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HYBRID ROCKET PROPULSION DEVELOPMENT AND APPLICATION

(An overview on applications of Hybrid Rocket)

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***Abstract*— Satellite technology is evolving. Satellite propulsion needs numerous desired rocket features. This is essential for 1 kilogram of payload. Launch vehicles no longer need rocket engines. Application includes satellite movement, orbit transfer, and probe and lander propulsion. Space flight is imaginative and fascinating.**
Research, production, and use costs must be minimized to make space transportation technologies publicly available. Security shouldn't be affected. Rocket propellants must be high-performing, non-toxic, and safe. Rocket engines have other components. Restarting and throttling are key. These are inaccessible to solid rocket engines. Developing a liquid rocket engine is hard and expensive, but it can be restarted and throttled.
It's being explored for use in hybrid rocket propulsion and other space applications. Space tourist vehicles, lunar and planetary landers, suborbital launch vehicles, satellite maneuvering systems, etc. are prospective applications for microsatellites (including orbit transfer) (including orbit transfer). More of these applications are seeking approval. Hybrid propulsion is uncomplicated, safe, and enables regenerative braking, throttling, and resuming. Hybrid propellants are typically non-toxic and storable. Separate oxidizer and fuel storage increase safety. This paper explores the history, development, contemporary uses, and future of hybrid rocket propulsion. We'll explore popular fuels and oxidizers. Explains hybrid rocket motor's low regression rate. The article incorporates the author research.

Keywords: Hybrid Rocket motor, Propulsion, advancements, combustion, propellant

I. INTRODUCTION

Overview of a Hybrid Rocket Motor

A hybrid motor uses different stages of propellants, unlike conventional rocket propulsion systems. Solid fuel and liquid oxidizer are employed. Reversed hybrids are the opposite. Cases hold the polymer fuel. Depending on thrust, fuel cross-sections are a ring or a star. Internal fuel grain port has a combustion chamber. Convection and radiation heat transfer melt and evaporate inner fuel surface. Combustion chamber liquid oxidizer. Because a hybrid only uses one liquid propellant, the injector plate is simpler. Near the fuel's inner surface, mixture formation and combustion occur. Fig.1 depicts a hybrid motor.

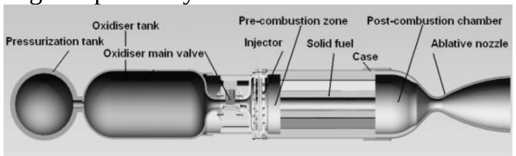

Fig. 1. Hybrid rocket motor scheme[2]

A hybrid motor requires an additional vessel, in which afterburning process occurs. It is called a post-combustion chamber. This chamber is essential because of the fact that there is not enough time and space in the inner port for complete combustion.
The thrust device is a convergent-divergent nozzle. Liquid oxidizer feed systems might be pressurizing as well as turbopump.

II. HISTORY

History of the hybrid rocket technology development

M.K. Tikhonravov's GIRD-9 Soviet short rocket employed a hybrid motor for the first time in 1933. Liquid oxygen and semi-liquid fuel powered the engine. It was a technological advance in rocketry. GIRD-9 used the world's first hybrid rocket motor and was the first Soviet rocket to employ liquid oxygen. The first launch occurred on August 17, 1933, near Moscow. GIRD-9 achieved a height of 400 metres. The rocket reached 1500 metres in 1934 with 500 N of force and a burn period of 15 seconds.

Between 1937 and 1939, Germans worked on hybrids. I. G. Farben experimented with hybrid engines that combined coal and nitrous oxide. Simultaneously, H. Oberth investigated hybrids based on liquid oxygen and a tar-wood-saltpetre combination. In the 1930s and 1940s, hybrid research was also carried out in the United States. The Californian Rocket Society experimented with engines powered by coal and gaseous oxygen. The Pacific Rocket Society tried a propellant arrangement of wood and liquid oxygen in 1947.

General Electric's research on employing polyethylene and 90% hydrogen peroxide was the next stage in hybrid rocket history. The Rocket Missile Research Society in California conducted the first test of a hybrid with spontaneous ignition at the same time. A solution of acids, asphalt, and potassium chloride was utilised. Europe joined the study and development of hybrid technology in the 1950s. On April 25, 1964, the French ONERA launched its first hybrid rocket with a thrust of 10 kN. Until 1967, French LEX hybrid rockets could go 100 kilometres. Sweden launched many FLGMOTOR sounding hybrid rockets between 1965 and 1971. A 20 kilogramme payload was launched at an altitude of 80 kilometres.

The flying target drone programme was achieved in the United States between 1979 and 1983. The Sandpiper, HAST, and Firebolt vehicles' propulsion systems were based on hybrid rocket motors produced by United Technologies Corp. from 1961. These engines used Plexiglas and oxygen as propellants. Starstruck Inc. created the sea-launched Dolphin sounding rocket between 1981 and 1985. The hybrid booster's lift-off thrust was 175 kN. HTPB and liquid oxygen were used in the engine. The Dolphin was launched on August 3, 1984. It was yet another milestone in rocket technology: the first flight of a privately produced big launch vehicle in the United States, as well as the first flight of a huge hybrid rocket.

From 1974 through 1987, the German DLR Lampoldshausen conducted research on hybrids using a variety of propellant configurations, including nitrogen tetroxide, red fuming nitric acid, hydrogen peroxide, and polymer fuels, as well as additives (aluminium, magnesium).

In 1985, Starstruck's creator, James C. Benett, co-founded American Rocket Company (AMROC). The organisation designed, produced, and tested hybrid rocket motors with thrusts of up to 324 kN. AMROC went bankrupt in 1995. Four years later, SpaceDev bought the rights to AMROC's hybrid technology and is actively developing it.

HPDP was established in 1995 by NASA and DARPA (Hybrid Propulsion Demonstration Program). The world's largest hybrid rocket motor was created, manufactured, and tested. For 15 seconds, the engine produced 1,1 MN of thrust. Several variants of the Hyperion rocket were created as part of the HPDP programme. HTPB/N2O technology was used to create hybrid motors. These were NASA's first hybrid rocket missions. Hyperion 1A was launched four times, each time covering 36 kilometers. It is planned to use a hybrid motor with a thrust of 890 kN in the Hyperion 2 project. The rocket is anticipated to reach a height of around 150 kilometers. Lockheed Martin successfully launched its own HYSR hybrid rocket in 2002. The engine produced 300 kN of thrust using a HTPB/LOX propellant combination. Other accomplishments have arrived at SpaceDev.

HYBRID PROPULSION ADVANTAGES. COMPARING TO LIQUIDS AND SOLIDS

Launchers can't be used in business because they are too expensive. At the moment, it costs a few tens of thousands of dollars to send 1 kilogramme of payload 800 km SSO. The cost of a single launch goes up because only a small number of commercial users are interested. It is a tough state because of a number of things. One of the most important is the propulsion system and its features, which include how easy it is to use, how well it works, what fuels it uses, how reliable it is, and how safe it is. Today, the effect on the environment is becoming more and more important.

With all of these things in mind, hybrid rocket propulsion is something to think about. So far, it wasn't seen as a good sign, especially in Europe. But hybrid rocket propulsion systems might be better than solid and liquid rocket propulsion systems in some ways. Table 1 lists the most important benefits that gases have over solids and liquids.

TABLE 1. ADVANTAGES OF HYBRIDS OVER OTHER TYPES OF ROCKET PROPULSION

	Advantages over	
Feature	**Liquids**	**Solids**
System	Mechanically simpler Less liquids – simpler injection, feed and control systems	• Chemically simpler (including fuel preparation process) • Restartable, throttle able
Safety	Reduced fire hazard Less prone to hard starts	• Reduced explosion hazard • Zero TNT equivalent • Able to stop
Performance	Higher propellant density Possible to improve performance by the addition of metals	Higher performance
Environment	Comparable with RP-1/LOX	Does not need any toxic and harmful propellant

Hybrid propellants

The first hybrid fuel that was ever put to use was a semi-solid kind of gasoline that was made by dissolving rosin into regular gasoline. In the early experiments on hybrids, wood and coal were also used in some of the applications. It was composed of solid fir wood, as well as a combination of tar, wood, and saltpetre. The advancement of the chemical industry made it feasible to employ polymers as hybrid fuels. Polyethylene and plexiglas are two examples. However, HTPB is by far the most frequent (hydroxyl-terminated polybutadiene). It is a type of artificial rubber. Because of its exceptional mechanical qualities, HTPB may be utilized both as a hybrid fuel and as a binder for solid propellant.

In order to achieve optimal performance, hybrid fuel may be fortified by the use of metal powder. Aluminum is by far the most prevalent. In addition to this, the fine aluminum, which ranges in size from 2 to 50 microns, has an effect on the solid fuel regression rate. Catalysts, plasticizers, and stabilizers are three more types of additives that could be used.

The liquid most usually used as an oxidizer is liquid oxygen. Additionally, it is possible to submit an application for hybrid motors. LOX is an oxidizer with outstanding performance. The particular impulse of LOX and hydrocarbons is larger than 3000 metres per second. In Table 2, the performance of various hybrid propellant compositions is compared to that of liquid oxygen and kerosene. These comparisons highlight the possible performance of hybrid propellants. Nevertheless, the use of liquid oxygen in hybrid applications has a number of disadvantages. It is a cryogenic material to begin with. You will also require a pyrotechnic ignition device. The igniter is only applicable in one circumstance. This signifies that the hybrid engine cannot be restarted. Consider gaseous ignition as an option. However, this substantially increases the system's complexity. In addition, the liquid oxygen must be evaporated prior to the creation of the compound. Under enlarged circumstances, the development of low-frequency combustion instabilities has been attributed to incomplete oxygen vaporization before to the combustion port, as demonstrated by experience. In addition, the flow field is full of waves that impact the duct wall and are reflected; this process is repeated until the under expansion is minimized and the pressure equals the back pressure. The reattachment length is proportional to the area ratio; it is shortest when the area ratio is smallest and gradually increases as the area ratio increases. When the flow is overexpanded for a specific Mach number, NPR, area ratio, and L/D ratio, the jet undergoes compression due to the existence of an oblique shock wave after leaving the nozzle, and this process continues until the ambient air pressure is reached.

A. Development tasks. The mechanism of combustion in a hybrid rocket motor.

There are two basic classifications for hybrid technology development issues: nontechnical and technical. The combustion instability that follows all types of rocket engines is a technological task. However, the phenomena in this situation is unique. Solid fuel must evaporate and combine with the oxidizer to generate a mixture. As the combustion products impede oxidizer intake and mixture formation, instabilities ensue. It produces brief decreases in chamber temperature and pressure.

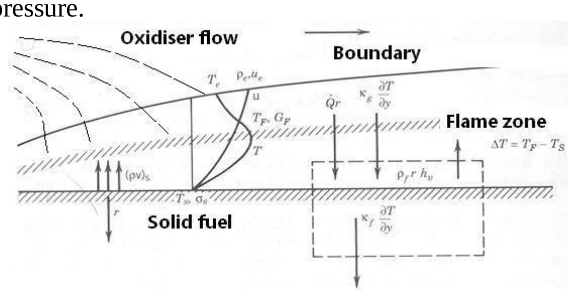

Fig. 2. A simplified model describing the hybrid motor combustion **[2,3]**

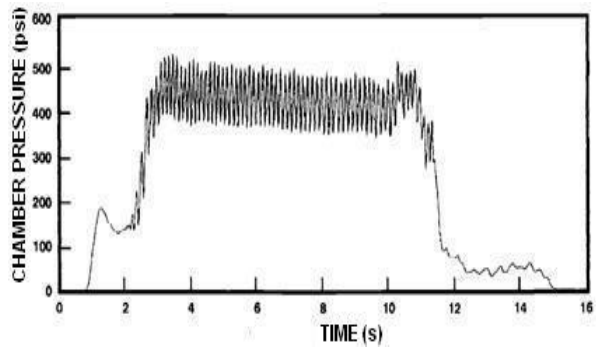

Fig. 3. Pressure oscillations as a result of combustion instabilities in a hybrid rocket motor[5]

Another concern is the hybrid rocket motor's weak fuel regression rate. In contrast to solid propellant motors, surface response intensity is modest with liquid propellant motors. As a result, heat transmission from the hot gas to the fuel surface is insufficient. It lessens the fuel vaporization intensity, resulting in a lower fuel regression rate than solid propellant (in which fuel and oxidizer are premixed) (in which fuel and oxidizer are premixed). Consequently, the fuel mass flow per surface area in a hybrid vehicle is modest.

III. RECENT RESEARCH AND DEVELOPMENT OF THE HYBRID ROCKET TECHNOLOGY

In 2004, the concept of a brand-new reusable orbiter was first proposed. It is anticipated that Dream Chaser would make use of hybrid rocket propulsion. After another three years, SpaceDev made the announcement that the Atlas V will serve as the boosting rocket for the Dream Chaser[4].

Maneuvering and orbital Transfer Vehicle was a project that SpaceDev undertook for the Air Force Research Lab to develop, build, and test. This vehicle was developed specifically for use with tiny satellites, and its functions include attitude and control adjustment, as well as transformation of an elliptical orbit into a circular one. The HTPB/N2O hybrid motor serves as the foundation for this system. Nitrous oxidizer that is cold is used in certain smaller engines for attitude and control.

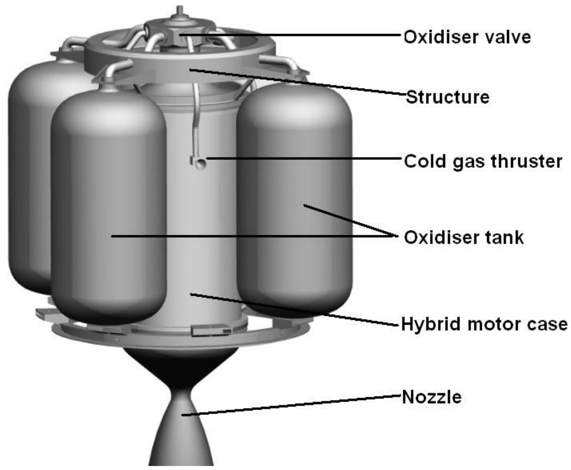

Fig. 4. A scheme of the Maneuvering and orbital Transfer Vehicle[3]

2007 was the year when the successful completion of the lunar lander test. This motorised conveyance is driven by a total of four hybrid motors. The creation of it took a full three years. Every engine has a throttle that may be used. The extensive and fruitful work carried out by a medium-sized business known as SpaceDev demonstrates that it is worthwhile to conduct research and development on hybrid rocket technology. Locating an appropriate use for hybrids is one of the most crucial things that has to be done. Experience has shown that the most fruitful fields of research are as follows: orbital manoeuvring and attitude control; space tourism; unmanned lunar and planetary landers; and space tourism. The consideration also extends to the higher phases.

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