S. and R.P.A. An optical diagnostic was proposed for an experiment during the flight to follow the erosion rate and to analyse the emission spectrum in a large visible optical range.

A new small HET using permanent magnets instead of magnetic coils has been recently manufactured in France. Experimental researches at the laboratories GREMI and ICARE show that the efficiency of the PPI thruster is 20% (electric power: 160W).

This work has been performed in the framework of the French Research group CNRS/CNES/SNECMA/ Universités n°3161 "Propulsion par plasma dans l'espace" and in the frame of the research agreement between the Universities of Paris 6, Orléans, Versailles-St Quentin and "KhAI" at Kharkov.

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НОВІ ФРАНЦУЗЬКІ РЕЗУЛЬТАТИ ДОСЛІДЖЕНЬ МАЛОГО ХОЛОВСЬКОГО ДВИГУНА У СПІВРОБІТНИЦТВІ З НАЦІОНАЛЬНИМ АЕРОКОСМІЧНИМ УНІВЕРСИТЕТОМ В ХАРКОВІ

А.В. Лоян, М.М. Кошелев, Т.О. Максименко, Т. Жиберт, С. Пелерін, А. Лефруа, А. Бушуль, Д. Паньон, М. Гуйот, П. Ренадин, М. Дудек

В даній статті показано значущість використання та дослідження холовських двигунів (ХД). Наведено досягнення в розробці ХД в цілому світі та діяльність України та Франції в цьому напрямку. ХД СПД-20М було розроблено в Національному аерокосмічному університеті «ХАІ». Оптичний метод було запропоновано для аналізу струменю плазми СПД-20М. СПД-20М було випробувано на двох випробувальних стендах (в Харкові та в Орлеані). У Франції було розроблено новий ХД PPI з використанням постійних магнітів замість котушок намагнічування. Було проведено нові випробування трьох успішних прототипів PPI у вакуумних камерах в лабораторіях GREMI та ICARE в Орлеані.

Ключові слова: електрореактивні двигуни, холовський двигун, оптична емісійна спектроскопія.

НОВЫЕ ФРАНЦУЗСКИЕ РЕЗУЛЬТАТЫ ИССЛЕДОВАНИЙ МАЛОГО ХОЛЛОВСКОГО ДВИГАТЕЛЯ В СОТРУДНИЧЕСТВЕ С НАЦИОНАЛЬНЫМ АЭРОКОСМИЧЕСКИМ УНИВЕРСИТЕТОМ В ХАРЬКОВЕ

А.В. Лоян, Н.Н. Кошелев, Т.А. Максименко, Т. Жиберт, С. Пелерин, А. Лефруа, А. Бушуль, Д. Паньон, М. Гуйот, П. Ренадин, М. Дудек

В данной статье показана значимость использования и исследования холловских двигателей (ХД). Приведены достижения в разработке ХД в мире и деятельность Украины и Франции в этом направлении. ХД СПД-20М был разработан в Национальном аэрокосмическом университете «ХАИ». Оптический метод был предложен для анализа струи плазмы СПД-20М. СПД-20М был испытан на двух испытательных стендах (в Харькове и в Орлеане). Во Франции был разработан новый ХД PPI с использованием постоянных магнитов вместо катушек намагничивания. Были проведены новые испытания трех успешных прототипов PPI в вакуумных камерах в лабораториях GREMI та ICARE в Орлеане.

Ключевые слова: электрореактивные двигатели, холловский двигатель, оптическая эмиссионная спектроскопия.

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