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Comparison of frequently used satellite propulsion systems at a quick glance

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Abstract

In this paper, the motions and positioning of satellite systems in space and orbits, the preferred methods and the comparison of these methods with each other are given. These methods include evacuating a spacecraft or satellite from the Earth's atmosphere and gravity and placing it in the desired orbit, and new generation propulsion systems that have the potential to be used in space travel. Basically, to take an equipment or vehicle out of the atmosphere, an escape velocity must be reached, to reach this velocity a thrust is required. The system and fuel types required to provide this thrust are determined and explained. The systems required for propulsion are classified as chemical propulsion systems, nuclear propulsion systems and electric propulsion systems. Studies and developments related to satellite propulsion systems are given in accordance with the literature.

Introduction

As humanity, we have always had an interest in space. As a result of the studies carried out with the idea of going out of the atmosphere or traveling in interplanetary space, various successes were recorded and in 1957, the Sputnik spacecraft was the first artificial satellite sent to space. Then, cosmonaut Yuri Gagarin became the first human to go into space. As a result of these developments, it has been seen that going to space is an achievable goal, and studies in this field have begun to be given importance. The 'Moon voyage', the first manned voyage to space, was carried out in 1969 with the Apollo project, with the team of Neil Armstrong, Buzz Aldrin and Michael Collins. Today, studies in this field, which can be diversified by using new generation propulsion systems, aim to reach Mars and farther planets, and to facilitate people's lives with satellites to be placed in Earth orbit. In these studies, from the past to the present, in order for the spacecraft to exit the atmosphere, it must be pushed with a force in the opposite direction to gravity, and it must rise and break its relationship with gravity. If the launch object is an artificial satellite, it must be positioned in orbit to fulfill its mission. This spacecraft must reach an escape velocity of 11.2 kilometers per second to exit Earth. The necessary thrust to reach such a speed is obtained by converting chemical, nuclear and electrical energies into kinetic energy. The propulsion systems are Newton's third law; It works on the principle that when one object exerts a force on another object, the second object exerts an equal and opposite force to the first, forcing the object to move in the opposite direction [1].

In chemical propulsion systems, ignition is made by mixing fuel and oxygen under suitable conditions in a solid propellant rocket. It is formed by the high temperature that occurs during this time. Exhaust gases resulting from combustion are thrown out at high speed and propulsion is provided. Our disadvantage in this method is that fuel and oxygen required for combustion are added on top of the weight of the spacecraft, so the amount of energy required for movement increases [2].

Although nuclear propulsion systems are a system that can produce more energy with less mass, this type of nuclear rockets has the risk of radiation leakage. Its use has been suspended, since the nuclear explosion effect that will be carried out in the atmosphere during take-offs on Earth will be devastating.

Electric propulsion systems offer a newer understanding than other methods, and these system technologies will be examined as electrostatic (grid) ion motors and Hall effect propulsion motors. They were first tested by placing them on SERT-I and SERT-II satellites built in 1964 and 1970, the engines worked for 2011 and 3781 hours, showing much higher fuel efficiency than other propulsion systems in this area and attracted the attention of researchers. The purpose of propulsion systems is to manage the speed and direction of the vehicle as desired. Since long-term thrust is required instead of high thrust in non-orbital journeys, the number of researches involving electric propulsion systems is increasing today [3].

Propulsion Systems

The main limiting factor in out-of-orbit travel is the need for propulsion. We have to wait since the planetary alignments used to reduce this need and the Hohmann intervals that facilitate the transitions between orbits are not continuous. Developing technology aims to enable us to use electric propulsion systems and to become suitable for traveling without waiting for these intervals. In electric propulsion systems, according to the way electric motors generate power; It is divided into three basic groups as electrostatic, electrothermal and electromagnetic propellants [4].

Electrostatic Propulsion Systems

Electrostatic repellent has emerged by designing the impulse that arises with the force that occurs in the opposite direction when ions are accelerated by electric charge and thrown out over the grids, based on Newton's third law, the principle of conservation of momentum. They use less fuel compared to chemical rockets and solar panels are used as a power source to obtain the required ionization energy. However, this situation is seen as a disadvantage in tasks that cannot benefit from the sun's rays. Mercury was used as a fuel in engines in the first years. However, since the amount of harmful toxic waste is high, the use of xenon, argon, iodine and krypton has become widespread. Xenon, which is one of the fuels, is a type of fuel that can be easily ionized with a high atomic number and high efficiency.

In grid ion propulsion engines, high energy electrons are obtained by heating the cathode with the energy taken from the solar panels. These electrons are given to the mixing chamber, and then the xenon atoms in the fuel tank are sprayed into the mixing chamber for ionization to occur. The heated high-energy electrons collide with the xenons, forming positively charged ions. The positively and negatively charged electrodes inside the tank accelerate the ions by separating them from the plasma. When the ions are ejected at their current velocity, they create a thrust. In such thrusters, the average power is 5 kW, the exhaust output speed is 30 km/h and the thrust force is 120 millinewtons. They work with about 70% efficiency. While the fuel consumption is low and the continuous thrust is an advantage, the low thrust force is a disadvantage for the long journeys to be made with this type of engine. Developments continued after Deep Space 1, Hayabusa and Dawn using this propulsion system. Today, NASA has achieved a working time of 48000 hours with 870 kg of fuel with the Evolutionary Xenon Thruster Project [3].

Electrothermal Propulsions

Electrothermal thrusters use plasma to heat the fuel. They direct the energy of the heated fuel to an injector, converting it into kinetic energy and providing thrust. These systems, in which hydrogen, helium and ammonia are used as fuel, are also considered rockets. These systems, which started to be used with Meteor-3 in 1971, are also used in A2100 satellites and Aerojet MR-510 series rockets [5].

Electromagnetic Propulsions

Electromagnetic thrusters do not require the use of electrodes, which is an advantage that reduces the number of consumable materials. Plasma formation is provided by electromagnetic fields and the resulting plasma is accelerated and sprayed. They work by a principle called the Hall effect. In 1879, Edwin Hall discovered in his study that when a conductor, in which an electric current is passed, is exposed to a magnetic field perpendicular to it, the electrons carried in the conductor are affected by the magnetic field, creating polarization and creating an electrical potential difference. In Hall effect motors, the potential difference between the negatively charged cathode and the positively charged anode creates an electric field. High-energy electrons are released by heating the cathode. Energetic electrons are exposed to the electric field and move towards the positively charged anode in the plasma chamber [6].

Electrons in the chamber begin to rotate around the cylindrical center, then xenon atoms are sent to the chamber as fuel. After the collision, electrons are ejected from xenons and plasma is formed from positively charged ions. The positively charged ions are ejected by moving outward by being caught in the electric field and create a thrust. This method is used to provide propulsion for Hayabusa 2 and TURKSAT 6A satellites. There are also different methods such as MPD (Magnetoplasmadynamic) that uses the Lorentz force for high velocities and works with the behavior of charged particles in a magnetic field. However, the use of solar panels as a power source is insufficient to obtain such impulses. Nuclear energy is needed as an alternative, and research on the subject continues [7].

Results

Sample data and research results of spacecrafts in various satellite propulsion systems are given in Table 1. Magnetoplasma dynamic propellant is considered suitable for manned space travel compared to another spacecraft. For maintenance, research and service missions, grate ion propulsion engines and hall-effect spacecraft come to the fore.

Table 1. Effective values in different satellite propulsion systems [1]

Method	Active Material Output Velocity (km/s)	Thrust (N)	Ignition Delay
Solid-fuel rocket	1	$<10^7$	minute
NSTAR motor	30	0,09	hour
Arcjet system	10	10	minute
Hall effect thrust	30	0,08	month
Magnetoplasmadynamics propulsion (MPD)	60	100	week

Conclusion

Traveling to different planets and providing data and communication flow with satellites orbiting the Earth have become an accomplished reality, rather than a dream for humanity. Manned journeys to Mars are planned in the near future with the new generation spacecraft, in which nuclear powered propulsion systems and electric propulsion systems will be used together with scientific studies to approach our goals [8].

Work continues in Turkey for satellite systems. Under the leadership of TUBITAK UZAY, Hale continues its research on the propulsion engine. Since 2014, our country has been strengthening its position in the sector with the TURKSAT 6A satellite, which was developed in the laboratory in the TUBITAK UZAY campus.

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