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An Overview of Cryogenic Engine

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Abstract

Cryogenics originated from two Greek words “kayos” which means “cold or freezing” and “genes” which means “born or produced”. Cryogenics is the study of very low temperatures or the production of the same. Liquefied gases like liquid nitrogen and liquid oxygen are used in many cryogenic applications.

The paper is all about Cryogenic Technology used in rocket’s engine for allit's space missions & it's applications. This technology consists of use of two basic elements of universe Liq. Hydrogen (-253°C) & Liq. Oxygen(-183°C).This engine follows Newton’s basic 3rd law of motion. This is the only engine that gives 100% efficiency without any Green house emissions or pollution up to the date on earth. It gives a thrust of 15000 lb. when basic methods are used.

When these fuels are mixed at their cryogenic temperatures they give out huge energy which is can be utilised to:

1) Take off of a Space vehicle it's escape velocity.

2) Launch a missile across continents.

3) Generate electric energy.

Keyword

Rocket engine, Cryogenic technology, Cryogenic temperature, Liquid hydrogen and oxygen , Newtons Third law of Mechanics.

1. Introduction

A cryogenic engine is typical rocket engine designed to either escape Earth’s gravity to send probes into spaced or to lift satellites into orbit. They use liquid fuels that are cooled to very low temperatures and which would otherwise be in gaseous state at normal atmospheric pressure and temperature, such as hydrogen and oxygen.

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These fuels are utilized in one of two main designs to produce propellant force. Either the hydrogen is vaporized as the fuel and ignited by the oxidizer of oxygen to generate standard hot rocket thrust, or they are mixed to create super hot stream that exits the engine nozzle and creates thrust.

They would otherwise be gas at normal temperature. In the cryogenic system engine components are cooled and the fuel doesn't boil to a gas in the line that feed in engine.

The thrust come from rapid expansion from liquid to gas with the gas emerging from the motor at very high speed. The energy needed to heat the fuel come from burning them once they are gases. Cryogenic engine are highest performing rocket motors.

The field of Cryogenics advanced during the World War 2 , when it was discovered that metals when frozen to low temperatures showed more wear resistance. Currently, only a few countries like United states , Russia ,China , France , Japan and India have mastered cryogenic engine technology. All the current rockets run on Liquid propellants. The first operational cryogenic rocket engine was the 1961 NASA design, RL-10 LOX LH2 rocket engine which was used in Saturn 1 rocket employed in the early stages of the Apollo moon landing program.

2. Principle

- The basic principle driving a rocket engine are:

  1) Newton's third law of motion

  2) Law of conservation of momentum

- Cryogenic rocket engines generate thrust like all other

  Rocket engines by accelerating an impulse carrier to high speeds.

- The chemical energy stored in the fuel is converted into kinetic energy
  By burning it in the thrust chamber and subsequent expansion in the nozzle.

3. History of Cryogenic Technology

The history of breakthroughs in cryogenics and their consequences and impact on the world make fascinating reading. This article has developed into a long contribution; yet it is all too brief in its coverage. Over the first 840 years of the millennium, cryogenics was mainly concerned with the collection, storage and use of ice.

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This Rocket Technology has a great History involving many giant nations including USA, Russia, Japan, France etc. A close competition was led in later half of 20th Century for this technology since it's invention by USA. When USA successfully launched it's 1st Atlas V rocket in 1963 , it boosted up the cold war between Russia & USA which played a great role in rapid advancement in this technology in such a short period of time.

After USA , Russia started it's tests of launch vehicles. Firstly Russia carried a dog named 'Lynus' in space in 1983. Russia was first to take human in space using a satellite named SPUTNIK . During this period, lot of European countries tried their rockets with same technologies & succeeded later, But no human being till 1985.

Here's is detail review of competition :-

Engine/Rocket used	Nation	Year
RL-10	USA	1963
LE5	Japan	1977
HM7	France	1979
N1	Russia	1983
GSLV-D5	India	2013
GSLV MK 3	India	2017

4. India

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Fig.2 ISRO Launched GSLV MK 3 by using Cryogenic Engine.

Indian Space Research Organisation was also trying it's hand on this technology in 20th Century. U.R RAO former chairman of ISRO , announced that it's Cryogenic engine will have a launch in just 4 years. Unfortunately it took more than 20 years to Ignite it's first Cryogenic Engine. so it joined the competition much lately in 21st Century due to its frequent failure & no technological support from other developed Countries. ISRO launched GSLV MK 3 by using Cryogenic Engine in 2017, but now it is working good with successful launch of it's Mangalyaan in first attempt, being the first country of this kind.

5. Construction

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Fig. 3. Construction of Cryogenic Engine.

1) The major components of a cryogenic rocket engine are the combustion chamber (thrust chamber), pyrotechnic initiator, fuel injector, fuel cryopumps, oxidizer cryopumps, gas turbine, cryo valves, regulators, the fuel tanks, and rocket engine nozzle.

2) In terms of feeding propellants to the combustion chamber, cryogenic rocket engines (or, generally, all liquid-propellant engines) are either pressure-fed or pump-fed, and pump-fed engines work in either a gas-generator cycle, a staged-combustion cycle, or an expander cycle.

3) Various cryogenic fuel-oxidizer combinations have been tried, but the combination of liquid hydrogen (LH2) fuel and the liquid oxygen (LOX) oxidizer is one of the most widely used. Both components are easily and cheaply available, and when burned have one of the highest enthalpy releases by combustion, producing specific impulse up to 450 s (effective exhaust velocity 4.4 km/s).

6. Working of Cryogenic Engine

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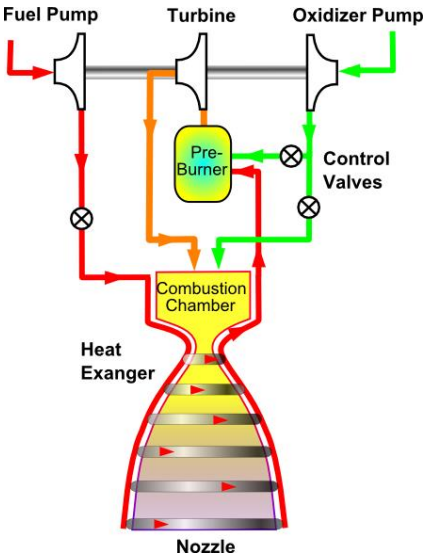

Fig. 4 Working digram of Cryogenic Engine.

This type of engines works on the basis of Newton third law of motion and law of conservation of motion. The design for liquid fuels have to be held at very low "cryogenic" temperatures to be liquid or they would otherwise be gases at normal temperature.

Typically hydrogen and oxygen are used which needs to be held below 20''k and 90''k to remain liquid. Cryogenic engine has proved to be the highest performing rocket motor. In this engine its components are cooled so that the fuel is not boiled to gas in the line that the feed the engine. The thrust comes from rapid expansion from liquid to gas with the gas emerging from the motor at very high speed.

Air moving around the vehicle is used to bring the liquid nitrogen to boil. Once it boils, it turns into gas in the same way as the heated water forms steam .Oxygen and hydrogen both are stored as cryogenic liquids to produce the required power. When vaporized by heat exchanger, it expands to about 710 times the volume of its liquid forms . The high pressurized gas formed is then to be fed at the expander where the force of nitrogen gas is converted into mechanical power.

In used power cycle are :-Pressure feed cycle, Expander cycle, Gas generator cycle, Stuged combustion cycle.

7. Advantages

1) High Energy per unit mass Propellants like LOX and LH2 give very high amounts of energy per unit mass.

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2) Clean Fuels: Their product give out only water thrown out of the nozzle in the form of very hot vapour.

3) Economical: LOX & LH2 costs less than gasoline.

8. Disadvantages

1) Boil off rate

2) High reactive gases

3) Leakage

4) Hydrogen embrittlement

5) Zero gravity condition

9. Future Scope

Being the most reliable engine and being used in all space missions, lot of advancement in this technology is made every day. This technology involves fuel hydrogen and oxygen which is cheaper than even fossil fuel, therefore this technology can give humans safe & reliable technology in near future. Generally any rocket engine burns their respective fuels to generate the thrust. If any other engine has capacity to generate thrust efficiently then it can be called rocket engine.

Currently the scientists from NASA are working on 'Xenon Ion Engine' which accelerates the ions or atomic particles to extremely high to create thrust more effectively and efficiently by usage of electrostatic or electromagnetic force by the principle of Lorentz force or Columbian force. In this technology ions are powered towards the anion at a speed of 30 km per second.

10. Conclusion

The area of cryogenics in Cryogenic Rocket Engine is vast one and it cannot be described in a few words. Now a days , Cryo propelled rocket engines are having a great demand in the field of space exploration.

Cryogenic Technology ensures the stability of fuel & by following Newtons 3rd law the thrust is generated. These two principles work hand in hand to make this engine a mega success of 20^{th} & 21st Century. Also while comparing Rocket engine with jet engine , thrust produced in rocket engine is outwards and that in the jet engine is inwards. Hence this efficiency cannot be achieved by any other engine.

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