JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

DESIGN AND ANALYSIS OF HYBRID ROCKET ENGINE TEST FIRE BY USING HONEY COMB PARAFFIN WAX

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Abstract: A computational tool ready to perform a quick analysis of hybrid rocket engines is presented, describing briefly the mathematical and physical models used. Validation of the code is additionally shown: 16 different static firing tests available within the open literature are accustomed compare measured operational parameters like chamber pressure, thrust, and specific impulse with the code's output. the aim of the program is to perform rapid evaluation and assessment on a possible first design of hybrid rockets, without wishing on computationally expensive simulations or onerous experimental tests. The validated program considers as benchmark and study case the look of a liquid-oxygen/paraffin hybrid rocket to be used because the upper stage of a small launcher derived from VEGA building blocks. A full-factorial parametric analysis is performed for both pressure-fed and pump-fed systems to search out a configuration that delivers the equivalent total impulse of a VEGA-like launcher third and fourth stage as a primary evaluation. This parametric analysis is additionally useful to focus on how the oxidizer injection system, the fuel grain design, and also the nozzle features affect the performance of the rocket.

***Index Terms* – Hybrid Rocket, paraffin, oxidizer injection system, pressure fed, pump-fed systems etc.**

I. INTRODUCTION

Rocket propulsion concepts in which one component of the propellant is stored in liquid phase while the other is stored in solid phase are called hybrid propulsion systems. Such systems most commonly employ a liquid oxidizer and solid fuel. Various combinations of solid fuels and liquid oxidizers as well as liquid fuels and solid oxidizers have been experimentally evaluated for use in hybrid rocket motors. Most common is the liquid oxidizer-solid fuel concept. The oxidizer can be either a non- cryogenic (storable) or a cryogenic liquid, depending on the application requirements.

In this hybrid motor concept, oxidizer is injected into a precombustion or vaporization chamber upstream of the primary fuel grain. The fuel grain contains numerous axial combustion ports that generate fuel vapor to react with the injected oxidizer. An aft mixing chamber is employed to ensure that all fuel and oxidizer are burned before exiting the nozzle.

The individualism of Hybrid Rocket Engines (HREs) is the physical separation of propellants, stored in several phases. Usually, the fuel is stored as a solid within the combustion chamber while the oxidizer is stored in an exceedingly pressurized tank as a liquid or a gas, fed into the combustion chamber through an appropriate injection system. This particular method of propellant storage may entail some benefits with relevancy both Liquid Rocket Engines (LREs) and Solid Rocket Motors (SRMs), like safety, thrust modulation, and ease. The propellants used for hybrid propulsion are considered environmentally friendly and offer a remarkable specific impulse, generally in between the values achieved by liquid and solid propulsion.

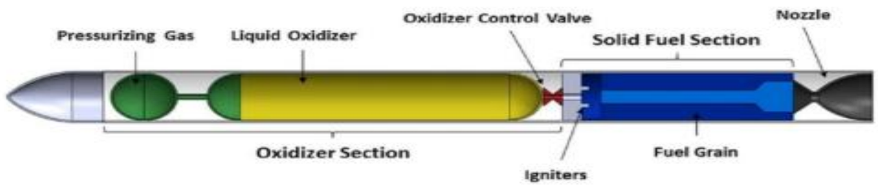

Fig1. Layout of Hybrid Rocket

II. LITERATURE SURVEY

Various Organization and Research Centers have been showing keen interest towards the Rocket Propulsion Systems due its increasing demand for further development in Communication and Navigation systems. Some of them are listed below:

- ✓ Space Propulsion Group was founded in 1999 by Dr. Arif Karabeyoglu, Prof. Brian Cantwell and others from Stanford University to develop high regression-rate liquefying hybrid rocket fuels. They have successfully fired motors as large as 12.5 in. diameter which produce 13,000 lbf. Using the technology and are currently developing a 24 in. diameter, 25,000 lbf. Motor to be initially fired in 2010.
- ✓ Orbital Technologies Corporation (Orbitec) has been involved in some US government funded research on hybrid rockets including the "Vortex Hybrid" concept.
- ✓ Environmental Aerospace Corporation (EAC) was incorporated in 1994 to develop hybrid rocket propulsion systems. It was included in the design competition for the Spaceship One motor but lost the contract to SpaceDev.
- ✓ Rocket Lab sells hybrid sounding rockets and related technology.
- ✓ The Reaction Research Society (RRS), although known primarily for their work with liquid rocket propulsion, has a long history of research and development with hybrid rocket propulsion.
- ✓ Copenhagen Sub orbitals, a Danish rocket group, has designed and test-fired several hybrids using N2O at first and currently LOX. Their fuel is epoxy, paraffin, or polyurethane.
- ✓ Several universities have recently experimented with hybrid rockets. BYU, the University of Utah, and Utah State University launched a student-designed rocket called Unity IV in 1995 which burned the solid fuel hydroxyl-terminated polybutadiene (HTPB) with an oxidizer of gaseous oxygen, and in 2003 launched a larger version which burned HTPB with nitrous oxide.
- ✓ Stanford University is the institution where liquid-layer combustion theory for hybrid rockets was developed. The SPaSE group at Stanford is currently working with NASA Ames Research Center developing the Peregrine Sounding rocket which will be capable of 100 km altitude.
- ✓ The WARR student-team at the Technical University of Munich is developing hybrid engines and rockets since the beginning of the 1970s. Using acids, oxygen or nitrous oxide in combination with polyethylene or HTPB. The development includes test stand engines as well as airborne versions, like the first German hybrid rocket Barbarella.

III. WORKING OF HYBRID ROCKET

The liquid oxidizer which is the stored in the separate tank is injected into combustion chamber. When liquid oxidizer mixes with the solid fuel in the combustion chamber combustion takes place automatically When the combustion takes place in the combustion chamber very high pressure and very high temperature gases are produced. The highly heated products of combustion gases are the allowed to expand in the nozzle section. In the nozzle pressure energy of the gas is converted into kinetics energy so the gases coming out from the unit with very high velocity. Due to high velocity of gases coming out from the unit a force thrust is the produced in the opposite direction this thrust produced the rockets.

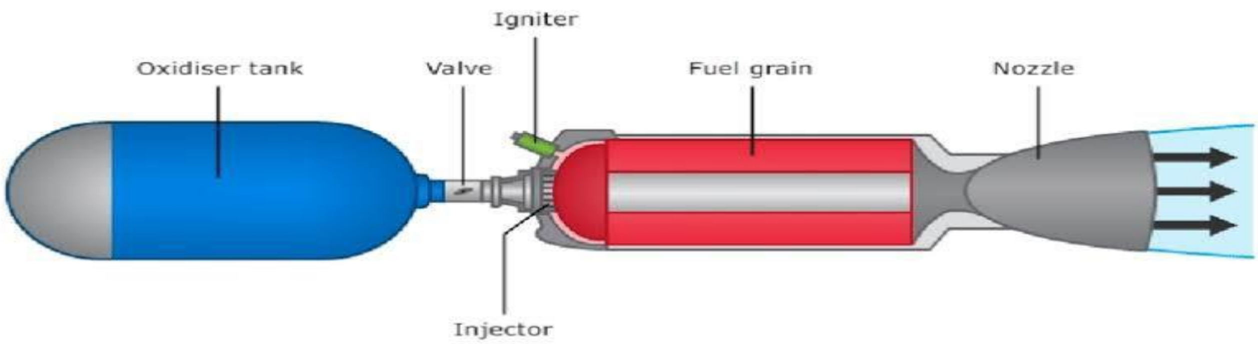

Fig 2. Working of Hybrid Rocket

IV. ADVANTAGES

A. COMPARED WTH BIPROPELLANT LIQUID ROCKETS

- ✓ Mechanically simpler - requires only a single liquid propellant resulting in less plumbing, fewer valves, and simpler operations.
- ✓ Denser fuels - fuels in the solid phase generally have higher density than those in the liquid phase, reducing overall system volume.
- ✓ Metal additives - reactive metals such as aluminum, magnesium, lithium or beryllium can be easily included in the fuel grain increasing specific impulse, density specific impulse, or both.

B. COMPARED WITH SOLID ROCKETS

- ✓ Higher theoretical I_{SP} is possible.
- ✓ Less explosion hazard - Propellant grain more tolerant of processing errors such as cracks.
- ✓ More controllable - Start/stop/restart and throttling are all achievable with appropriate oxidizer control.
- ✓ Safe and non-toxic oxidizers such as liquid oxygen and nitrous oxide can be used.
- ✓ Can be transported to site in a benign form and loaded with oxidizer remotely immediately before launch, improving safety.

C. MAIN ADVANTAGES

The main advantages of a hybrid rocket propulsion system are:

- ✓ Safety during fabrication, storage, or operation without any possibility of explosion or detonation;
- ✓ Start-stop-restart capabilities;
- ✓ Relatively low system cost;
- ✓ Higher specific impulse than solid rocket motors and higher density-specific impulse than liquid bipropellant engines; and
- ✓ The ability to smoothly change motor thrust over a wide range on demand.

V.DESIGN PHILOSOPHY

Our main design philosophy is to use paraffin wax due to its suitable properties such as non-toxic, non-carcinogenic, non-hazardous and most importantly environment friendly. Paraffin wax refers to a white or colorless soft solid that is used as a lubricant and for other applications. It is derived from petroleum and consists of a mixture of hydrocarbon molecules containing between twenty and forty carbon atoms. It is solid at room temperature and begins to melt above approximately 37 °C (99 °F). In chemistry, paraffin is used synonymously with "alkane", indicating hydrocarbons with the general formula C_nH_{2n+2}. The name is derived from Latin partum ("barely") + affine, meaning "lacking affinity" or "lacking reactivity" indicating paraffin's unreactive nature.

Paraffin wax is mostly found as a white, odorless, tasteless, waxy solid, with a typical melting point between about 46 and 68 °C (115 and 154 °F), and having a density of around 900 kg/m3. It is insoluble in water, but soluble in ether, benzene, and certain esters. Paraffin is unaffected by most common chemical reagents but burns readily. The hydrocarbon $C_{31}H_{64}$ is a typical component of paraffin wax. Paraffin wax is an excellent electrical insulator, with an electrical resistivity of between 1013 and 1017ohm meter. This is better than nearly all other materials except some plastics (notably Teflon). It is an effective neutron moderator and was used in James Chadwick's 1932 experiments to identify the neutron.

Some of the major reasons for choosing paraffin wax as fuel for hybrid rockets are listed below:

- ✓ Paraffin wax on melting layer produces a very thin, low viscosity, low surface tension liquid layer on the fuel surface when it burns.
- ✓ The instability of this layer is driven by the oxidizer gas flow in the port and leads to the lift-off of droplets and entrainment of droplets into the gas stream greatly increasing the overall fuel mass transfer rate.
- ✓ Regression rate is 3-5 times as high as the classic polymeric fuels (including HTPB) enabling efficient, single-port designs.
- ✓ The fuel is non-toxic, non-carcinogenic, non-hazardous and environmentally friendly.
- ✓ No polymerization reactions are involved. No curing agents are required.
- ✓ Being inert, paraffin -based fuels effectively have an infinite storage life.

- ✓ The paraffin -based fuel also works under challenging environmental conditions, like the very low temperature found on the surface of Mars.

VI.DESIGNED MODEL OF NOZZLE

Here we have designed some of the existing normal nozzle model along with our proposed model design. All the models were designed with the help of Catia software and analyzed using ANSYS 2021 model.

A. CATIA MODELS

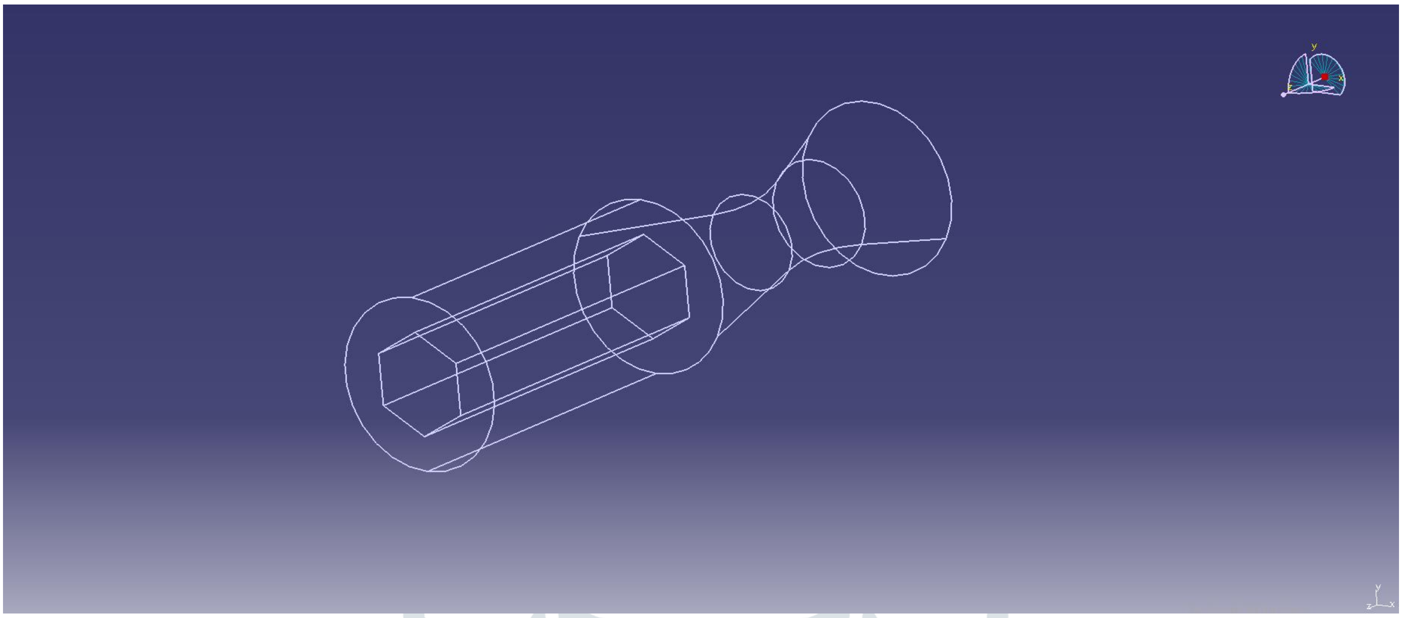

Fig 3. Normal Honey comb

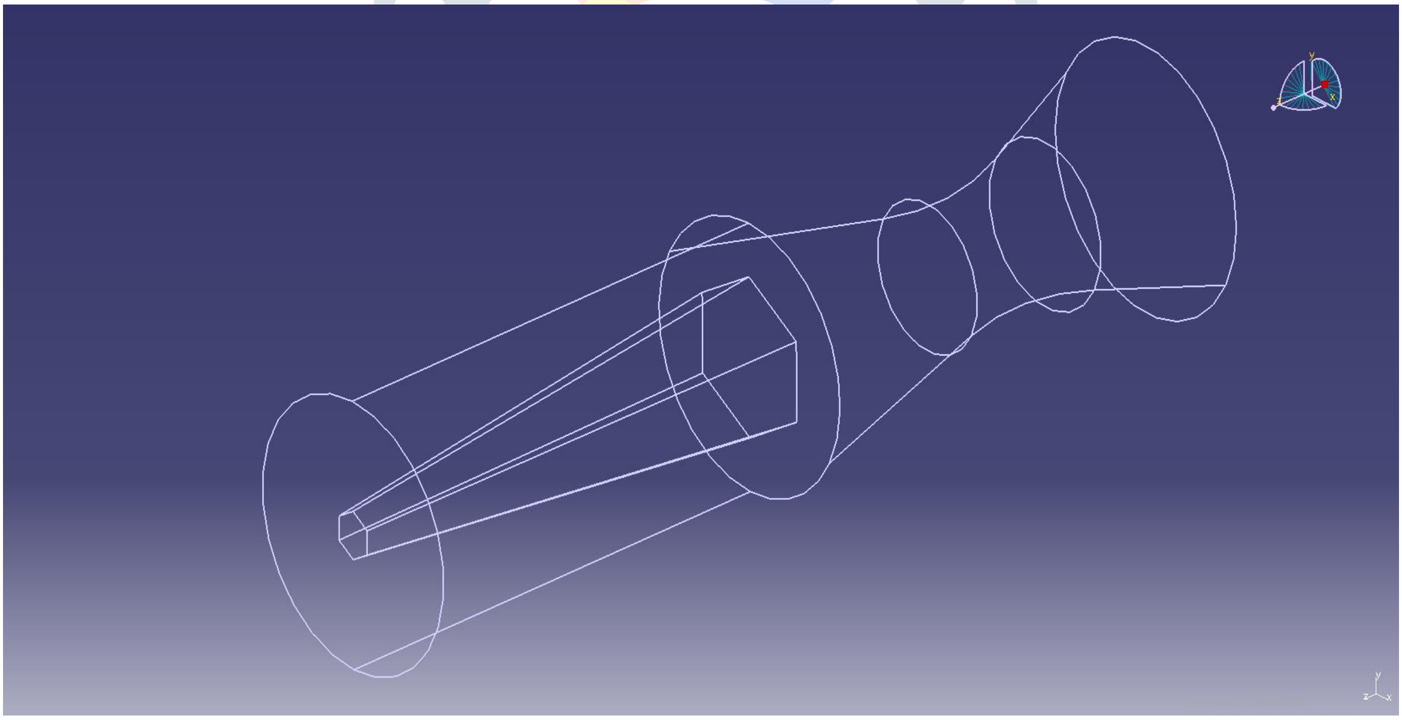

Fig 4. Divergent model

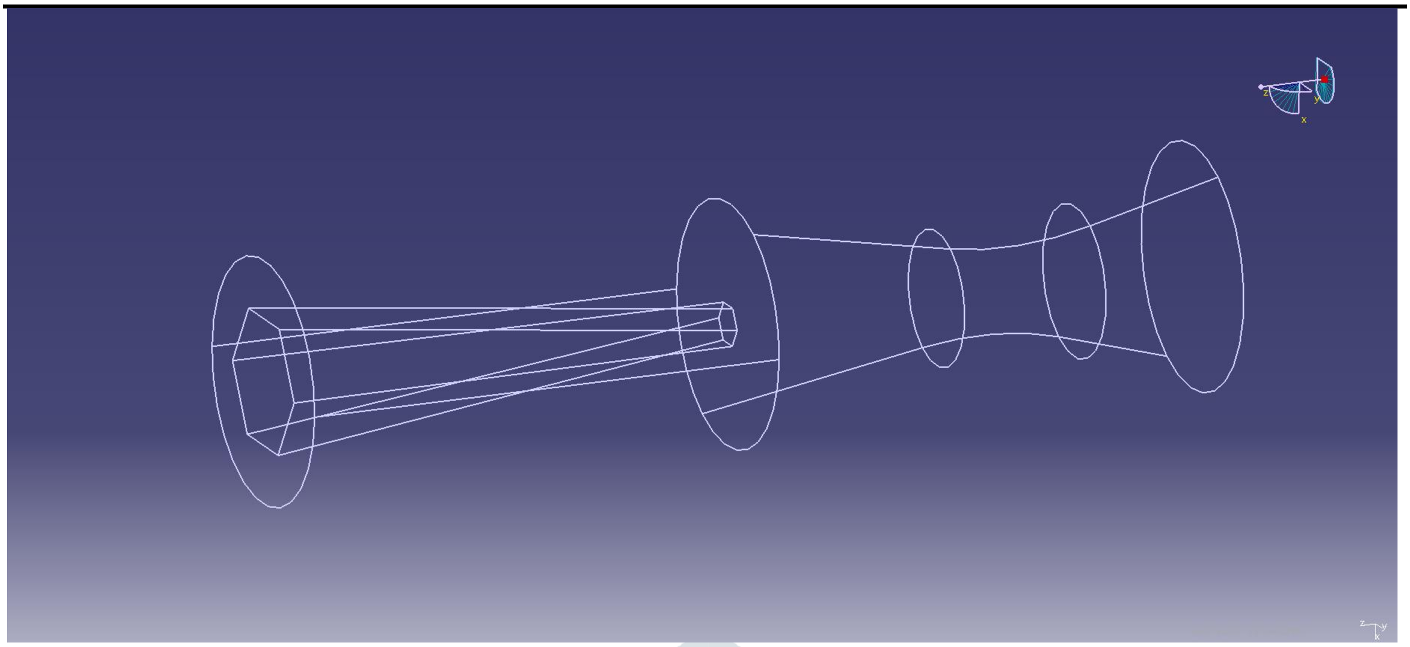

Fig 5. Convergent Model

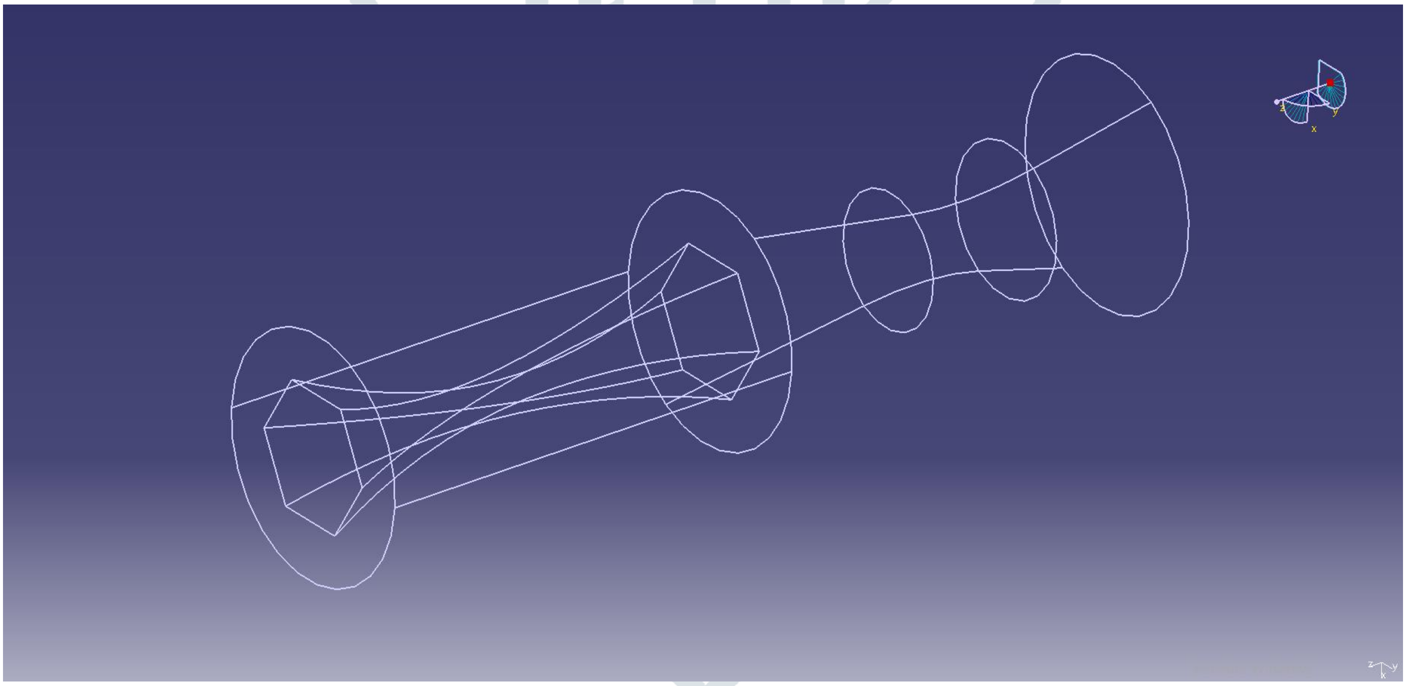

Fig 6. Our Proposed Model (Convergent -Divergent Model)

B. MESHING OF OUR PROPOSED MODEL

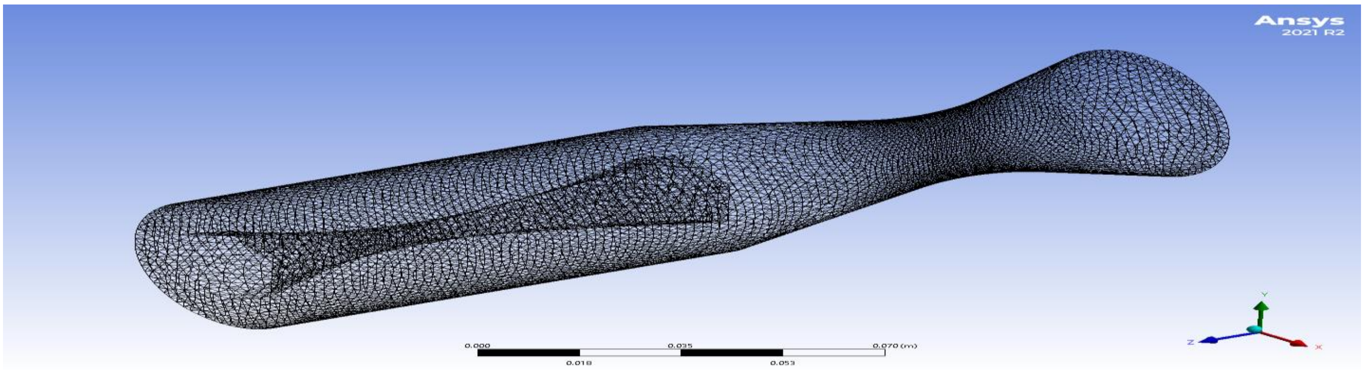

Fig 7. Meshing of Convergent- Divergent Model

C.ANALYSIS THROUGH ANSYS

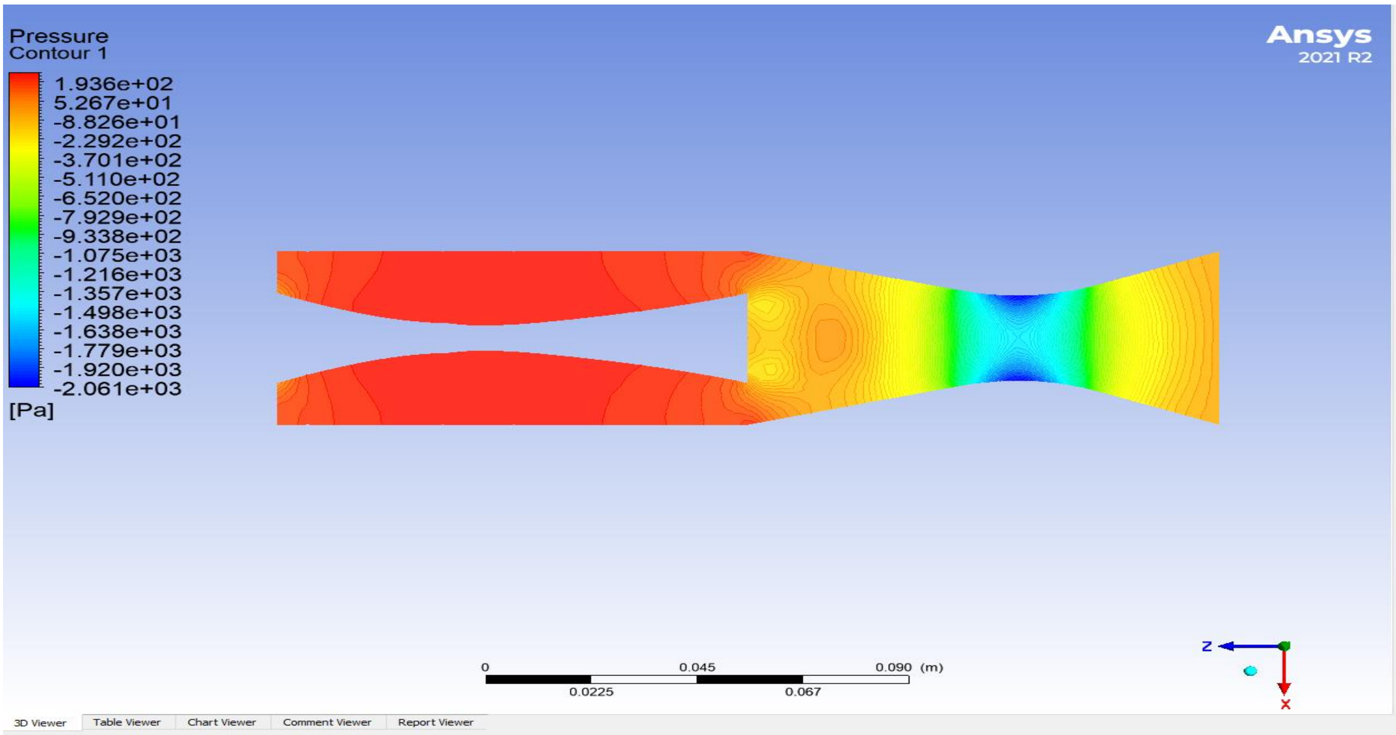

Fig 8. Pressure graph for C-D nozzle

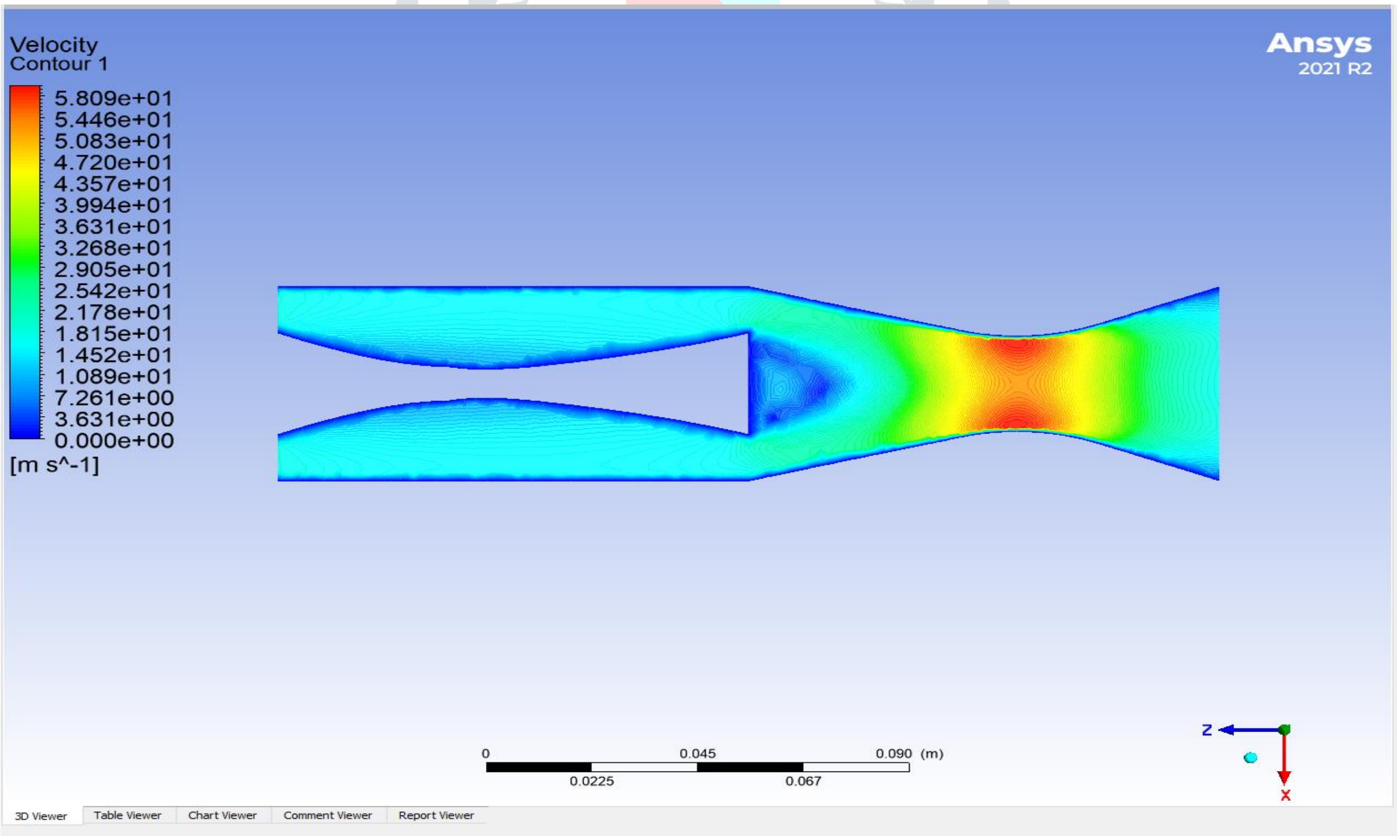

Fig 9. Velocity graph of C-D nozzle

VII.CONCLUSION

This paper provides a clear conclusion that a commercial paraffin wax possessing high amount of branched alkenes, can be selected for its capacity to form micro-crystals, which allow high fracture toughness and workability. A wide thermal and rheological characterization was carried out supporting the manufacturing process and thermal analyses. Additionally, the formation of ashes during the thermo-oxidative degradation of paraffin wax has to be taken into account for the re-ignition tests of the fuel grain. Rheological characterizations gave information on the storage and loss moduli, and viscosity of both solid and liquid paraffin wax. In particular, the viscosity value at high temperature. A wide thermal and rheological characterization was carried out supporting the manufacturing process. Thus, we hope this project helps our friends and colleagues, reseachers to know more about the paraffin wax, its advantages over the solid and liquid rocket fuels.

VIII. ACKNOWLEDGMENT

First and foremost, we want to offer this endeavor to our GOD Almighty for the wisdom he bestowed upon us, the strength, peace of mind and good health in order to finish this research. We thank Dr. S.P. VENKATESAN., Ph.D., Head of the Department, Aeronautical Engineering, our professor Dr.P. KARUNAKARAN., Ph.D., for their guidance and constant inspiration. We express our gratitude to our professor Mr. S.R. ARUN., MTech., for encouragement and dedicated guidance. We take privilege to record our everlasting and loving thanks to our parents for their kind help and support which render in bringing our Project fruitful manner. We would like to thank and appreciate our colleague Mr. Rakesh Kumar Shah who have helped us throughout the completion of this project.

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