Governing Principles of Rocket Flight

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Abstract: ***This paper gives you the information regarding rocket flight; the principles behind the flight and various technologies used. It also includes the various factors which improve or increase the rocket flight.***

Keywords: Separation mechanism, Newton's law, Law of Conservation.

1. Introduction

An incredibly enormous amount of energy is required for a rocket to escape the Earth's gravity and reach space. Therefore fuel occupies greater part of rocket weight. So there occurs the problem, a huge lifting force is doing required for the rocket to escape from the earth's gravitational force.

2. Development of rockets and technological elements involved

Wide verities of technological elements are involved in the development of actual rockets. These include:

a. Structural mechanics and materials engineering – to develop the rocket airframe as a structural body.
b. Propulsion and combustion engineering – to develop the engine that produces thrust.
c. Aerodynamics – to evaluate the impact of aerodynamic forces;
d. Control engineering – to stabilize rocket attitude and guiding satellites into their targeted orbits.
e. Flight analysis – to calculate the rocket's flight performance.

3. Separation mechanism

Development of the "separation mechanism" proved a very tough challenge. When assembling a multi-stage rocket, we use a mechanism known as the "separation joint" to connect the first and second stages. During the first stage combustion after launch, the separation joint, as an integral part of the rocket, must securely connect together the first and second stages. The stages must then separate without fail at the moment first stage combustion ends and the second stage prepares to ignite. Today we can choose from a variety of separation mechanisms, such as pyrotechnic devices, and these essential components benefit from improved reliability. However, everyone involved in rocket launches remain on pins and needles from the moment of launch until the artificial satellite has separated safely from the rocket's final stage.

4. Law of action-reaction / Newton's Third Law

If you release an inflated balloon, it will zip about, expelling air. A force is generated forward in "reaction" to the air being expelled backward ("action"), thus causing the balloon to take flight. This reactive force is known as "propulsion" or "thrust."

Likewise, a rocket is thrust skyward in reaction to the gas being expelled from its body. The rocket is loaded with solid or liquid fuel. A substantial amount of vertical thrust is generated by burning the fuel and jetting the resultant gas backward. Gas sufficiently pressurized in the combustion chamber is jetted out from the nozzle (action), providing the vertical thrust (reaction). In addition to fuel, the rocket is loaded with oxygen. The oxygen enables the rocket to burn its load of fuel and generate high-speed gas even in an environment devoid of air. Rockets use reactive power to achieve acceleration underwater, in the air and even in the vacuum of space.

5. Law of conservation of momentum

Mass multiplied by speed equals "momentum." It is expressed by the equation:

Momentum=mass*speed

Every object exhibits the propensity to maintain constant momentum before and after a motion. This is what is known as the "Law of Conservation of Momentum." Here we will cite and apply this law to explain the physics of rockets. For the sake of simplicity, let's assume that a rocket at rest has a certain mass: Mass=M+m, with "M" being the mass of the rocket body and "m" the mass of fuel. The rocket burns its fuel in an instant and expels backward gas with a mass "m" at a speed "Ve." The value "V" is the speed the rocket has acquired by jetting out fuel (assuming air resistance=0).

As the rocket's speed before jetting out fuel is 0, momentum is naturally 0. The momentum "p" of the fuel expelled is expressed as p=m*(-Ve), and the momentum "P" of the rocket that has begun to move due to the reactive force is expressed as P=M*V. Thus the total of the two momentums is: P+p=MV-mVe. With this equation, the minus symbol in –

mVe means that the direction of the fuel expelled is opposite to the direction to which the rocket moves.

Momentum before motion = momentum after motion = total of the rocket's momentum and the momentum of fuel expelled. This is expressed as:

$$O = MV - mVe$$

From this equation, the following equation is deduced:

$$V = (m/M)\, Ve \;\ldots\ldots\; (A)$$

In other words, it means that the rocket moves forward so as to compensate for the momentum of the fuel that has been expelled. In this way, we can think about the rocket's motion in an easy-to-understand way by employing the concept of momentum. Note, however, that with a real rocket the fuel is burned over a fixed period of time and not in an instant. Therefore, the rocket's eventual speed is equal to the speed obtained by successively summing up the above equation (A).

For example, the speed required by an artificial satellite orbiting the Earth is approximately 7.9km/s, i.e. 28,500km/hr – almost equivalent to a surprising Mach 23. What needs to be done to allow the rocket to achieve such an amazing speed? To accelerate the rocket as in the above mentioned equation (A), the following three approaches are feasible:

5.1 Increase speed of gas being expelled

An effective way to increase the speed of the gas being expelled is to reduce the gas' molecular weight. Assuming the pressure inside the combustion chamber is constant, the lower the gas' molecular weight the greater the acceleration, enabling the combustion chamber to expel the gas at higher speeds. In this respect, rocket engines that employ as fuel a mixture of liquid oxygen and liquid hydrogen are known to be superior in performance as the resultant combustion gas (= steam) has a lower molecular weight. The molecular weights of combustion gases deriving from alcoholic liquid fuel and solid fuel are greater than that of steam. As such, their jetting speeds are lower.

We can also achieve higher gas expulsion speeds by increasing pressure during combustion. However, applying excessive pressure may result in damage to the combustion chamber and/or pipes. The materials used for the chamber and piping each have a maximum acceptable pressure. Furthermore, the rocket structure (including the engine) must be as light as possible, since a heavier body means a greater fuel requirement. Making the combustion chamber heavier and stronger is not advisable.

As for liquid propellant rocket engines, we enhance their thrust performance by employing a turbo pump system that utilizes combustion gas to rotate the pump, and by employing a regenerative cooling system designed to effectively transfer the heat inside the combustion chamber to the pre-combustion low-temperature fuel.

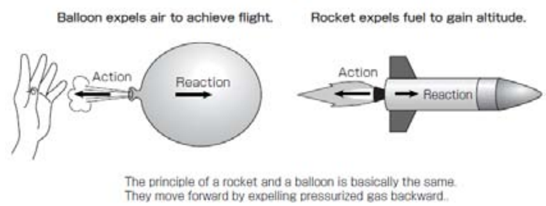
A bell-shaped device, or "nozzle," is attached to the combustion chamber's point of egress. The shape of the nozzle contributes to accelerating the jetting gas. Inside the chamber, the passage becomes increasingly narrower toward the point of egress, accelerating the combustion gas to the speed of sound. As it passes through the nozzle, the gas gradually expands and accelerates further, finally jetting out in a supersonic stream. The nozzle's function is to accelerate the speed of the jetting gas.

5.2 Reduce rocket airframe mass "M"

To reduce the rocket airframe's mass, or "M," engineers turn to lightweight yet strong materials. Multi-stage rockets are used since each stage can be jettisoned once its fuel has been depleted. Discarding useless stages is an effective way to increase the speed of the rocket.

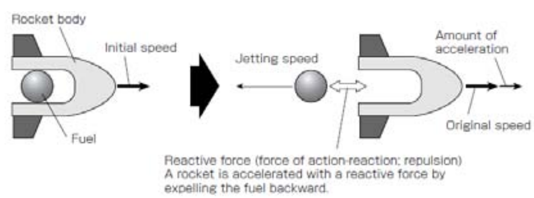
6. Figures

a.



Newton's Law

b.



Law of Conservation of Momentum

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