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Research Article

Plasma propulsion for rocket engine using ion thruster

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Abstract

We know that Rocket is a device which moves on thrust provided by accelerating fuel &oxidizers which is nothing but the propellant and exhausting it from the nozzle of the rocket. But in plasma propulsion ,ionized gas is used to produce thrust. plasma contain charged particles, whose motion is strongly affected due to electric and magnetic fields, so with the application of electric or electromagnetic fields to plasma, it can accelerate its constituents and forward them to the back of rocket to produce the required thrust.The necessary fields can be generated by using magnets and electrode, or by passing electric currents through the plasma.

Keywords: *Propulsion, ion thruster, Hall effect, lorrentz force, MPDT, VASIMR*

1. Introduction

Plasma propulsion using Ion thruster uses plasma in thrust generation process. Even it gives less thrust than conventional rockets, they are able to operate at higher efficiencies for longer periods of time. Plasma engines are best solution for long distance space mission. But on other hand Plasma propulsion systems offer much greater exhaust speeds. Instead of burning chemical fuel & oxidiser to generate thrust, ion thrusters accelerates electrically charged atoms of inert gas like xenon to very high velocities. Plasma is produced by adding energy to a gas, by subjecting it to strong electric or magnetic fields, plasma contain charged particles, whose motion is strongly affected due to electric and magnetic fields, so with the application of electric or electromagnetic fields to plasma, it can accelerate its constituents and forward them to the back of rocket to produce the thrust. The necessary fields can be generated by using magnets and electrode, or bypassing electric currents through the plasma.

The electric power for creating and accelerating the plasma typically comes from solar panels that collect energy from the sun. But we can use solar power only up to asteroids belt. After this, electric power is must generated by nuclear power sources, because solar energy gets too weak at long.

Various ion thrusters have been designed, but mainly they are categories by two methods according to how the ions are accelerated.

1) Electrostatic ion thruster
2) electromagnetic ion thruster

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In electrostatic ion thruster, the Coulomb force is used and are categorized as accelerating the ions in the direction of the electric field.

Electromagnetic ion thrusters use the Lorentz force (which is created by the interaction of a radial electric current pattern with a concentric magnetic field) to accelerate the ions.

Electric thrusters tend to produce low thrust, which results in low acceleration.

Using 1 g is 9.81 m/s2;

$F = m\,a \Rightarrow a = F/m$.

If thruster producing a thrust (force) of 100 mN will accelerate a satellite with a mass of 1,000 kg by

0.100 N / 1,000 kg = 0.0001 m/s2

Thrust=2*η*power/(g*Isp)

Where
thrust is the force in N
η = the efficiency,
power =electrical energy going into the thruster in W
g is a constant, the acceleration due to gravity 9.81 m/s2
Isp = Specific impulse in s.
Electrostatic ion thrusters:-
Gridded electrostatic ion thrusters
These trusters commonly uses xenon gas. This gas has no charge and is ionized by bombarding it with energetic electrons. Due to this positive charged ions are forms. The electrons are provided from a hot cathode filament and get accelerated by the

oscillating electric field induced by an alternating magnetic field of a coil.

The positively charged ions are drawn out by an extraction system. This system consisting of 2 or 3 grids. After entering the grid system through the plasma sheath, the ions are accelerated due to the potential difference between the first and second grid. 1st grid is called as screen while other is known as accelerator grid.

2. Hall effect thrusters

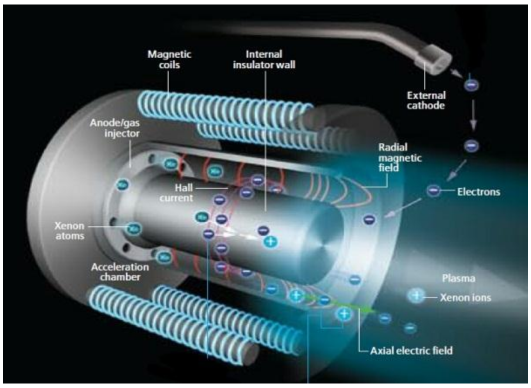

Fig.1: Hall thruster

The system is based on an effect discovered by Edwin H. Hall in 1879. Hall showed that when electric and magnetic fields are set such that they are perpendicular to each other inside a conductor, an electric current flows in a direction perpendicular to both fields. This current is known as hall current. These thrusters uses acceleration of ions with the help of an electric potential which is maintained between a cylindrical anode and a negatively charged plasma which is nothing but the cathode. In these thrusters, xenon gas as a propellant is introduced near the anode, where molecules of gas becomes ionized, and as result the ions are attracted towards the cathode, and leave the thruster at high velocity.

Electromagnetic thrusters

1) Magnetoplasmadynamic thruster (MPDT) or lithium Lorentz force accelerator (LiLFA)

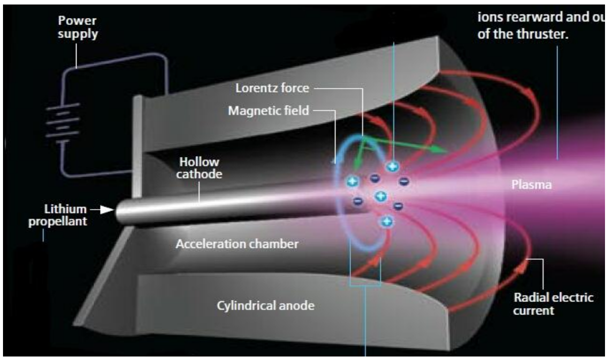

Fig.2 Magnetoplasmadynamic thruster (MPDT

Principle

An MPDT relies on the Lorentz electromagnetic force to accelerate the plasma to produce thrust. The Lorentz force which act along the axial direction, is created by the interaction of a radial electric current pattern with a concentric magnetic field In this thruster, a gaseous fuel is 1st ionized and then fed into an acceleration chamber, where the magnetic and electrical fields are created with the help of power source. The particles are then propelled by the Lorentz force as explained earlier.

An MPDT consists of a central cathode fitted within a larger cylindrical anode. A gas, mostly lithium, is fed into the annular space between the cathode and the anode. There, it is ionized by an electric current flowing radially from the cathode to the anode. This current induces an magnetic field such that field encircles the central cathode(azimuthal field), which interacts with the same current that induced to generate the Lorentz force which produces the thrust

2) Electrode less plasma thrusters

Electrode less thrusters have two unique features: the removal of the anode and cathode electrodes and the ability to throttle the engine. The removal of the electrodes reduces the percentage of erosion, due to this lifetime of ion engines get increased. Neutral gas is ionized by electromagnetic_waves and then send to another chamber where it is accelerated by an oscillating electric and magnetic field. Due to this separation of the ionization and acceleration stage, it give the engine the ability to throttle the speed of propellant flow, so that we can changes the value of thrust magnitude and specific impulse.

3) Variable Specific Impulse Magneto plasma Rocket (VASIMR):-

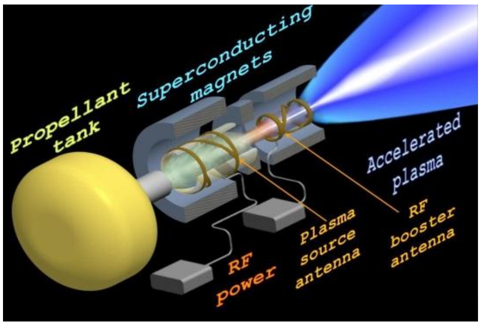

Fig .4 VASIMR

Principle

It is an electromagnetic thruster used for propulsion in space which uses radio waves to ionize and heat a propellant, and magnetic fields to accelerate the plasma to produce the thrust. This type of engine is electrod less and able to reach higher propellant temperature by limiting the heat flux from the plasma to the structure. Due to absence of electrodes its advantages are same as like of electrode less ion thruster .Every part of a VASIMR engine is magnetically shielded and does not come into direct contact with plasma that's why the durability of this engine is much greater than any other ion/plasma engine

VASIMR can be most basically thought of as a convergent-divergent nozzle for ions and electrons. The propellant (a neutral gas such as argon or xenon) is first fed into a hollow cylinder surfaced with electromagnets. When gas enters into the engine, the gas is first heated to a cold plasma by coupler (which is nothing buthelicon RF antenna) which bombards the gas with electromagnetic waves. By varying the amount of energy given to RF heating and the amount of propellant delivered for plasma generation, VASIMR is capable of generating either low-thrust & high–specific impulse exhaust or high-thrust & low–specific impulse exhaust.The second stage consist of a strong electromagnet which compress the ionized plasma in a similar manner as in convergent-divergent nozzle that compresses gas in conventional rockets.

Conclusions

1) Ion, Hall and MPD, VASIMR thrusters are variants of electric plasma rocket technology.
2) Few of them generate plasmas through electrode based discharge while others use coil-magnetic induction or antenna-generated radiation.
3) To accelerate plasmas, some use Lorentz forces; others accelerate the plasmas by feding them into the magnetically produced current sheets or by travelling them through electromagnetic waves.

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