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A Review on Cryogenic Rocket Engine

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Abstract-A coupled finite element fluid-structure interaction analysis of re generatively cooled rocket combustion chambers, which allows the computation of the coolant flow and the heat conduction between the coolant and the combustion chamber structure, is presented. Furthermore, the resulting elasto-plastic deformation of the combustion chamber under cyclic thermal and mechanical loading is analysed.The developed solution strategy is applied to the prediction of the heat transfer and thermo mechanical load-induced deformation process of the European rocket engine Vulcain. Based on the results, the failure mechanism of the combustion chamber and its governing parameters are identified. It is demonstrated that this mechanism significantly reduces the lifetime of the rocket engine. Besides the conceptual design by the engineer, a mathematical optimization procedure based on the finite element model of the combustion chamber is investigated. This optimization method allows the improvement of an initial design with respect to a finite number of design variables such that the stress, plastic strain, or temperature levels are decreased, and accordingly. The lifetime will be increased.
Keyword:- Cryogenic Rocket Engine, principle, Fuel, Parameter

I. INTRODUCTION

Cryogenic engine are design for rocket engine to used fuel are oxidizer which must be refrigerated to remain in liquid state and the mean of cryogenic is the steady of production of very low temperature (150”c or -283”f or 123k) and behaviour of materials at those temperature .they would otherwise be gas at normal temperature.
In the cryogenic system engine component are also cooled 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.

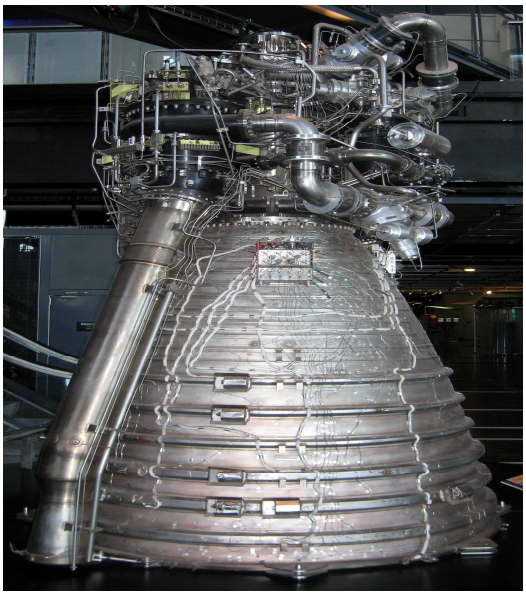

Fig.1Ccryogenic engine

II. WORKING PRINCIPLE OF CRYOGENIC ENGINE

In this type of engine work at Newton third law of motion and law of conservation of motion .design for liquid fuels that have to be

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held at very low "cryogenic" temperature to be liquid they would otherwise be gas 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 is highest performing rocket motors.in this engine its components are cooled that reason the fuel are not boil to gas in the line that the feed the engine. The thrust come from rapid expansion from liquid to gas with the gas emerging from the motor at very high speed.

The extremely cold temperature at which liquid nitrogen is stored. Air moving around the vehicle is used to hat liquid nitrogen to boil. Once it boils.it turn to gas in the same ways that heated water form the steam engine .oxygen and hydrogen both are store as a cryogenic liquid to produce its power , it vaporized by heat exchanger expand s to about 710 times the volume of its liquid forms . the high pressurized gas form then to be feed at 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

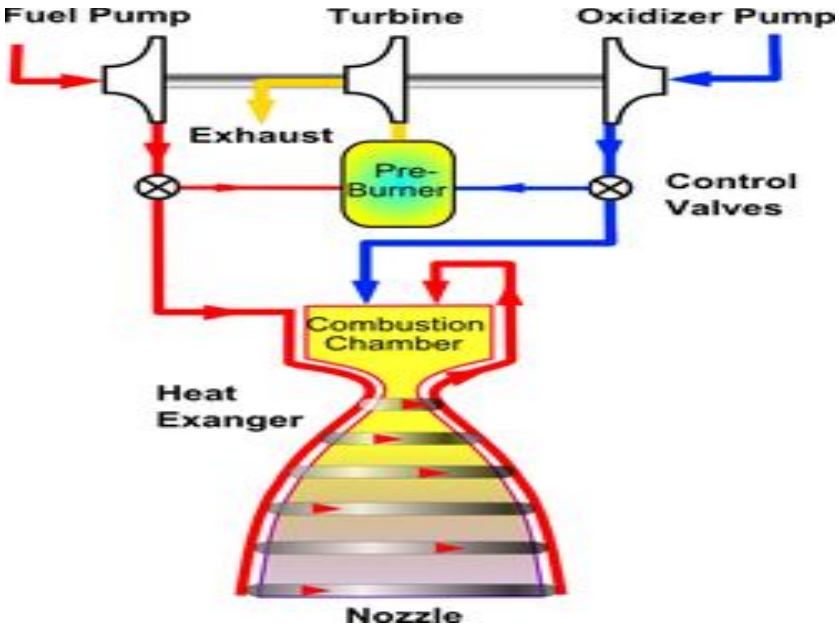

Fig.2 working principle of cryogenic engine

III. TYPES OF CRYOGENIC ENGINE

There are mainly two types of cryogenic engine

A. HM-7B Cryogenic

HM-7 Cryogenic propellant rocket engine has been used as an upper stage engine on all version of the ariane launcher.the more power full HM-7B version was used on ariane 2,3 and 4 and is also used on the ESC-A cryogenic upper stage of ariane 5. Important principle used in HM-7 combustion chamber where adopted by nas aunder license and it is this technology that formed the basis of today's US space shuffle main engines – the first reusable rocket enginein the world. The HM 7 engine was built upon the development work of the 40kN HM4 engine. In 1973 the ottobrunn team started development of the HM7 thrust chamber for the 3rd stage of ariane. 6 year later the HM 7 engine was suscessfully qualified with 1st launch of ariane in December 1979.

B. Vulcain Engine

The Vulcain engines are gas-generator cycle cryogenic rocket engines fed with liquid oxygen and liquid hydrogen. They feature regenerative cooling through a tube wall design, and the Vulcain 2 introduced a particular film cooling for the lower part of the nozzle, where exhaust gas from the turbine is re-injected in the engine They power the first stage of the Ariane 5 launcher, the EPC (Étage Principal Cryo technique, main cryogenic stage) and provide 8% of the total lift-off thrust(the rest being provided by the two solid rocket boosters). The engine operating time is 600 s in both configurations 3 m tall and 1.76 m in diameter, the engine weighs

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1686 kg and provides 137 of thrust in its latest version.The oxygen turbo pump rotates at 13600 rpm with a power of 3 MW while the hydrogen turbo pump rotates at 34000 rpm with 12 MW of power. The total mass flow rate is 235 kg/s, of which 41.2 kg/s are of hydrogen.

Table.1 Characteristics of cryogens

Cryogen	Triple point [k]	Normal boiling point [k]	Critical point [k]
Methane	90.7	111.6	190.5
Oxygen	54.4	90.2	154.6
Argon	83.8	87.3	150.9
Nitrogen	63.1	77.3	126.2
Neon	24.6	27.1	44.4
Hydrogen	13.8	20.4	33.2
Helium	2.2	4.2	5.2

IV. PARAMETER OF CRYOGENIC ENGINE

In this type of engine fuel tank to be bulky and required heavy insulation to store the propellant ,
out weight. High energy per unit mass propellant like oxygen and hydrogen in liquid form give very high amount of energy per unit mass due to which the amount of fuel to be carried aboard the rockets decreases.
The cryogenic (or rocket) engine throws mass in one direction, and the reaction to this is a thrust in the opposite direction.
The cryogenic engines uses liquid nitrogen as the fuel and the exhaust is also nitrogen. Since nitrogen is present nearly 78% in our atmosphere, the engine is non pollutant. whereas in the case of normal IC engine,
the exhaust is carbon monoxide, CO2 and other harmful gases.
Efficiency is higher in the case of cryogenic engine than that of petrol engines

V. CONCLUSION

A cryogenic engine is important because it will carry heavy payloads the geosynchronous transfer orbital . this is highly essential for future technology or telecommunication and space exploration. It is able to carry up to five ton to the 1.5 ton payload capacity of p.s.l.v.s .

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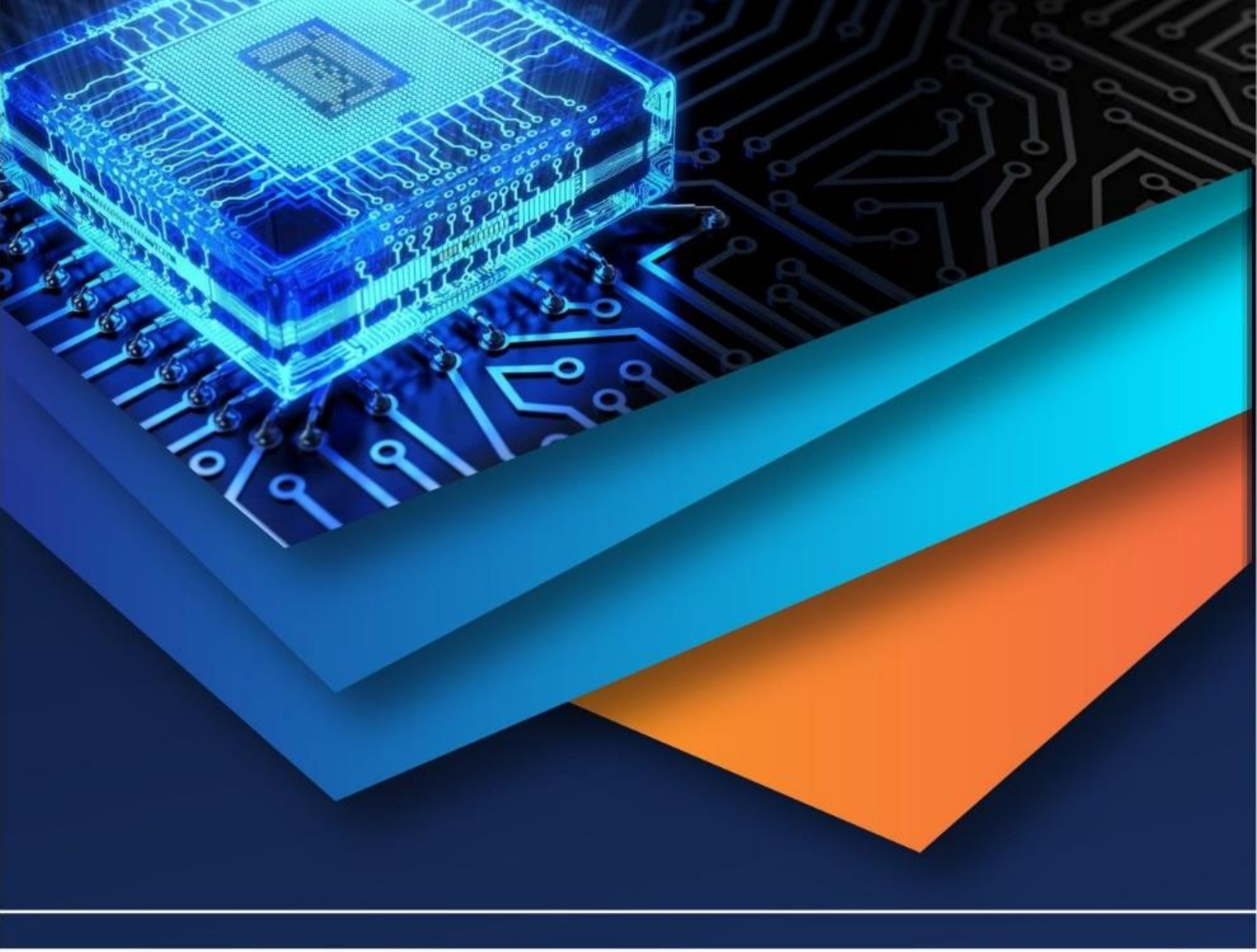

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