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Hybrid Rocket Propulsion Systems

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Abstract— In recent years the aerospace industry market expanding, much at the expense of a huge demand for launching services, such as the orbit placement of communication satellites, but also due to a growing interest in space tourism and the decommissioning of space shuttle. Therefore there is a need and market for a rocket that allows lower costs and greater simplicity, while ensuring a good level of performance. Hybrids typically enjoy higher specific impulse than solids, can be throttled, stopped /restarted, and have more flexibility in their packaging configuration. Hybrids are more compact and easier to throttle than liquids and have similar performance levels. This paper introduces the features of the Hybrid rocket propulsion system with its working, applications and demonstrates for future space exploration missions.

Index Terms— *Rocket Engine,Propulsions,convection,Hybrid motors,.*

1 Introduction

Hybrid Rocket motors are a form of chemical propulsion system where the fuel and oxidizer are of different phases. Hybrids are mechanically simpler than, liquid engines as they require only one engine liquid feed system and are also typically more compact than liquid systems, due to higher density of propellants. Hybrids are much safer than both solids and liquid systems as the fuel and oxidizer are separate phases. Hybrid rocket engine design is a long and elaborate process with a lot of constraints. All the design parameters include the optimization of a lot of factors like propulsion technology, payload capacity, maneuvering capacity and nozzle design aspects.

2 Rocket Propulsion

The major components for any full scale rocket are; the structural system, or the frame, the payload system, and the propulsion system. The propulsion of a rocket includes all of the parts which make up the rocket engine; the tanks, pumps, power head and the rocket nozzle. The primary function of a rocket is to produce thrust.

Thrust is the force which moves a rocket through the air and through space. Thrust is generated by the propulsion system of the rocket. Different types of propulsion system develop thrust in different ways, but all thrust is generated through the application of Newton's third law of motion. For every action there is an equal and opposite reaction. In any propulsion system, a working fluid is accelerated by the system and the reaction to this acceleration produces a force on the system. The amount of thrust generated depends on the mass flow through the engine and the exit velocity of the gas.

In a rocket engine, the fuel and a source of oxygen called oxidizer are mixed and exploded in a combustion chamber. The combustion produces hot exhaust which is passed through a nozzle to accelerate the flow and produce thrust. For a rocket the accelerated gas, or working fluid, is the hot exhaust gases produced during the combustion.

3 Hybrid Rocket Propulsions

3.1 Design

The whole system comprises of a oxidizer tank, control valve, igniter, and the combustion chamber with solid fuel grains. A hybrid rocket system, as the name suggests, consists of one solid propellant and one liquid propellant. The fuel can either be liquid or the solid and the same goes for the oxidizer. However, useful oxidizers tend to be liquids and so the typical configuration of a hybrid rocket consists of a liquid oxidizer reacted with a solid fuel.

3.2 Operation

In hybrid rocket system the fuel is contained within the combustion chamber, in the form of a ported cylinder. The oxidizer is stored separately in a tank and when the thrust is desired the valve is opened and vaporized oxidizer flows down the port where combustion takes place. The main combustion chamber is divided into pre-combustion chamber and post-combustion chamber. When the oxidizer flows from the port the igniter, ignites the mixture and the temperature of the oxidizer mixture thereby reaching a very high temperature at the pre-combustion chamber.

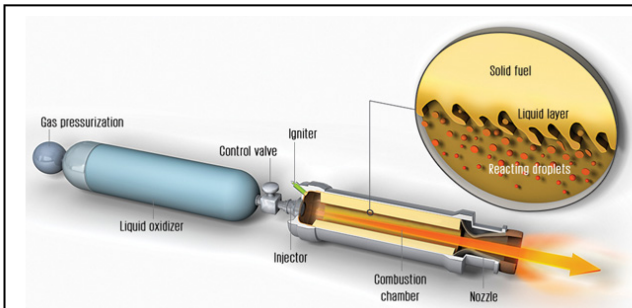

Fig. 1. Describes the combustion process,here the solid fuel is vapourized as a result of heat transferred from flame zone to fuel grain.

As this high temperature oxidizer mixture then moves through the main combustion channel the fuel in the chamber vaporizes and thereby sustaining combustion and the fuel surface regresses in the radial direction as it is consumed. The oxidizers mainly used are of the following types
MON-3(97%Nitrogentetroxide,3%Nitrogenoxide),IFRNA (Inhibited Red-Fuming Acid), Hydrogen-peroxide. The fuels used are paraffin wax, HTPB(Hydroxyl-Terminated-Poly-Butadiene),PMMA(Poly-Methyl Meth-Acrylate).

The fuel is vaporized as a result of heat transferred from the flame zone to the fuel grain. This happens through two main process mainly (1) Convection (2) Radiation

Initially the turbulent diffusion flame is established over the fuel surface. The heat transfer from mixture vaporizes the fuel grain thereby creating a sustaining combustion. At the end of the combustion is the post-combustion where the mixture is of proper ratio and the propellant mass is ejected out thereby producing desirable thrust.

3.3Comparison With Solid And Liquid Propulsion

These type of rocket engine are much more efficient than the other conventional engines .Hybrid rockets are chemically and mechanically simpler, and are tolerant to processing and fabrication errors. As the hybrid rocket eliminate the complex mechanical systems whereas in liquid propellant they uses various pumps and other auxiliaries which make the overall system more complex .Unlike other propulsion systems the hybrids can be easily throttled/restarted as required. This ensures the safety regarding the thrust termination and abort possibility.

The performance of the hybrid rockets can be improved further by changing the fuel grain mixture ratio by adding addictive's to the fuel grain such as metals and metal hydrides, or by improving the design of the rocket nozzle. The shape of the nozzle determines the nozzle efficiency.

3.4 Future Space Exploration Missions

The propulsion system required to provide the specific impulse, TVC (Thrust Vector Control) ACS(Altitude Control System),are the important criteria for the mission selection. All these parameters are considered for a deep space mission to explore planets and to assign the satellites in the designated orbit. Specifically, each hybrid rocket propulsion system is required to provide propulsion for large maneuvers, with the capability to provide total high specific impulse, TVC during the main engine operation, ACS in the event that reaction wheels are not being used. It also necessitates the consideration of only storable or high-pressure gas oxidizer options.

4 Conclusion

The hybrid rockets are much simpler and more efficient than other conventional rocket propulsion systems. The specific impulse and the performance of the system is much more higher than other conventional propulsion rocket. At the end the hybrid rocket propulsion system compensates all other problems related to other systems by making the design much more simpler by eliminating complex auxiliaries, and introducing certain addictive's in propellants make it more stable and increasing its specific impulse and performance of the system making it more suitable for outer planet exploration missions.

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