DEPARTMENT OF AEROSPACE ENGINEERING

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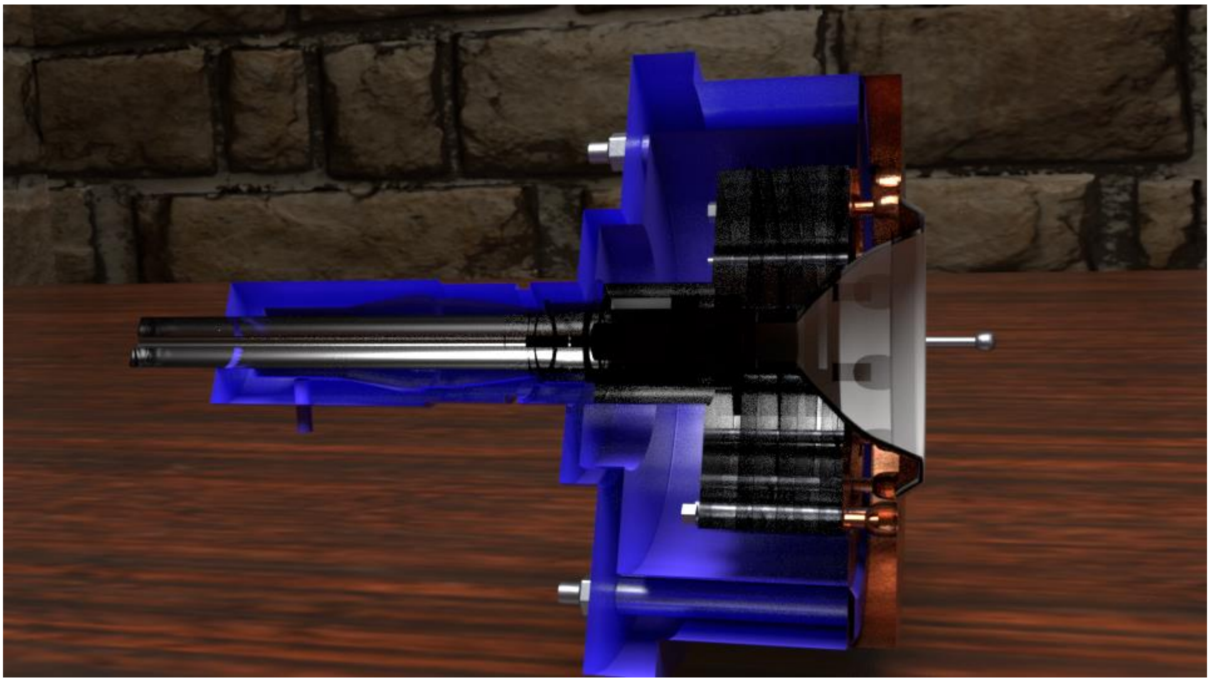
UNIT VI - FUNDAMENTALS OF ROCKET PROPULSION

MPD Thrusters and their Applications

Magnetoplasmadynamic (MPD) thrusters are electric thrusters that use electric and magnetic fields to generate thrust, offering high specific impulse and potential for high thrust densities, making them suitable for missions requiring rapid orbital changes or deep space travel.



What they are:

MPD thrusters are a type of electric propulsion system that utilizes the interaction between electric and magnetic fields to accelerate a plasma (ionized gas) and produce thrust.

How they work:

- A high-power electric current is passed through a propellant (e.g., hydrogen, argon) within the thruster, ionizing it into a plasma.
- A magnetic field, either generated by the current itself (self-field MPD) or an external source (applied-field MPD), interacts with the plasma, causing it to accelerate and be expelled as a jet, creating thrust.

Types:

Self-field MPD (SF-MPD): The magnetic field is generated by the discharge current itself. Self-field MPD (Magnetoplasmadynamic) thrusters are a type of electric propulsion system that uses magnetic fields to accelerate plasma to generate thrust. Unlike traditional chemical propulsion systems, which rely on the combustion of propellants, MPD thrusters rely on electromagnetic forces to ionize and accelerate a propellant to extremely high speeds. In a **self-field MPD thruster**, the magnetic field is generated by the current passing through the plasma itself, as opposed to using external magnetic coils, which are common in other types of MPD thrusters. Here's a basic breakdown of how they work:

Components:

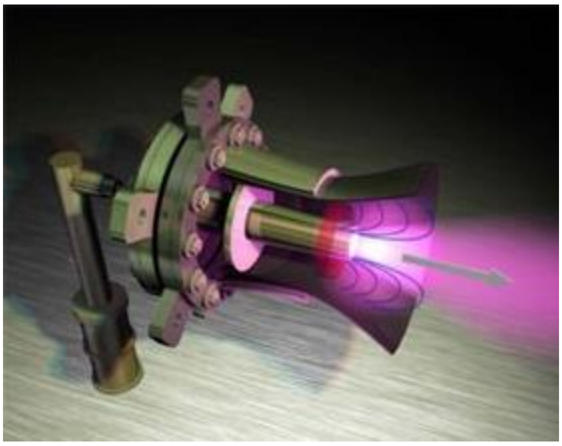
1. **Plasma Generation**: A propellant (like xenon or another ionizable gas) is introduced into the system and ionized by an electrical discharge, turning it into plasma.
2. **Electromagnetic Acceleration**: A high current is passed through the plasma and this current interacts with the self-generated magnetic field. The resulting Lorentz force accelerates the plasma, pushing it out of the thruster at high velocities.
3. **Thrust Generation**: The plasma exits the nozzle at high speeds, and the resulting action generates thrust based on Newton's third law (for every action, there is an equal and opposite reaction).

Advantages:

- **High Specific Impulse (Isp)**: MPD thrusters can achieve much higher specific impulses compared to conventional chemical propulsion systems. This means they can generate more efficient thrust over long periods, making them suitable for deep space missions.

- **Scalability**: MPD systems can scale to various sizes depending on the mission requirements, from small spacecraft to larger, more power-intensive missions.
- **Efficiency**: The ability to accelerate ions to high speeds allows for more efficient use of propellant

Applied-field MPD (AF-MPD): An external magnetic field, generated by electromagnets or permanent magnets, is used. Applied-field magnetoplasmadynamic thrusters (AF-MPDTs) are a type of electric propulsion system that uses an external magnetic field to accelerate plasma, offering high-thrust density and potential for high-power applications in space missions.



Key Features and Concepts:

- **External Magnetic Field:**

Unlike self-field MPD thrusters, AF-MPDTs employ an external magnetic field, typically generated by coils or magnets, to interact with the plasma and produce thrust.

- **High Thrust Density:**

AF-MPDTs are known for their ability to generate high thrust per unit power, making them attractive for applications requiring rapid maneuvers or high-speed travel.

- **Potential for High-Power Applications:**

The high power requirements of AF-MPDTs have historically limited their use, but advancements in power generation and storage (e.g., solar power) are making them increasingly feasible.

- **Thrust Mechanisms:**

The thrust of an AF-MPDT is typically assumed to be the sum of the applied-field, self-field, and gas-dynamic thrust components.

- **Applied-field thrust:** The Lorentz force (J x B) generated by the interaction of the plasma current with the applied magnetic field is a primary thrust mechanism.
- **Self-field thrust:** The magnetic field generated by the plasma current itself also contributes to the thrust.
- **Gasdynamic thrust:** The expansion of the plasma through a nozzle can also contribute to thrust, although it's often less significant under normal operating conditions.

  - **Applications:**

AF-MPDTs are being considered for a variety of space missions, including:

- **In-orbit servicing:** Enabling fast and efficient maneuvers for spacecraft servicing and repair.
- **Cargo missions:** Reducing mission time and costs for transporting cargo to the Moon or Mars.
- **Deep space exploration:** Providing the necessary thrust for long-duration missions to distant destinations.

Advantages:

- **High Specific Impulse:** MPD thrusters can achieve very high specific impulse (a measure of propellant efficiency), potentially exceeding that of current ion thrusters.
- **High Thrust Density:** They can generate higher thrust densities than electrostatic electric propulsion systems.
- **Scalability:** MPD thrusters can be scaled to operate at various power levels, from kilowatts to megawatts.
- **Potential for Rapid Orbital Transfers:** Their high thrust and specific impulse make them suitable for missions requiring quick delta-v maneuvers, such as capturing into orbit around another planet.
- **Cost-effectiveness:** MPD thrusters can be a cost-effective option for high-thrust electric propulsion.

Applications:

- **Interplanetary and Deep Space Missions:** MPD thrusters are being developed for cargo transport to lunar and Mars bases, crewed missions to Mars and the outer planets, and robotic deep space exploration missions.
- **Orbital Maneuvering:** They can be used for maneuvering, rapid orbital transfer, and decreasing trip durations on missions to the Moon, Mars, or other destinations.
- **Attitude Control and Stationkeeping:** MPD thrusters could be used for attitude control and stationkeeping of large space structures.
- **Small Satellites:** Miniature and low-power versions of MPD thrusters are being developed for small satellites (CubeSats).