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2. Development of A Gas Propelled Rocket Engine

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ABSTRACT

When it comes to getting people and cargo into space, the rocket engine is king. This research paper looks at how a gas propellant rocket motor could be built with readily available, low-cost components. The lathe and the drilling machine were among the several machine tools used to create the prototype rocket engine. No specialised curved-surface techniques were used to create the internal radius around the nozzle throat area. Two runs were made with the engine's temperature and pressure recorded. The temperature was too high, and two thermocouples were ruined as a result. Therefore, the analyses of the test findings made use of temperature estimates. Some parameters showed a range of 0-15% in discrepancy between the initial test and the corresponding theoretical results, but in most cases, the test results were determined to lay between 70 and 80% of the assumptions. The sonic boom occurred at Mach 1, and a 1.70-meter-long, bright yellow flame was pushed out. The exit velocity was measured to be 1664 m/s at Mach 1.87, and the resultant thrust was determined to be 7.65 KN by multiplying the exhaust velocity by the propellant mass flow rate. At roughly 2000 degrees Celsius, a combustion pressure of 16 bar was reached. The second trial taught us a lot about the repercussions of mishandling a rocket engine.

KEYWORDS:

Rocket Engine, Gas Propelled Rocket Engine, Propelled Rocket Engine, Propulsion, Experimental Research.

Introduction:

A rocket's engine is where the rocket's mass of propellant is stored in preparation for being ejected as a high-velocity propulsive jet. Rockets are the popular name for vehicles that use rocket propulsion. Newton's third law of motion is crucial to how rockets work. However, while combustion is the norm for rocket engines, there are alternative non-combustion types (such as cold gas thrusters) that can be used. The major objective of this project is to put students' understanding of gaseous propellant rocket engines from the Faculty of Aerospace Engineering to use by having them design, construct, and test a fully functional rocket engine. The next step is to install the engine on a rocket and assess how well the rocket and engine function together. As a last objective, we hope to break the amateur altitude record.

The SpaceShipOne rocket engine is a hybrid propulsion system, meaning it can use both solid and liquid propellants. Some types of liquid rocket engines use only one type of fuel, while others use two. For example, hydrazine (N_2H_4) or laughing gas can be used in mono-propellant engines that function as a basic cold gas system, or they can be used in engines that include a catalyst for the exothermal degradation of the propellant (N_2O). Low thrust propulsion systems for satellites often exclusively use these types of engines. It is common for bi-propellant engines to use either earth-storable propellants like nitric acid or its anhydride and hydrazine derivatives like asymmetric di-methyl-hydrazine (UDMH) or mono-methyl-hydrazine (MMH) or a hybrid of the two, like liquid oxygen and kerosene, or fully cryogenic propellants like liquid oxygen and liquid hydrogen. Although rocket engines vary greatly depending on the nature of the mission and the launcher's configuration, it is possible to group them into four broad categories. Satellite propulsion and attitude control systems, including booster, main stage, and upper stage engines [1-2].

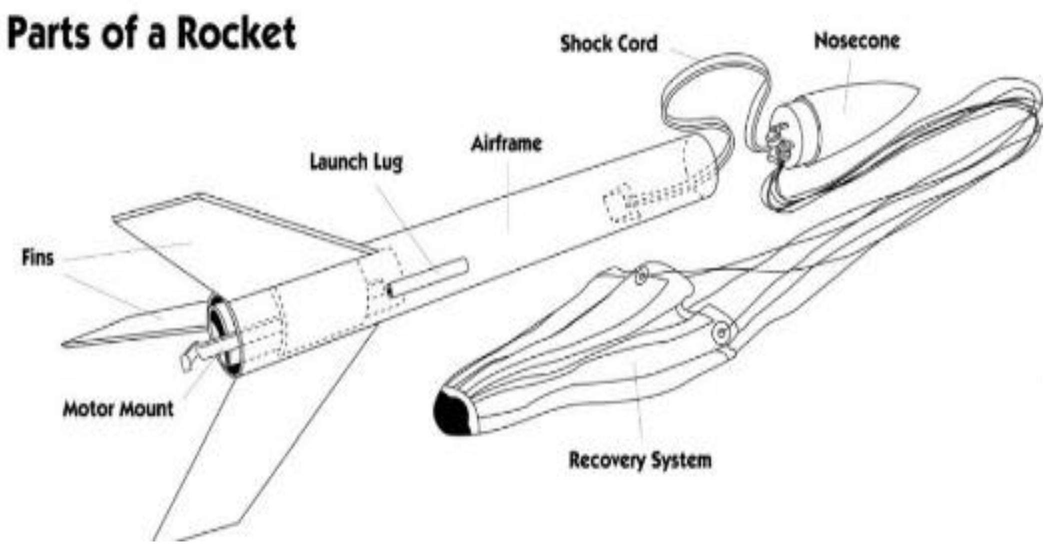

Figure 1: Parts of Model Rocket

Figure 1: "Parts of a Rocket" shows the common components and their locations on a model rocket airframe. The length of a model rocket's airframe compared to its diameter is typically quite considerable. The model rocket's engine is normally placed at the tail end of the airframe, with the payload and electronics bay situated closer to the rocket's centre of gravity. To connect the rocket's nose cone to the airframe tube, a coupler is attached to the back of the nose cone.

History of Rocket Engine:

Ancient Roman historian Aulus Gellius, Inc. 400 BC claims that a Greek Pythagorean named Archytas used steam to fly a wooden bird along wires. However, it wouldn't show up because it lacked the necessary propulsion. Tippu Sultan, king of Mysore, too made use of rocket engines. There was a wide range of sizes for these rockets, but the most common design involved a tube made of soft hammered iron that was 8 inches (20 centimetres) long and 1 1/2 to 3 inches (3.8 to 7.6 centimetres) in diameter, closed at one end, and strapped to a shaft of bamboo that was 4 feet (120 centimetres) in length. The black powder propellant was tightly packed inside the iron tube that served as a combustion chamber. About one pound of powder may propel a rocket nearly a thousand feet (910m). These 'rockets,' outfitted with swords, utilised a variety of pointy things and had a tall peak, allowing them to travel great distances and ascend several metres into the air before crashing down on their foes. Effectively aimed at the British Empire, these rockets were a game changer. The evolution of rocket propulsion systems is detailed in Table 1 below.

Table 1: History of Rocket Engines

Name of Scientist	Description	Use of its application	Limitation
Archytas (400 BC)	using steam	---	It did not produce much amount of thrust, to fly somebody.
Aeolipile	Hero's Engine (Steam Rocket)	Steam rocket on bearing	The principle behind it was not well understood, and its full potential was not realized for a millennium.
Chinese Taoist alchemists	Black Powder	Fire arrows	It was only used for small objects.
Liber IgniumadComburendos Hosts	It has recipe that combines one pound of sulfer, two pounds of charcoal, and six pounds of saltpetre-all finely powdered on a marble slab.	Use of creating incendiary weapons.	------
Conrad Haas (Germany military engineer in (159-1576)	Construction to multistage rockets	Use as missiles	------
Konstantin Tsiolkovsky (19th Century)	Liquid-flued rocket engines.	Tsiolkovsky rocket equation	Is was not published for a long time.
Robert Goddar (american Physicist – (in 20th Century))	Modern Liquid-fueled rocket engines.	First to use a De Laval nozzle and this was the birth of modern	----

Fun fact: the Chinese Han Dynasty, which ruled from around 200 B.C. to roughly 220 A.D., invented rockets, which were naturally employed for fireworks.

However, the underlying idea of a jet engine may be traced back to the Hero of Alexandria (about AD 67), an Egyptian mathematician and inventor who developed a number of devices that made use of water, air, and steam.

Types of Rocket Engines:

There are two main types of rocket engines, chemical rockets and non-chemical rockets. There are three types of chemical rocket engines that are distinguished by the state of the chemical propellant:

(1) solid propellant, (2) liquid propellant, and (3) hybrid propellant. However, there are other subcategories for non-chemical engines based on their source of energy: there are three types of rockets: (1) nuclear, (2) electrical, and (3) solar.

1. Chemical Rocket Engines:

Chemical rocket engines use the heat and pressure created by expanding gas via a compressed-diameter (CD) nozzle to generate thrust.

This expansion is powered by the chemical energy released when fuel and oxidizer are burned. There are three main types of chemical rocket engines:

1.1 solid propellant,

1.2 liquid propellant, and

1.3 hybrid propellant. A brief overview of these motors is provided.

1.1 **Solid-Propellant Rocket Engine (SPRE):** It is believed to have been employed in China for military purposes as early as the thirteenth century, making it one of the earliest non-air-breathing engines. Several modifications were made to the original black powder formula for the solid propellant.

1.2 **Liquid Propellant Rocket Engine (LPRE)**: The LPRE is now used in many different types of engines and gas generators. It offers variable thrust from a few Newtons up to several hundred. The turbocharger's injectors and valves could become stuck, making it less reliable.

1.3 **Hybrid Propellant Rocket Engine (HPRE)**: Combining features of SPREs with LPREs, the new engine is called the. Although still in the early stages of development, these engines have the potential to be used in a broad variety of civilian and military settings. [3-4]

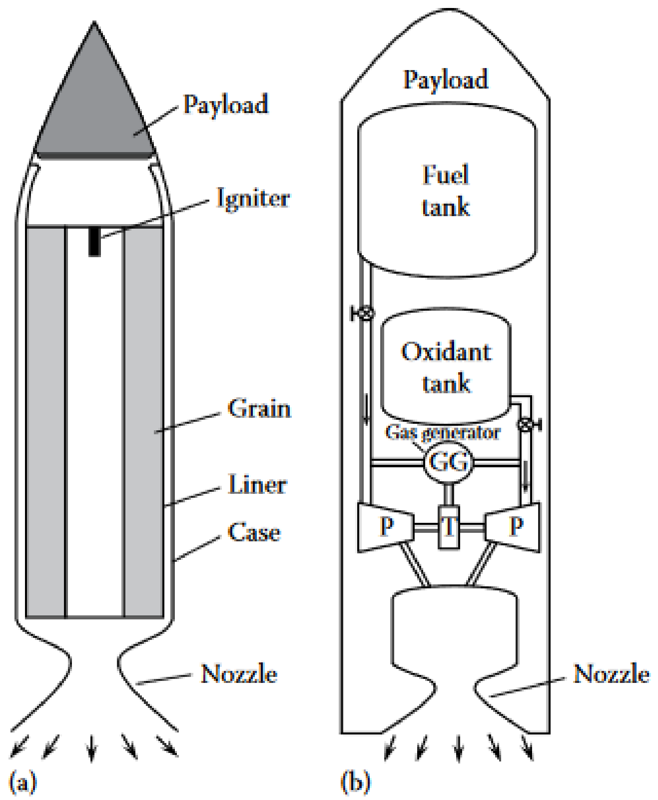

Figure 2: Three Types of Chemical Rocket Engines: (a) Solid Propellant, (b) Liquid Propellant, and (c) Hybrid Propellant

2. Non-Chemical Rocket Engines:

For some missions, using chemical rocket engines is unsuitable due to their higher propellant mass per unit impulse, hence non-chemical rocket engines have been under development for some time.

Nonchemical rocket engines are highly sought after for use in certain deep-space applications. It's possible to classify these motors into three broad groups:

(1) electrical rocket engines (2) nuclear rocket engines (3) solar rocket engines. [5]

Objectives:

1. We study on history of rocket engine.
2. Analysis of types of rocket engines.
3. Review literature of gas propelled rocket engine.
4. We study of result of various types of rocket engines.

Review of Literature:

To better understand High-Powered Model Rocketry, we combed through the available literature. The importance of this project is first discussed in this publication. Next, the engine's constraints are laid out, along with a potential rocket layout for the next stage. The engine's manufacturing geometry and technical parameters, as well as the design process that led to them, are discussed next. At last, the options and strategies for the engine's testing are assessed. [6]

This paper details a student-built rocket motor that uses gaseous propellants. It's a group project the authors worked on with other aerospace engineering students at TU Delft, under the guidance of the DARE (Delft Aerospace Rocket Engineering) [1] committee of the Society of Aerospace Students 'Leonardo da Vinci. DARE's primary focus since its inception four years ago has been the development of rockets using solid propellants. Several of these rockets were developed and successfully launched, proving that DARE could manufacture solid-propellant rocket engines, flight electronics, parachute systems, and composite rocket frames. Since a more difficult task was required, work on a gaseous propellant engine was initiated. [7]

The earliest "propellant" (a mixture of saltpetre, sulphur, and charcoal called black powder) had been in use for about a thousand years before the concept of rocket propulsion thought to have originated in 1200-1300 in Asia. It is typical that the military was the first to adopt a new technological advancement. Black powder charges propelled rockets into space, and the most successful of these bombardment weapons were the early 1800s' Congreve rockets (named for William Congreve, a British officer important in their development). Black powder, the only available propellant, is not suitable for propulsion, hence the performance of these early rockets was low in comparison to modern standards. Between the years of 1815 and 1936, rockets were used in fewer military engagements than they had been previously because cannons were more effective. As is typical with scientific theory and invention, progress was made in different parts of the world simultaneously. Goddard took his experiments into space further than the Russian and German pioneers of the time did by successfully launching his modest but complex rocket engine. While Goddard was busy crafting models of a spaceship, a teacher in a small town in Russia was just as enamoured with the idea of human space travel as he was. The Soviet Union recognised the 1903 publication "Investigations of Space by Means of Rockets" by Konstantin E. Tsiolkovsky as the progenitor of space travel. German pioneer Hermann Oberth released his space-flight dissertation Die Rakete zu den Planetenräumen in 1923, four years after the publication of Goddard's early monograph.

After moving to Worcester, Massachusetts in 1908, Goddard spent the next several decades teaching physics, conducting rocket experiments, and earning his doctorate from Clark University. He was the first to show that thrust and, by extension, propulsion, can occur in a vacuum, without the presence of air. He pioneered the use of mathematics to investigate the relative energy and thrust of different fuels, such as liquid oxygen and liquid hydrogen, per unit of weight. Also, 15 years later, the German V-2 rocket weapon would exploit his invention of a rocket motor powered by liquid fuels (liquid oxygen and gasoline). In 1925, he stated, a liquid-propelled rocket "worked satisfactorily and lifted its own weight" during a static test in a tiny building next to his laboratory.

On his aunt Effie's home in Auburn, Massachusetts, the first liquid-propelled rocket engine ever flew for a short period of time on March 16, 1926. [8]

Research Methodology:

We mostly relied on secondary sources such books, educational and development publications, government papers, and print and online reference materials to learn about the construction, application, and effects of gas powered rocket engines. A test cell that was once employed in the production of explosives now serves as the home of the rocket engine. The North wall of the test chamber is designed to blow out under excessive pressure. Sealing the test chamber protects its contents from the elements and makes it possible to use fielded precision optical instruments for extended periods of testing. The northern wall is removed for rocket engine test launches. Optical diagnostics of the exhaust plume beyond the test area are made possible by the inwardly receding exit plane of the modern engine nozzle. The control room is where the facility's operators and control systems are located. The control room is conveniently located near the test cell, allowing for speedy adjustments to be made in the fuel galley and the rocket engine's setup. From the command centre, lines for data collecting and control are run through special conduits in the reinforced concrete walls to the fuel galley and the test cell.

Result and Discussion:

SPREs are favoured over the other two chemical rocket systems whenever extremely high thrusts are needed for a brief period of time (booster phase). By enhancing propellant chemistry and processing, their service life can be lengthened, allowing them to find use throughout the sustained phase as well.

Table 2: Comparison between a Solid-Propellant Rocket Engine and a Liquid Propellant Rocket Engine

Characteristics	Solid-Propellant Engine	Liquid- Propellant Engine
Propellant	Solid	Liquid
Storage	Stable for 10-15 years	Stable for 1-2 years
Burning rate	Low	High
Chamber pressure	Higher (1-70 MPa)	Lower (0.3-10 MPa)
Chamber thickness	Low	High
Applications	Booster (generally)	Booster and sustainer
Thrust	High	Low
Reliability	Higher (99%)	Lower
Design	Simple	Complex

As the propellant in the combustion chamber is used, the SPRE system becomes lighter than an LPRE even after a relatively extended period of burning time. Because of this, it is used in the missile industry. Keep in mind that the solid propellant serves to insulate the structure's exterior from any heat generated by its operation. It has been utilised in antitank and antiaircraft missiles because of its remarkable reliability, even beyond 99%, and its small weight. An SPRE's thrust coefficient is larger than that of LPREs because the pressure inside its combustion chamber is significantly higher. See [Table 2] for a summary comparison of SPRE and LPRE characteristics. [9-10]

Table 3: Comparison of Various Parameters between Typical Liquid-Propellant Rocket Engine Combustor and Aerogas Turbine Engine Combustor

Sr. No	Parameter	Aerogas Turbine Engine Combustor	Liquid-Propellant Rocket Engine-Combustor
1	Peak temperature	2300 K	3400 K
2	Chamber pressure	5-40 atm	50-200 atm
3	Liquid flow rate	2.5 kg/s	600 kg/s
4	Droplet size	20-60 µm	20-150 µm
5	Mode of spray	Dilute	Dense
6	Recirculation zone	Significant	Very little
7	Heat release rate density	10 MW/m^3	1000 MW/m^3

Because of the high pressure and high temperature circumstances (see Table 3) that exist in a rocket engine, the rate of heat release during the burning of propellant is much higher than in a typical aerogas turbine combustor in an aeroplane, at 1000 MW/m 3. Rocket engines have a larger droplet size distribution than aerogas turbine combustor. Therefore, in a rocket engine, the diameter and length of the combustion chamber are carefully selected to ensure that the vast majority of the droplets are vaporised there. With contrast, in an aerogas turbine engine, the droplets are completely combusted in the first section of the combustion chamber, while the remaining section is used to maintain a constant temperature at the engine's outlet. [Table 3] [11-12]

Conclusion:

Areas have been identified and physical and technological constraints have been presented based on a description of the basic components and features of rocket engines, paving the way for a discussion of future improvements. Though some of the techniques described for thrust chambers, ignition systems, or injectors should be relevant to other combustion devices, these areas were not included in the list of prospective breakthroughs.

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