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Basics and Types of Rocket Propulsion: A Review

Suvetha Navaan Ansar Pranith

BE-Aerospace BE-Aerospace BE-Aeronautical Mahendra Engineering College Mahendra Engineering

Collage Mahendra Engineering College Namakkal Namakkal

Abstract: For space travel and the insertion of satellites into planetary orbits, rocket propulsion is essential. Military applications use it extensively as well. Jet propulsion in the category of rocket propulsion creates thrust by ejecting burning propellant. This paper discusses different rocket propulsion techniques for space travel.

Keywords: Propulsion, thrust, fuel, oxidizer, specific impulse

INTRODUCTION

Since rockets can operate at any altitude, they need to bring their own fuel and oxidizers. The force that a rocket uses to lift off from the ground is known as rocket propulsion. For space travel and the insertion of satellites into planetary orbits, rocket propulsion is essential. It is useful in military applications as well. Jet propulsion that produces thrust by ejecting burning propellant is referred to as rocket propulsion. The third law of motion of Newton is used to generate the thrust. According to the type of energy source, rocket propulsion systems can be broadly categorized (chemical, solar, electric, or nuclear). Solid and liquid propellant rocket motors are the two types of rockets that are most frequently utilized.

PROPULSION SYSTEM

Every full-scale rocket has four main parts: the structural system, or frame; the payload system; the guiding system; and the propulsion system. The components of a rocket engine, such as the tanks, pumps, propellants, power head, and rocket nozzle, are all included in the propulsion system. Thrust generation is the purpose of the propulsion system. The power that propels a rocket through the atmosphere and into space is called thrust. The propulsion The mechanism of the rocket creates thrust. A working fluid is accelerated in every propulsion system. Fuel and an oxygen source, known as an oxidizer, are combined and ignited in a combustion chamber to create a rocket engine. Hot exhaust from thecombustion is sent via a nozzle to speed up theflow and create thrust. The hot exhaust createdupon combustion serves as the rocket'saccelerated gas or operating fluid. This is adifferent kind of operating fluid than what youwould find in an airplane with a gas turbineengine or propellers. While rockets use thecombustion exhaust gasses as their workingfluid, turbine engines and propellers utilizeatmospheric air. Turbines and propellerscannot function in space because there is no atmosphere. This explains why a propeller or turbine engine does not operate in space whereas a rocket does.

TYPES OF ROCKET PROPULSION

The major types of rocket propulsion are

1. Liquid-fuel chemical propulsion.
2. Solid fuel chemical propulsion.
3. Cold-gas chemical propulsion.
4. Ion.

A.Liquid-fuel chemical propulsion

The propellant is transported via liquid propellant systems in tanks outside the combustion chamber. A liquid oxidizer and a liquid fuel, which are used in the vast of these engines, are transferred from their respective tanks by pumps. Propellers are then pumped into the engine in a way that ensures atomization and quick mixing once the pumps boost pressure above the engine's working pressure.

O/F	Bulk density (kg/m^3)	C^*(m/s)	T (K)
4.83	320	2385	3250
2.77	1030	1780	3700
2.37	1200	1720	4100
1.42	1220	1770	3260

Propellant Isp(s) LO_2/LH_2 455.3 LO_2/RP-1 358.2 N_2O_4/MMH

341.5 N_2O_4/N_2H_4 343.8

TABLE I. Characteristics of Liquid Propellant Combinations

Advantages

They often have higher specific impulses than solids, the system can be restarted as often as intended, the thrust can be throttled, and the propellant flow can be monitored and controlled to accurately control the size of the thrust.

Disadvantages

The major drawback of liquid fuels is the additional mass that the launch vehicle must carry due to the need for pumps, pipelines, and separate storage for the fuel and oxidant. By combining various rocket motors, many launch vehicles circumvent the issues.

B. Solid fuel Chemical Propulsion

Air-to-air and air-to-ground missiles, model rockets, and satellite launchers all use solid rocket engines as boosters. In a solid rocket, the fuel and oxidizer are combined to form a solid propellant that is crammed into a solid cylinder. The combustion chamber is created by a hole in the cylinder. On the surface of the propellant, combustion occurs when the compound is ignited. A flame front is produced and it ignites the mixture. High pressure and temperature exhaust gasses are produced in large quantities during combustion. Engine designers utilize a variety of hole designs to manage the change in thrust for a certain engine since the volume of exhaust gas produced relies on the size of the flame front. The hot exhaust gas is forced via a nozzle to speed up the flow. The third law of motion of Newton is then applied, resulting in thrust

Advantages

Compared to liquid propellant rockets, solid propellant rockets are much simpler to store and handle. High propellant density also results in a small size. Solid propellant rockets are the best choice for use in space and the military due to their simplicity and low price.

Disadvantages

Upon ignition, the motor cannot be regulated, and the specific impulse is fairly low due to the solid propellant's low chemical energy.

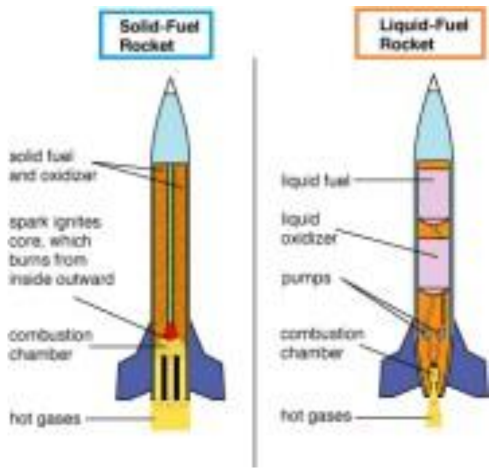

Fig. 1 Solid-Fuel Rocket and Liquid-Fuel Rocket

C. Cold-gas chemical propulsion

A cold gas thruster, also known as a cold gas propulsion system, is a form of rocket engine that produces thrust by the expansion of a pressurized gas that is normally inert. A cold gas thruster has less thrust and efficiency compared to conventional monopropellant and bipropellant rocket engines since it lacks combustion, in contrast to normal rocket engines. Cold gas thrusters' simple design, which only includes a fuel tank, a regulating valve, a propelling nozzle, and the little plumbing needed, has led to their being referred to as the "simplest manifestation of a rocket engine." They are the most affordable, straightforward, and dependable propulsion systems for attitude control, orbital maintenance, and maneuvering.

Advantages

Compared to traditional rocket engines, the cold gas system and its fuel are affordable.Compared to a conventional rocket engine, the basic design is less prone to malfunctions.When used, cold gas thrusters prevent the spaceship from accumulating a net charge.

Disadvantages

High thrusts cannot be produced using cold-gas thrusters. Less mass efficient compared to traditional engines. Pressure inside the storage tank decides the maximum thrust of cold gas thrusters.

Ion

Ion thrusters are being developed for a wide range of tasks, from guiding spacecraft across our solar system to station-keeping, which involves positioning communications satellites in the right location. For a given mission, these thrusters utilize substantially less propellant than chemical propulsion would, due to their high specific impulses—ratio of thrust to the rate of propellant consumption. In some circumstances, if the spacecraft cannot carry enough chemical fuel to complete the targeted mission, ion propulsion is even thought to be mission-enabling. Ion thrusters produce ions by ionizing propellant by adding or withdrawing electrons. The majority of thrusters ionize fuel by bombarding it with high-energy electrons, which release electrons from the fuel atom and create positively charged ions when they hit neutral fuel atoms. Positive ions and negative electrons are present in the gas in amounts that yield no overall electric charge. This is referred to as a plasma. Plasma resembles a gas in certain ways, but it is influenced by magnetic and electric forces. Lightning and the material found inside fluorescent light bulbs are two typical examples. Over 100 geosynchronous Earth orbit communication satellites are currently maintained in place by ion thrusters , and the three NSTAR ion thrusters that power the Dawn spacecraft utilize technology pioneered by Glenn. The protoplanets Vesta and Ceres are orbited by Dawn, the first spacecraft to do so in the asteroid belt between Mars and Jupiter.

Advantages

It has a very high specific impulse.The efficiency of an ion drive is high. It has a very long duration of its small thrust.Unlike chemical engines, which take vast amounts of gas and spout it out at moderate speeds, ion engines use extremely small amounts of gas to accelerate it to very high speeds.

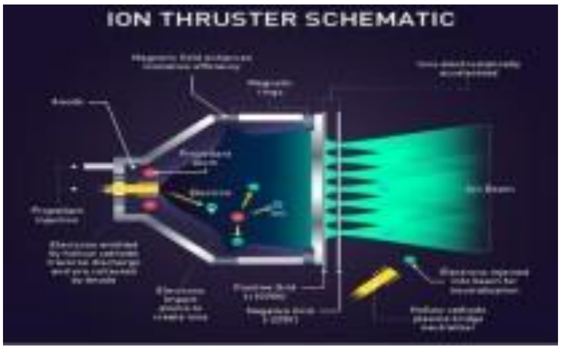

Fig. 2 Ion Thruster

Disadvantages

Extremely slow acceleration when in comparison to chemical rockets.As a result of its low thrust, it cannot be used to launch from a planetary surface because the spacecraft would not be able to move at all (besides ion drives work only in a vacuum).An external energy source is also required for an ion drive, unlike chemical rockets where the fuel serves as both the fuel and the energy source.

ADVANCED PROPULSION TECHNIQUES FOR DEEP SPACE TRAVEL

There exist a lot of traditional propulsion techniques for space travel, since a never ending development takes place in the field of aerospace which results in the arrival of new techniques. Some of the advanced rocket propulsion techniques are,

1. Plasma propulsion engine.
2. Magnetoplasmadynamic thruster.
3. Electrodeless plasma thruster.
4. Pulsed inductive thruster.
5. Pulsed plasma thruster.
6. Variable specific impulse magnetoplasma rocket (VASIMR)
7. Vacuum arc thruster.

Due to their moderate thrust, electrically powered rocket propulsion approaches are more suitable for spacecraft than for rockets. As a result, these techniques are excellent for unmanned vehicles like satellites and for probes that are intended for missions in deep space. On the other hand, nuclear propulsion is ideally suited for deep space rockets since it can provide strong thrust for an extended length of time while using less fuel, as well as for manned deep space missions. Exploration and Comprehension of deep space relies heavily on the

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use of nuclear energy.

FUTURE OF ROCKET PROPULSION

Chemical fuels will continue to be used for Earth launched rockets for the near future. Eventually, nuclear engines might take over and provide propulsion to accelerate spaceships through space once they are in orbit.

CONCLUSION

A lot more spacecraft have been launched since the first unmanned satellite, Sputnik I, with each one starting a different mission as a result of the romanticism surrounding space travel. In order to advance the frontier in space, mankind has also explored the possibility of various rocket propulsion. We discussed four distinct rocket propulsion drives in this paper. They were meaningfully described and analyzed, varying from the practical to the seemingly impossible. Certainly, each of them offers a variety of unique chances and opportunities for upcoming space exploration.

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