

Experience of Moscow Aviation Institute in the field of Electric Propulsion: history and state of the art

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Abstract: The MOSCOW Aviation Institute National Research University (MAI) has been and is one of the leading research institutes in the field of electric space propulsion. This paper gives an overview about the history of the EP activities in this institute and the ongoing research.

I. Introduction

MOSCOW Aviation Institute National Research University (MAI) since its foundation in 1930 has been aimed to qualify engineering and research specialists covering all subjects dealing with aviation and aerospace.

In the end of 50th years of the last century Prof. A. Kvasnikov initiated study ways for creating modern propulsion technology to achieve specific impulses orders higher than it was for chemical rocket engines. As a result in 1962 the Department of electric propulsion and space power plants was founded, which became later on one of the main research centres for investigating processes taking place in power production, power conversion and plasma devices. For more than 60 years the department graduated more than 150 candidates and 20 doctors of science under the leadership of the famous professors L. Latishev, L. Klochkova, L. Kvasnikov, I. Panevin, V. Tikhonov. The Department field of activity in various research programs are as followed: MPDs, arcjets, SPTs and Ion Thrusters; the thermo-physical processes in low and high pressure arcs; solar power converters of different types; fuelcells and thermoemission generators; accumulators and batteries; new ceramics materials; the influence of the outer environment and Electric Propulsion onto Spacecraft (SC), high energy particles interaction with materials. The Department scientists made great contribution to the development of EP theory on MPD, SPT and Ion Thrusters, prototypes creation for industry, etc. Some of this works are briefly summarized and foremost results are highlighted in this paper to show the great contribution of MAI in EP development in the USSR, Russian Federation and the worldwide.

The Research Institute of Applied Mechanics and Electrodynamics (RIAME MAI) was branched from the Department in 1987 for transferring better space technologies accumulated in the Department to the industrial companies. Many MAI scientists previously working at the Department formed the core of RIAME scientific command. The company Platar Ltd was founded in 1992 for securing on earth based technology needs in high power particles generators and ion sources, as well as production of specific power sources and measuring equipment for EP testing. Both this organizations invite the Department scientists for establishing their new scientific projects and hardware design.

Nowadays scientific interests of the Department cover the four main branches:

- electric space propulsion (under the direction of Prof. Sergey Khartov);

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- high performance on-board power plants (under the direction of Ass. Prof. Stanislav Sevruck);
- space craft / electric propulsion interaction (under the direction of Prof. Andrey Nadiradze);
- thermal and electrical problems of plasma technology (under the direction of Department chief, Prof. Igor Nazarenko).

50 scientists, including 2 Academicians (G. Popov and A. Koroteev), 4 professors, 3 associated professors, 1 senior lecturer and 1 assistant are currently working at the Department.

The unique experimental facilities have been developed by the Department. Test facilities in various sizes and pressure ranges that operate with different plasma sources and propulsion technologies equipped with modern diagnostic and measurement units are used both by MAI and by RIAME. All of them are involved for educational purposes as well as for performing different scientific researches by the orders of Russian and foreign aerospace companies. The Department scientists work in close cooperation with Russian leading scientific and aerospace centers, among which are: TSNIIMASH, Keldysh Research Center, NRC "Kurchatov Institute", S.P. Korolev Rocket and Space Corporation "ENERGIA", NPO named after S.A. Lavochkin, JSC Academician M.F. Reshetnev "Information Satellite Systems", "VNIIE Corporation" JSC, "Experimental Design Bureau Fakel" and others.

II. MAI contribution in the field of EP

Founder of the scientific school of "Power-propulsion plants of the Spacecraft's" was Professor A. Kvasnikov. Under his leadership in the end of 50th group of young scientists started researches in the field of propellant acceleration mechanisms in the new types of propulsion devices which later on got the name of electric propulsion.

Activity of the department staff, based on the works of Prof. Tikhonov, L. Latyshev, I. Panevin, L. Kvasnikov, O. Kudrin, L. Klochova, R. Chuyan, G. Popov, V. Rybakov, Y. Krasilnikov, M. Burgasov, I. Nazarenko, in the frame of more than 50 years was related to the investigations of the working processes in electric propulsion devices and power plants for the spacecraft's.

Scientific school of "Power-propulsion plants of the Spacecraft's" for the period of its operation was formed as few scientific areas as described hereinafter.

A. High current plasma thrusters

Founder of this area was Prof. V. Tikhonov. This scientific group had intensively studied working processes and acceleration mechanisms of the Magnetoplasmadynamic Thrusters (MPD) and Pulsed Plasma Thrusters. Prototypes and experimental models of plasma thrusters in various sizes had been developed through their work. For the achievements in the field of plasma accelerator researches V. Tikhonov was awarded the state prize of the USSR in the year 1990.

B. Electrostatic thrusters

This research area was led by Prof. L. Latyshev. Under his supervision researches of the working processes in Hall Effect Thrusters, Gridded Ion Thrusters and Colloid Thrusters was held and methods of optimization for the thrusters of named types was delivered. Also experimental models in power range from 50 W to 3-5 kW were developed and possibilities of usage in the related industries like fusion reactors or ion-plasma technology were outlined.

C. Thermal physic of Plasma Systems

This area was led by Prof. I. Panevin. Activity of established by him group was related to investigations of optical, thermal and thermodynamic properties of plasma and electro conductive mediums in electric and/or magnetic fields. Models of Low Temperature Plasma Generators of various types were developed by the group. Furthermore, they suggested computational methods of the processes, taking place in the sheath area, and its characterization and also radiation transfer processes inside plasma and dispersion medium. Thermal physic group suggested recommendation for organization of operational processes in Gas-cooled Nuclear Reactors and Droplet Refrigerators.

D. Power plants of the Spacecraft's

Prof. L. Kvasnikov was leading this scientific branch. Under his guidance was carried out investigation of solar concentrators, photovoltaic and thermionic convertors operational principles and performances. Group worked out scientific and technical base of the diagnostic of the surface conditions of thermionic elements. Laboratory prototypes of new types energy converters – electrochemical and thermo-electrochemical - was created and multistage power plants schemes on base of nuclear reactors

E. Integration of Electric Propulsion and Power Plants with Systems of the Spacecraft

Works of this sector, founded by Prof. M. Burgasov, were connected with detection of impact factors originating during Electric Propulsion and Power Plants operation on Spacecraft structures. In frame of this branch computational models was created, that gives insight to the mechanical, thermal and erosion influence of thrusters beam and individual factors to the SC.

For the researches in the field of the Electric Propulsion and Power Plants development most of the staff of the department – G. Popov, M. Burgasov, L. Kvasnikov, Y. Krasilnikov, L. Latyshev, I. Panevin, V. Rybakov, R. Chuyan, L. Klochkova, Y. Vasilyev, I. Nazarenko, S. Khovrin and other - in 1990 was awarded the prize of of the Council of Ministers of the USSR.

Scientific school of “Power-propulsion plants of the Spacecraft’s” is notable by organic combination theoretical and experimental investigation methods. From the first day of its foundation great attention is paid to intense training of the engineers, who is able to successfully work in high technology fast changing space industry. In order to do so department initiated education in the “Electric Propulsion and Power Plants” specialty and established unique experimental base, that is used for both scientific investigations and training of the students from the first year of they study.

As in former time, department is intensively working on various power and propulsion technologies in order to increase knowledge’s on their physical and operational principles and prepare recommendation for design and usage of different devices for spacecraft’s, most of which are being transferred to the industry for following implantation. Some of those works are being held in closed collaboration with RIAME MAI and Space Industrial Companies of Russian Federation.

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