# Rocket Propellant.

Rocket propellants consist of rocket engines powered by propellants. These are used both in space vehicles as well as in offensive weapons such as missiles. The propellants are chemical substances which on ignition provide thrust for the rocket to move forward. These substances are called **rocket propellants**. A propellant is a combination of **an oxidiser** and **a fuel** which when ignited undergoes combustion to release large quantities of hot gases. The passage of hot gases through the nozzle of the rocket motor provides the necessary thrust for the rocket to move forward according to Newton's third law of motion.

The function of a rocket propellant is similar to that of petrol in a motor car except that in the later case, the oxygen needed for burning the fuel is taken from the atmospheric air.

(1) **Types of rocket propellants:** Depending upon the physical state, propellants can be classified as :

(i) **Solid propellants:**The solid propellants are mixtures of solid fuel and a solid oxidiser. These are further divided into two classes,

(a) Composite propellants: These are solid propellants which use polymeric binder such as polyurethane or polybutadiene as a fuel and a solid oxidiser such as ammonium perchlorate, nitrate or chlorate. The performance of these propellants can be increased by using some additives such as finely divided magnesium or aluminum metal along with the fuel.

(b) Double base propellants: These are solid propellants which mainly use nitroglycerine and nitrocellulose. The nitrocellulose gels in nitroglycerine set in as a solid mass.

The main disadvantage of solid propellants is that these propellants once ignited will continue burning with predetermined rate. These cannot be regulated.

(ii) **Liquid propellants**: These consist of an oxidizer such as liquid oxygen, nitrogen tetroxide $(N_2O_4)$ or nitric acid and a fuel such as kerosene, alcohol, hydrazine or liquid hydrogen. These are further classified as,

(a) Monopropellants: The propellants in which a single chemical compound acts as fuel as well as oxidizer are called monopropellants. For example, hydrazine, nitromethane, methyl nitrate, hydrogen peroxide, etc. Except hydrazine, the other compounds contain both the oxidizer and the fuel elements in the same molecule.

(b) Bipropellants: These are propellants in which the fuel and oxidiser are stored separately but are allowed to combine at the time of combustion. For example, kerosene and liquid oxygen.

Note: Hydrazine can act both as a monoliquid as well as a biliquid propellant. Hydrazine $(H_2N-NH_2)$ acts as a monoliquid propellant as it decomposes exothermally into hot gaseous mixture of $N_2$ and $H_2$,

$H_2N-NH_2 \rightarrow N_2+2H_2+$ heat

As a biliquid propellant with liquid oxygen as oxidiser,

$H_2N-NH_2+O_2 \rightarrow N_2+2H_2O+$ heat

**Advantages of Biliquid Propellants over Solid Propellants**

- ❑ The biliquid propellants give higher thrust than solid propellants.
- ❑ The thrust generated by liquid propellants can be controlled by switching on and off the flow of propellants. On the other hand, the thrust cannot be controlled in solid propellants.

(iii) **Hybrid propellants:** These are the propellants which consist of solid fuel and a liquid oxidiser. For example, liquid $N_2O_4$ (liquid oxidiser) and acrylic rubber (solid fuel).

(2) **Examples of Propellants used in Different Rockets**

(i) **Saturn booster rocket** of American space programme used a mixture of kerosene and liquid oxygen as the propellant in the initial stage whereas liquid oxygen and liquid hydrogen were used as propellant in high altitudes.

(ii) Russian rockets such as **Proton** used a liquid propellant consisting of kerosene and liquid oxygen.

(iii) The Indian satellites SLV-3 and ASLV used composite solid propellants.

(iv) The rocket PLSV will use solid propellant in the first and third stages and liquid propellant in second and fourth stages. The liquid propellant will consist of $N_2O_4$ and unsymmetrical dimethyl hydrazine (UDMH) and $N_2O_4$ andmonomethyl hydrazine (MMH) respectively.

In our country, Indian Space Research Organization (ISRO) has been set up to launch and utilize two classes of satellites : remote sensing satellites and communication satellites. The Polar Satellite Launch Vehicle (PSLV) is a remote sensing satellite. India has succeeded in launching several space vehicles using various rocket propellants. India's latest vehicle, PSLV–C4 took flight on 12$^{th}$ September, 2002 and it was named METSAT MISSION. It consists of four stage vehicle. The first stage is one of the largest solid propellant boosters in the world and carries about 138 tonnes of hydroxyl terminated polybutadiene (HTPB) based propellant.

The second stage uses indigenously built VIKAS engine and carries 40 tonnes of liquid propellant unsymmetrical dimethyl hydrazine (VDMH) as fuel and nitrogen tetroxide ( $N_2O_4$ ) as oxidizer.

The third stage uses 7.6 tonne of HTPB based solid propellant.

The fourth and terminal stage of PSLV-C4 has a twin engine configuration using liquid propellant. Each engine uses 2.5 tonnes of monomethyl hydrazine as fuel and mixed oxides of nitrogen as oxidizer.

(3) **Calculation of specific impulse of propellant**

The function of rocket propellant is based on specific impulse which measures the kinetic energy producing ability of the propellant. The specific impulse $(I_s)$ can be calculated from the following equation,

$$I_s = \frac{1}{g}\sqrt{\left(\frac{2\gamma}{\gamma-1}\right)\left(\frac{gRT_c}{M}\right)\left(1-\frac{p_c}{p_e}\right)^{\frac{\gamma-1}{\gamma}}}$$

Where,

γ = Ratio of specific heat at constant pressure to specific heat at constant volume.

$T_c$ = Combustion chamber temperature.

M=Average molecular mass of exhaust products.

$P_e$=External pressure

$P_c$ = Chamber pressure, and

R = Gas constant

The above equation shows that the conditions favouring high specific impulse are high chamber temperature and pressure, low molecular mass of exhaust products and low external pressure.

The higher the temperature and pressure achieved in the chamber, the higher the kinetic energy of the gases escaping through the nozzle.