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Никонова В. А.
Hybrid electric motor designing in the usa and russia: comparative analysis

***Nikonova V.A.**, 2nd year student {Design, Production and Operation of Rockets and Space-Rocket Complexes}*

***Scientific adviser: Romanov P.S.**, Doctor of Pedagogy, professor*

Leonov Moscow Region University of Technology, Korolev, Russia

This article we will learn how a hybrid electric works and its structure. And also the state of development of hybrid electric motors on the example of the Space race between Russia and the United States.

Keyword: propulsion, thruster, NASA, missions.

Introduction

Electric propulsion is a technology that uses plasma as the propellant. It typically has a higher specific impulse, or fuel efficiency, than conventional chemical rockets. Work on electric propulsion was initiated in 1906 by R. Goddard. Significant experimental research on electric propulsion was not started until the mid1960s. Electric propulsion currently has the potential to revolutionize space utilization. It can, for example, shorten interplanetary travel times between Earth and Mars, as with theVASIMR engine and the NSTAR's ion. Electric propulsion is an effective choice for deep space missions and longterm orbital station-keeping. The type of electric propulsion system required is dependent on its primary function. An electrothermal thruster is a type of electric thruster that uses a conventional rocket nozzle with an inert fluid as the propellant. This type of thruster has the lowest specific impulse of the three main EP types but yields a significant amount of thrust. An electrostatic thruster uses electrostatic grids to accelerate ions. The resulting propulsive force is comparatively small, typically millinewtons. This small force is enough to propel many spacecraft operating in low gravitational environments, making it ideal for deep-space missions because of its high specific impulse and efficiency. An electromagnetic thruster is a thruster that the plasma (a hot, electrically neutral mixture of electrons, positive ions and neutral atoms or molecules) is propelled from the Lorentz; this enhances specific impulse while yielding a relatively high level of thrust. These definitions, along with other definitions, are explained in the Glossary.

History

The original concept of electric propulsion was proposed by Dr. Robert Goddard in 1906. He theorized that electrons could be used to propel a spacecraft. The primary challenge to his idea was that the mass of the electrons are too small to provide any substantial thrust. The use of electrons would also charge the spacecraft. When he published his article in September 1906, he failed to calculate the amount of energy required for the electrons to attain a velocity near the speed of light. Although Goddard never considered using ions (much heavier than electrons) as the main propellant of electrostatic propulsion, this original theory initiated research into electric propulsion. After Goddard's study of electric propulsion, numerous scientists, such as Oberth and Glushko, started researching the study of electric propulsion.

How a hybrid electric motor works

The hybrid engine is designed in such a way that both engines work, relatively speaking, on each other. The internal combustion engine turns the generator and supplies the electric motor with energy, and that allows the «partner» to work in optimal mode without sudden fluctuations and loads. In addition, hybrids are usually equipped with a KERS kinetic energy recovery system (similar to the one used on Formula 1 cars).

This system allows you to charge the batteries during braking and when the car is rolling. The principle of its operation is that when braking, the wheels actuate an electric motor, which in this case itself plays the role of a generator and charges the batteries. KERS is especially useful when driving around the city in the «started-stopped» mode.

Progress of Electric Propulsion Research

Electric propulsion technology may be divided into three main types: electrothermal, electrostatic, and electromagnetic. Electrothermal propulsion uses fluid10 (liquid or gas) as a heated propellant in a conventional nozzle.

Electrostatic propulsion uses Coulomb-force electric fields to accelerate positive ions. Electromagnetic propulsion uses Lorentz forces to propel the plasma. Overall, electric propulsion offers a promising method to improve the performance of space propulsion systems, increase the fuel efficiency of these thrusters, and lower overall the cost of spacecraft.

1. The Space Race

1.1. USA experience

In 1958, the first ion engine model was demonstrated at Rocketdyne. In early 1959, another model was demonstrated at Electro-Optical-Systems. In 1960, the first full size electrostatic ion engine was tested at the National Aeronautics and Space Administration (NASA) Lewis (now Glenn) Research. In early 1964, the first sub-orbital flight using an ion engine was performed by the United States. Later that same year, the first electric engine used in an interplanetary probe was developed by the Soviets. During the mid-1960s, NASA Glenn Research Center developed the magnetoplasmadynamic (MPD) propulsion system. The MPD research was intermittent because of limited access to high-power electric supplies. In October 1998, the first ion thruster designed for deep space missions came into operation on Deep Space 1, a spacecraft developed by Jet Propulsion Laboratory (JPL). The mission was to perform a flyby around the asteroid

9969 Braille. JPL and NASA worked on NSTAR (NASA Solar Electric Power Technology Application Readiness program) to develop the ion engine for Deep Space 1. The spacecraft completed its mission flying by a near-Earth asteroid in July 1999 and comet Borrelly in September 2001, reaching a record-breaking maximum change of speed at 4000 m/s without the use of gravitational assistance. In June 2010, NASA's Dawn spacecraft broke Deep Space 1's speed record, reaching its maximum change of speed at 4300 m/s.

1.2. Russia experience

In 1918, Hermann Julius Oberth theorized the potential for electric engines to propel large spacecraft. He also envisioned the development of manned spaceflight. Oberth proposed a two-stage rocket for spaceflight that used an alcohol-oxygen liquid-propellant engine in its first stage and hydrogen-oxygen liquid-propellant engine in its second stage. This was discussed in his book Wege zur Raumschiffahrt (Ways to Spaceflight), published in 1929. A chapter on electric propulsion, titled Das elektrische Raumschiff (The Electric Spaceship), explained the fuel savings of an electric engine used for deep space missions. In 1929, Valentin Glushko tested the first electrothermal engine at the Laboratory Gas Dynamics located in Leningrad, USSR. Electrothermal propulsion creates thrust using a high-temperature gas (typically liquid in storage) as a propellant. The test was conducted on a standard test stand where the thrust or propulsive force was measured.

83 years ago, on August 17, 1933, the first domestic liquid rocket was launched, which began the development of a new industry.

In the USSR, practical work on the creation of liquid jet engines was launched in 1930. Various scientific organizations worked on the design of rocket engines. One of these organizations was created by F.A. Tsender in collaboration with a young aircraft designer S.P. Korolev at the Defense Society — a creative team called the Jet Propulsion Research Group (GIRD) and united many enthusiasts of rocket technology.In April 1932, the group was able to organize a design bureau of four design teams and launch serious research, which by the end of that year was conducted on eight independent projects. Korolev decided to take on another — the ninth project. So a new item appeared in the plans of the GIRD: «09 is a missile-projectile for data corresponding in range and payload weight to a 122-mm howitzer projectile, with an engine running on liquid oxygen and solid gasoline.»

Present time

— USA

The US National Aeronautics and Space Administration (NASA) has announced a research collaboration with GE Aviation to launch a new hybrid electric vehicle testing program. Flight tests of hybrid electric technology will be conducted on a modified Saab 340B test aircraft equipped with GE CT7—9B turboshaft engines.

As part of the Electric Drive Flight Test Project (EPFD), NASA will fund GE Aviation and its partners a total of $260 million over five years to accelerate the use of hybrid electric flight technologies in commercial aviation. After many years of developing parts for engines, generators and power converters of hybrid electric systems, GE will systematically improve the integrated hybrid electric transmission for narrow-body aircraft to demonstrate flight readiness.

Hybrid electric propulsion technologies that save fuel and optimize engine performance are central to GE's drive to contribute to a more sustainable future for aviation. While GE Aviation aims to achieve zero emissions from its products by 2050, the developed hybrid electric motors will help achieve this goal. Hybrid electric technologies are well compatible with environmentally friendly aviation fuel (SAF) and hydrogen, as well as with advanced engine architectures such as an open fan and new advanced engine core designs.

NASA and its partners will accelerate the transition of EAP (Electric Aircraft Propulsion) technologies to commercial products and become a catalyst for economic growth.

GE, in collaboration with NASA in the EPFD program, will also provide recommendations and data for setting standards, certification and regulatory requirements for hybrid electric motors.

The EPFD contract is based on GE Aviation's extensive experience in hybrid electrical systems and power generation, extensive research and flight component development capabilities at GE Research and GE Power. The most important GE milestones are listed below:

2009: Participation in the Boeing Subsonic Ultra Green Aircraft Research (SUGAR). NASA has requested the definition of aviation technologies that will reduce emissions and fuel consumption for future aircraft after 2030. The team evaluated hybrid electric power plants.

2013: The grand opening of the EPIS Center (Center for Integrated Power Supply Systems) in Dayton, Ohio, is dedicated to the development and testing of components and power supply systems for aircraft.

2015: 110 MW of electricity was successfully received from the F1 engine in a test chamber at ground level. Then, in 2016, a demonstration of the power consumption in megawatts was carried out at an altitude that corresponds to flight.

2016: An electric machine consisting of an MW class engine/generator was presented at the test stand, which supplies electricity to a propeller with a diameter of 3 meters 35 cm.

2019: Demonstration of an MW class engine / generator at an altitude of 36 feet at the NASA Electric Aircraft Test stand (NEAT) in northern Ohio. GE considers it the world's first energy-intensive electric vehicle of the MW and kilovolt class tested in flight conditions.

— **Russia**

2021: Soyuz created and tested a hybrid power plant GSU-0,5—300, based on the GTP-0,5—300 engine and a high-speed electric generator with a capacity of 500 kW. A hybrid power plant using electricity from gas fuel and modern generators will solve the problem of optimizing the use of gas fuel. In the near future, with their help, it will be possible to save energy and reduce emissions of harmful substances into the atmosphere, thereby reducing the carbon footprint. They will make it possible to abandon traditional schemes and take advantage of modern technologies, the press service of JSC «AMNTC «Soyuz» reports.The GTP-0.5—300 engine has previously passed a number of autonomous tests and confirmed its operability. At the first stage of combined testing of a gas turbine engine and a high-speed electric generator, it is planned to use the latter from third-party manufacturers.

Hybrid traction is a promising direction in the modern aircraft industry. This is one of the defining technologies for the future of aviation, which is why JSC «AMNTC «Soyuz» is currently making every effort to create a fully proprietary aviation hybrid engine, engaged in its own development of the VEG-0.5—300 power 500 kW and simultaneously organizing production facilities for its manufacture. In addition to the VEG-0,5—300, work is underway to create a line of generators with a capacity from 200 kW to 10 MW, for various applications.

It is also very important that, according to some scientific studies, the cost of aviation fuel can be reduced by more than 50%. Accordingly, carbon dioxide emissions will be reduced by the same amount. The emission of nitrogen oxides can be reduced to zero altogether. The liquefied natural gas used as fuel can also be used to cool an electric motor, thereby increasing the efficiency of electrical mechanisms at low temperatures and increasing their power.

Considering the dimensions (1900mm x 550mm x 650mm) of the GSU-0.5—300, its weight of 350 kg. and the assigned resource of 100,000 hours, it can be confidently stated that the scope of its possible use is very extensive, in such industries as aviation, helicopter construction.

2022: The range of hybrid and electric engines, including hydrogen-powered power plants, is being developed by CIAM specialists.

The Central Institute of Aviation Engine Building named after Baranov (CIAM) has revealed plans for the development of new power plants for aircraft. The Russian-designed units will include electric and hybrid engines, including hydrogen-fueled engines.

Upon completion of these research works, Russia will come very close to the opening of development work on the creation of a line of GSU and ESU (electric power plant) for aircraft with dimensions from 1 to 100 seats, including for promising aircraft of new shapes: multirotor type, tiltrotor, vertical takeoff and landing (air taxi)

In 2022, testing is planned at the Sigma 4E flying laboratory with an 80 kW electric motor with lithium-ion batteries of an electric power plant, and then a hydrogen version of the engine will appear. In addition, a hydrogen unit is being created on the basis of the VK-2500 aircraft engine.

CIAM plans for this year to begin work on the creation of a GSU with a multiple of 1.5–2.0 MW capacity. Its feature will be the use of not only a more powerful drive based on the VK-2500 engine, but also the use of liquid hydrogen as fuel and refrigerant.

It is expected that a Russian-designed hydrogen aircraft demonstrator may appear after 2035. It will be the first hydrogen-powered aircraft since 1988.

Recall that in the USSR, flight tests of the NK-88 engine on hydrogen were already carried out on the basis of the Tu-155 laboratory aircraft.

Conclusion

The hybrid electric thruster has been shown to have performance characteristics that would make it a suitable thruster for small spacecraft. The different operational modes of the engine offer versatility in performance. Optimisation of the design of the thruster may improve its performance further. A list of future optimisation work may include: Plasma Generation: The hybrid electric thruster could be refitted using alloys to reduce material fatigue and to improve the performance of the thruster. Additionally, the chamber could utilise permanent magnets to improve ionization for the ion thruster mode using electron cyclotron resonance to increase the degree of ionization by electron bombardment. Nozzle Design: The nozzle could be refitted with a range of exhaust-throat area ratios to determine the optimal design. As a cost of increasing that ratio, the nozzle might experience structural problems due to the force of the fluid. The nozzle could also be redesigned with a variable-geometry inlet. Electrostatic grids: The acceleration grids in the electrostatic thruster mode could be improved by using a different type of mesh grid. The mesh grid could be varied in geometry, porosity, and material choice. Addition of gas species: There is a possibility that the addition of another inert gas, such as argon, may further increase the performance of the thruster. Exposing the nozzle to solar radiation to reheat the plasma: Doing this may improve the performance of the thruster. The disadvantage of this is that the method only works when there is sufficient solar radiation. For deep-space missions to Mars and beyond, the solar radiation may be too weak for reheating.

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