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ROCKET PROPULSION : CLASSIFICATION OF DIFFERENT TYPES OF ROCKET PROPULSION SYSTEM AND PROPULSIVE EFFICIENCY

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Abstract—Abstract - In this paper my main accentuation is on Rocket Propulsion and classification of different types of propellant and propulsion system and their application is the one of the part of Propulsion. Rocket Propulsion play a predominant role in space Mission, Defense and Propulsion Research and Analysis. The importance of different types Rocket propulsion is increasing in Space Mission like Satellite launching, orbit achievements etc., warfare and Defense Aviation Application. The application of Rocket propulsion is used in the missile, satellite, warfare, defense security and in defense aviation.

Keywords— Rocket propulsion, Staging, Propulsion efficiency

I. INTRODUCTION

The rocket is a reaction device which work on the Sir Isaac Newton's Third Law of Motion which states that "every action there is an equal and opposite reaction". Although a rocket is a reaction device, but all reaction devices are not rockets. A rocket is a special case because in which all the important operating elements are available, including fuel and oxygen both.

The history of rocket propulsion can be traced back to eighth century when the Greeks learnt the art of flying fire. On that time the use of the principle of rocket is quite uncertain, Chinese were the first to use this principle in fire arrows since 1234. In spite of the fact a huge number of observers were working on rockets, it was only during the two World War that rocket was given its due importance for warfare and other uses.

In 1919, Dr. R.H. Goddard from USA published the first report on rockets. After that, with the advent of German V-1 and V-2 rockets, the rockets started establishing. V-1 is the first rocket working on the constant -volume explosion type combustion; it was actually a pulsejet. Than V-2 rocket is came as a liquid propulsion device, using liquid oxygen and ethyl alcohol in water as main propellants. In many ways the rocket is similar to the other jet power plant but the major difference between rocket engine power plant and other jet propulsion system is that it carries its entire propellant

(oxidizer and fuel) with it, other jet propulsion systems depend upon atmospheric air.

II. CLASSIFICATION OF ROCKETS

In rocket propulsion the necessary energy and momentum that can be imparted by a propellant can be achieved in many ways, e.g. chemical, nuclear, solar etc. With the help of electric power propellant can be heated than expelled in a nozzle. Figure.1. shows the classification of rockets on the basis of the methods used for accelerating the propulsion devices.

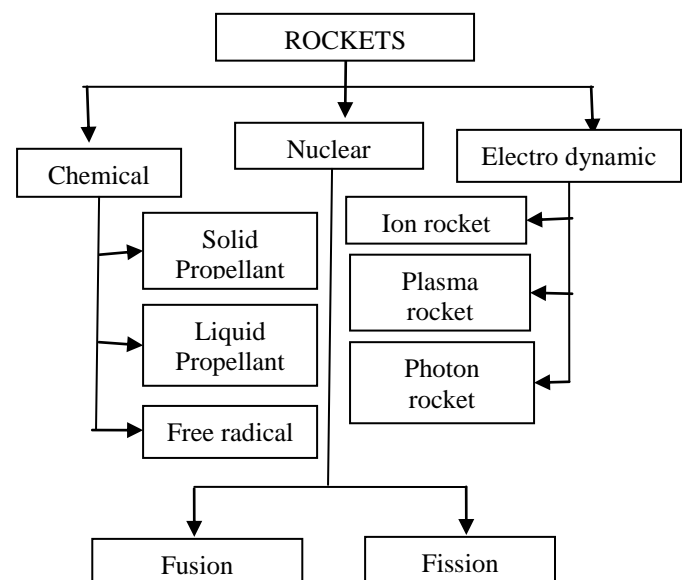


Fig. 1. Clasification of rockets.

A. Chemical Rocket –

Chemical rockets are mainly categorize on the basis of the type of propellant used:

- Solid propellant rocket
- Liquid propellant rockets
- Free radical rockets

Solid propellant rocket engine –

Solid propellant rocket engine consist of a combustion chamber, an expansion nozzle and an igniter. In this type of rocket entire propellant is contained in the combustion chamber which has its oxidant within the fuel itself. The time period of combustion is relatively short usually less than a minute. Solid propellant grain is the homogeneous mixture of fuel and oxygen. Combustion done with an igniter which is a pyrotechnic mixture triggered by an electric system. The solid rocket motor cannot be shut off once started and that its duration is short.

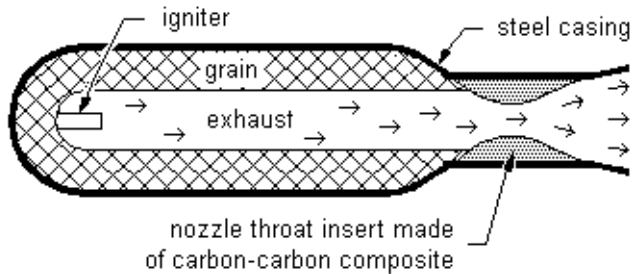


Fig. 2. Solid Propellant Rocket Motor.

A modification of solid propellant engine is the Hybrid engine, which is the combination of both solid propellant and liquid propellant rocket engine. In which solid propellant use as fuel because of high energy potential and liquid propellant use as the oxidizer.

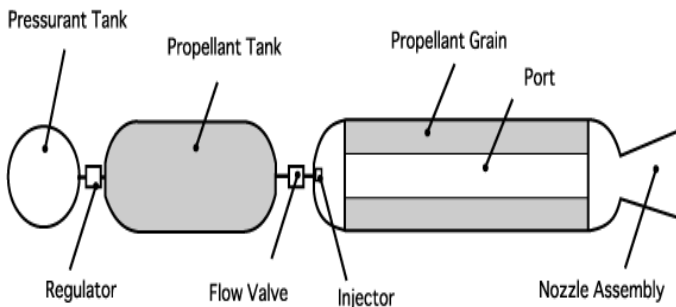


Fig. 3. Hybrid propellant rocket engine system.

Liquid propellant rocket engines –

Liquid propellant engine divided into some categories these include monopropellant systems, cryogenic and storable bipropellant systems and hybrid systems.

Liquid propellant rocket consists of a fuel tank, an oxidizer tank, different lines of control valve and rocket motor. In which the injector receive the liquid oxidizer and fuel and direct them in liquid stream so that they mix up with one another and make a chemical reaction in the combustion chamber. Due to reaction of fuel and oxidizer in combustion

chamber, very high pressure and temperature gases are produced which is expanded in nozzle to produce a high supersonic exit velocity. In which a cooling system is necessary to prevent the walls of motor from heating because temperature of reaction often exceeds 2700°C.

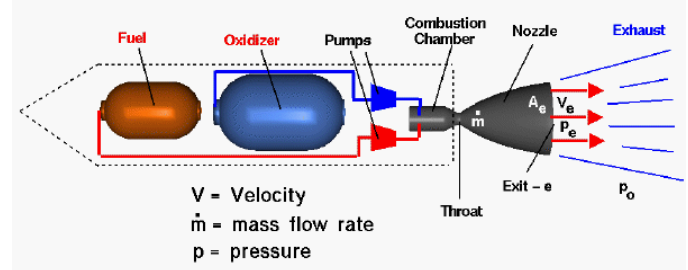


Fig. 4. Liquid propellant rocket engine.

Free Radical Propulsion –

Free radical propulsion utilizing the recombination energy of dissociation low molecular weight gases to produce thrust. In which a stable chemical material is supplied with sufficient energy to break the energy bonds some unstable free radical will be produced. The molecular Hydrogen, with certain concentration of unstable free radicals in it, is the best propellant due its lower molecular weight.

B. Nuclear Propulsion –

Nuclear propulsion includes a wide variety of propulsion methods that fulfill the promise of the Atomic Age by using some form of nuclear reaction as their primary power source. Only two type of nuclear reactions which can be used to produced energy.

1. Fission.
2. Fusion

In fission, heavy molecule is broken into fragments by the bombardment of neutron on its nucleus. It consist a nuclear core having ^{235}U as the nuclear fuel. Reaction controlled by control rods. To avoid leakage of neutrons a reflector is provided. As propellant hydrogen is used, which takes up heat from the reactor and expands in the nozzle.

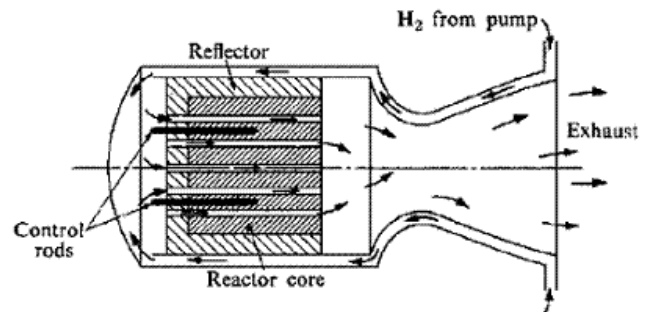


Fig. 5. Solid core nuclear-heated hydrogen engine.

In fusion, which is also known as thermonuclear reaction, light elements nuclei are fused into a heavy nucleus and in the process huge amount of energy. Coulomb repulsive forces



between the nuclei must be overcome to start fusion reaction, its required temperature is in order of 10^6 K.

C. Electro Dynamic Propulsion –

The exhaust velocity of the electro dynamic propulsion engines is much more than 4 to 10 times of chemical rocket engines and thus they have considerable potential for space propulsion. Basic electric rocket motor propulsion engine is:

1. Ion rocket propulsion.
2. Plasma rocket propulsion
3. Photon propulsion

These engines energy source is separate from propulsion devices.

Ion rocket propulsion engines –

The main components are

1. Propellant supply and propellant feed mechanism.
2. Thrust chamber
3. Electric power supply.

There are two basic ion propulsion engine, electrostatic and electromagnetic.

An **electrostatic** ion engine works by ionizing a fuel (often xenon or argon gas) by knocking off an electron to make a positive ion. The positive ions then diffuse into a region between two charged grids that contain an electrostatic field. This accelerates the positive ions out of the engine and away from the spacecraft, thereby generating thrust. Finally, a neutralizer sprays electrons into the exhaust plume at a rate that keeps the space vehicles electrically neutral.

An **electromagnetic** ion engine also works by ionizing a fuel. In this case a plasma is created that carries current between the ionizing anode and a cathode. The current in turn generates a magnetic field at right angles to the electric field, and thereby accelerates the positive ions out of the engine via the Lorentz force – basically the same effect on which railguns are based. Again a neutralizer keeps the spacecraft electrically neutral.

Plasma rocket propulsion –

Plasma propulsion engine generate thrust from a quasi-neutral plasma. Plasma propulsion is differs from ion propulsion because in which to accelerate the propellant the electrical forces are not used directly. Before expansion of propellant through nozzle, propellant is heated at very high temperature. It is a hybrid thermal-electrical propulsion system. It relies on expansion of hot plasma for bulk of its thrust but its energy is supplied electrically rather than by chemical combination or by nuclear fusion or fission. The plasma rockets are mainly two types: 1. Arc plasma rocket engine and, 2. Magneto plasma rocket engine.

Photon Propulsion –

Photon propulsion engine consist a hot nuclear power source to generate a flux of photons, which is shaped by a photon absorber and then escapes through the nozzle producing a thrust.

Photons are electromagnetic quanta of energy but protons have no intrinsic mass, it carry a momentum which is equal to hf/c , where

h = Plank’s constant

f = frequency of radiation and,

c = velocity of light

According Einstein’s equation $m=E/c^2$ when photons are produced some mass disappears or some mass is transferred in photon emission.

On that time such rockets are not feasible, but probably have a great future potential!

III. ROCKET PROPULSION PRINCIPLE

The rocket engines in the simplest form consist of a combustion chamber and an exhaust nozzle. The fuel and oxidants ignite with each other and produced combustible exhaust gases. These gases produced required propulsive forces. These high velocity gases expands through the rocket nozzle and produce the thrust and propel the rocket. That means the principle of rocket propulsion depends upon Newton’s Third Law of Motion which states that “every action there is an equal and opposite reaction”. Power required to produce an exhaust jet velocity, C_j

$$P = \frac{1}{2}mC_j^2$$

Thrust can be written as

$$F = mC_j = Ma$$

Where: M = mass of the rocket

m = mass rate of consumption of propellant

C_j = exhaust velocity from the nozzle

F = thrust

P = power required to give an exhaust jet velocity C_j

a = acceleration of the rocket

Note: for going out of the earth’s gravitational field high acceleration needed. For this chemical or nuclear systems may be used. Once the gravity limit is crossed the low acceleration by ion or plasma devices is sufficient for inter-planetary travels.

IV. STAGING

During the launch the rocket sheds excess weight usually empty tankage and associated engines. Staging is the serial where the rocket become light after every previous stage has fallen away, where rockets are burning together and then detach when they burn out.

Multistage rocket – a multistage rocket uses two or more stages, each stage contains its own engines and propellant. In tandem or serial stage is mounted on top of another stage but in parallel stage is attached alongside another stage. Two stages rockets are quite over but rockets with many stages have been successfully launched.

In serial staging the first stage is at bottom and usually it is large than another stage, the second stage and subsequent upper stages are above it, usually decreasing in size.



In parallel solid and liquid rocket booster are used to assist with lift off preferred as stage 0 sometimes. First stage is use to propel rocket upward, when booster run out of fuel, they are detached from rocket and fall away. Similarly another second stage and subsequent stage burn and detached, this process repeated until the final stage's motor burn completion.

V. EXPERIMENT AND RESULT

Propulsive efficiency is considered here as result of the Rocket propulsion. Propulsive Efficiency is known as the ratio of useful power output to the rate of energy input. For flight, propulsive efficiency, the expression is:

$$\text{Thrust} * \text{Flight Speed}$$

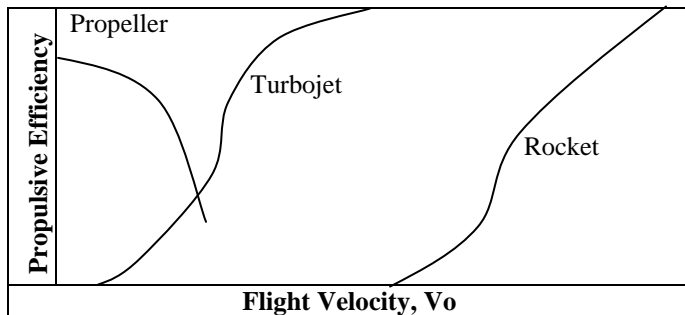


Fig. 6. Propulsive efficiency at different speed of various propulsion system

Power Plant	Thrust per unit engine weight	Frontal area per unit thrust	Specific fuel consumption
Rocket			
Ramjet			
Turbojet			
Piston			

Fig. 7. Performance details of different propulsive systems.

VI. CONCLUSION

In summary, there are two general measures of the performance of a rocket engine.

1. Specific impulse, which will determine the amount of propellant that must be used to accomplish a given task.
2. Fixed weight of the engine, including the necessary tankage, power supply, and structure.

Chemical rocket engine are light in weight and its specific impulse is not high. In present solid and liquid propellant is use and deliver an impulse of around 250 seconds.

Nuclear rocket is not limited by propellant binding energies, its constrained by temperature limitations of wall materials. Using hydrogen as a propellant to specific impulse value 1,000 seconds or more are feasible.

The first consideration in obtaining useful thrust from ion or plasma rockets is the construction of lightweight electric power. Which use in solar system flight due to the low thrust devices.

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