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

Numerical and Experimental study on Truncation of Aerospike Nozzle with Rotating Detonation Engine

[1]Amartya Sen Ayush, [2]Gursharan Kaur , [3]Nishchay Bansal , [4]Avni Gupta ,

[5]Nikhil Gangamkote

[1,2,3,4,5]Propulsion
[1,2,3,4,5] Aerospace Engineer,
[1,2,3,4] Chandigarh University, Punjab, India , [5]Prime Toolings , Bengaluru , India

Abstract : An Aerospike nozzle is used over a Conventional Bell-shaped Nozzle because of its additional advantages, such as altitude compensation. However, It faces major drawbacks, i.e., thermal and acoustics effect (excessive heating and excessive sound), which degrade its efficiency. In order to keep that in mind, we focused on Truncation of the nozzle to optimize the nozzle and make it more Efficient. We have a compact Butane fueled Rotating Detonation Engine setup with different aerospike nozzles. First of all, we had experimentally tested each one of them. The experimental setup includes an Ignitor, Dynamic plate, Spike, Combustion Chamber, and Fuel Oxidizer Injector. Experimental tests revealed that 40% truncated nozzle gives best efficiency, and efficiency increases with increase in truncation upto 40% which is further being verified with CFD analysis of each Aerospike nozzle too. The Main aim of our research is to experimentally study the effect of truncation on aerospike nozzle.

IndexTerms – A*erospike Nozzle , Truncated Aerospike Nozzle , Rotating Detonation Engineer*

I. INTRODUCTION

In the modern world, it is very essential to mitigate the drawbacks of the bell nozzle i.e. it do not have altitude compensation effect.That is the main reason why the Aerospike nozzle is introduced in order to mitigate it but the main drawback with the Aerospike nozzle is its thermal and acoustic effects; that is, it produces excessive heat and sound, which makes it very tough to use.
Currently, heavy research is going on aerospike nozzles, including organizations like NASA, US Air force in order to make it more efficient because of its advantages over the conventional types of nozzles. Various works includes adding base bleed in the nozzle, adding a cooling channel, and making it truncated.

In this current study, we have tested aerospike nozzles at different truncation percentage having Rotating Detonation Engine integrated in it. We had experimentally tested it with butane fuel and oxygen oxidizer. Different colors of the flame came out at different percentage which we has been attached in order to conclude our study.

II. AIM

The AIM is to analyse both Experimentally and Numerically Truncated Aerospike Nozzles in order to find out which one is most efficient.

III. OBJECTIVE

The main objective of this research is to enhance the efficiency of an Aerospike nozzle in a Rotating Detonation Engine setup by making it truncated and doing a comparative study on different truncation percentage. Our main goal is to make the Aerospike nozzle work most efficiently.

The Work involves:
1. Design different percentage of truncated Aerospike nozzles with a rotating detonation engine setup in Catia Software
2. Fabricating the Engine from Stainless Steel
3. Adding fuel and oxidizer and experimentally testing the model for :

- d. Analyzing the flame
- e. Numerical Validation

IV. WHAT IS A ROTATING DETONATION ENGINE ?

A Rotating Detonation Engine is an Advanced propulsion system that produces Thrust using continuous detonation waves instead of conventional combustion.

Working of a Rotating Detonation Engine involves the following Steps :

1. Fuel and oxidizer are continuously injected into the annular combustion chamber.
2. Ignitor initiates the first detonation wave.
3. Detonation waves start rotating continuously around the annular combustion chamber at supersonic speed.
4. Waves compress and ignite the incoming fresh propellant mixture as it rotates.
5. High-pressure and high-temperature combustion products start to be produced, which further expand through the nozzle to generate thrust.
6. Because of detonation, energy starts getting released at a much faster rate, which further results in greater efficiency.

V. EXPERIMENTAL SETUP

A. CAD Design

The complete design is made in Catia Software with proper dimensions which ensures efficient expansion and exhaust through aerospike nozzle.

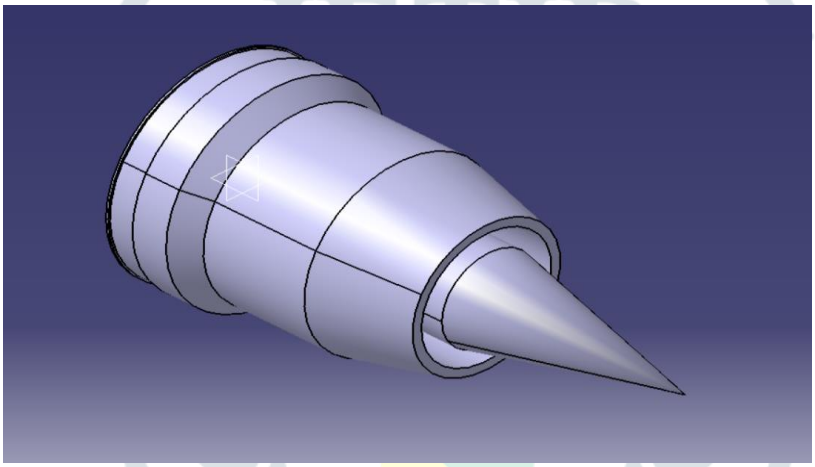


Fig 1: 0 percent truncated Aerospike Nozzle with Rotating Detonation Engine

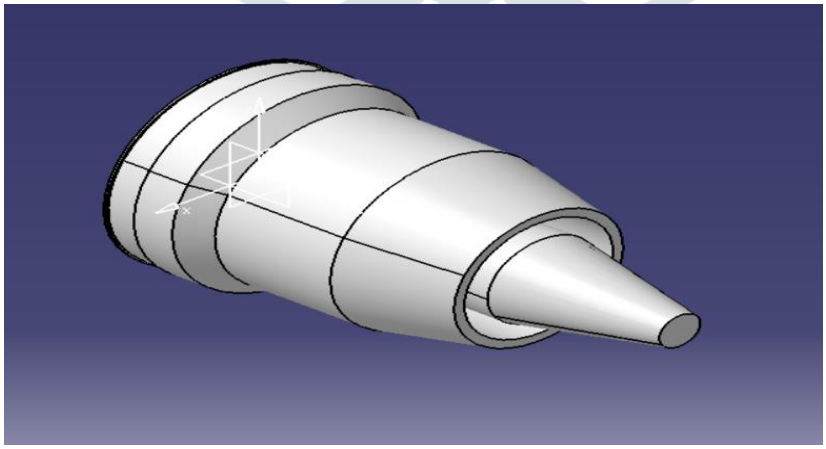


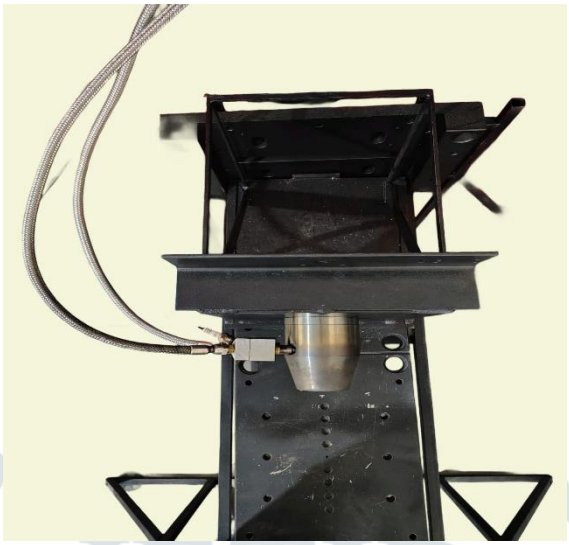
Fig 2 : 40 percent truncated Aerospike Nozzle with Rotating Detonation Engine

B. FABRICATING AND PROTOTYPING

CAD design is fabricated using CNC Machining having stainless steel as a material.

MAJOR COMPONENTS:

1. Engine Mounting stand -



2. Gas Cylinder -



3. One way Return Valve -



4. Engine Casing -



5. Pintle injector with Spark plug -



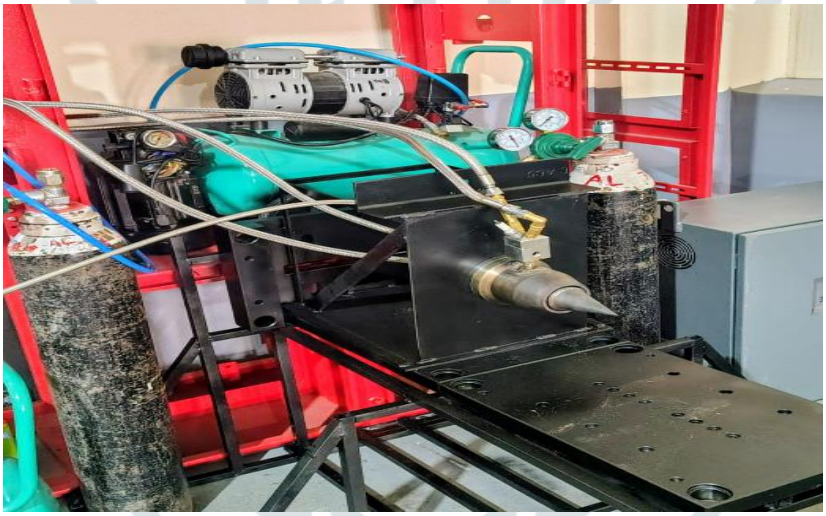
6. Dynamic Plate -



7. Aerospike Nozzle -



8. Full setup -



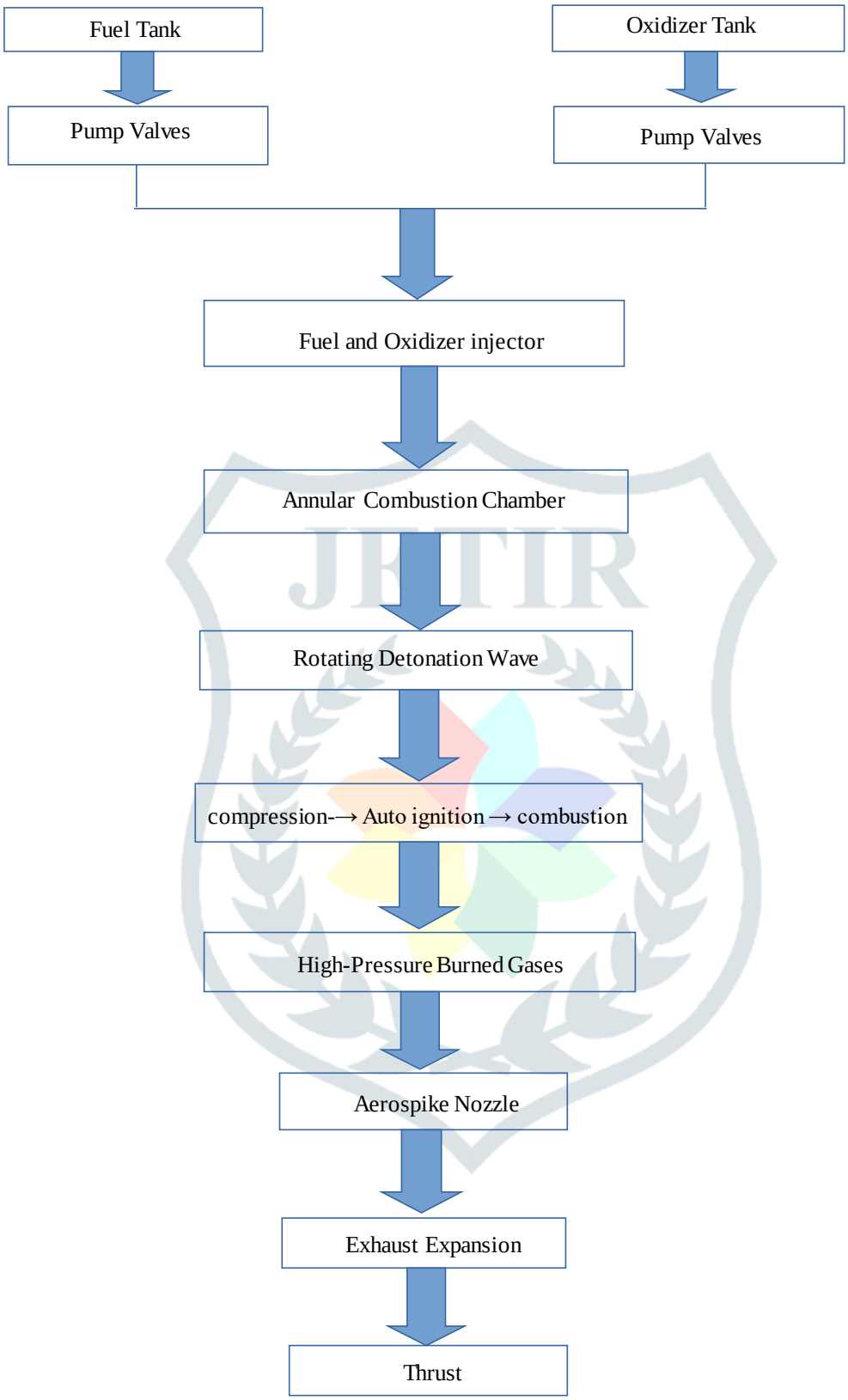
C. FUEL AND AIR SUPPLY :

1. Fuel - Butane Gas

2. Oxidizer – Oxygen (O2)

3. Where they are getting mixed? – They Mix in the Annular Chamber

VI. OVERALL FLOW SEQUENCE OF THE COMPLETE SET- UP :



VII. FLAME COLOR INDICATION

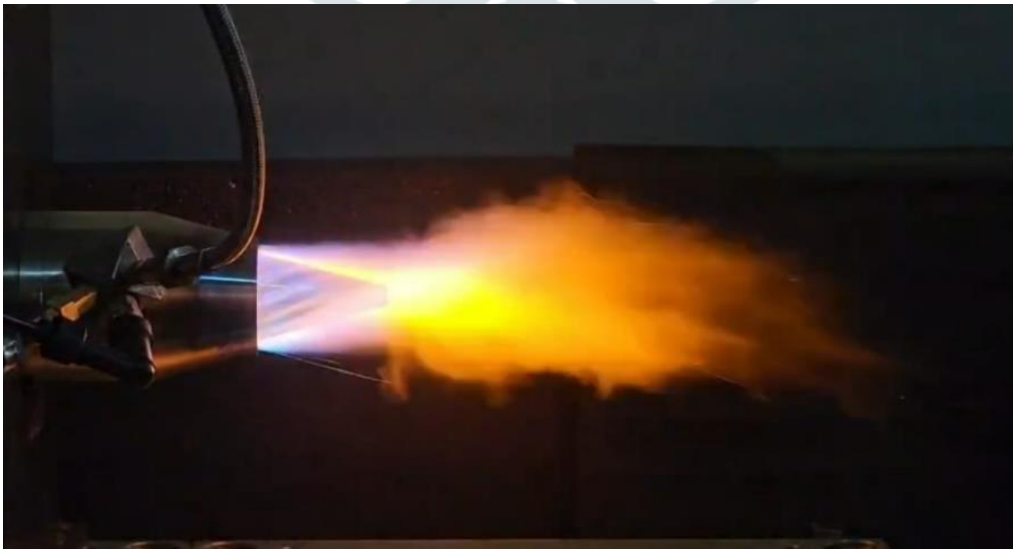
1. Blue Flame	It indicates complete combustion. A steady blue flame suggests efficient detonation with minimum unburnt fuel.
2. Yellow-Orange Flame	It indicates incomplete combustion or sooth and unburned hydrocarbons are present which also indicates irregular pressure oscillations.
3.White Flickering or Pulsating Flame	It indicates unstable detonation which is generally caused by strong acoustic coupling and rapid-ignition extinction cycles.
4. Faint or Transparent Flames (with heat waves visible)	It indicates weak detonation conditions. It is a very lean mixture usually under low pressure.

VIII. EXPERIMENTAL SETUP

1. 0 Percent Truncated Aerospike Nozzle :



2. 20 Percent Truncated Aerospike Nozzle :



3. 30 Percent Truncated Aerospike Nozzle :

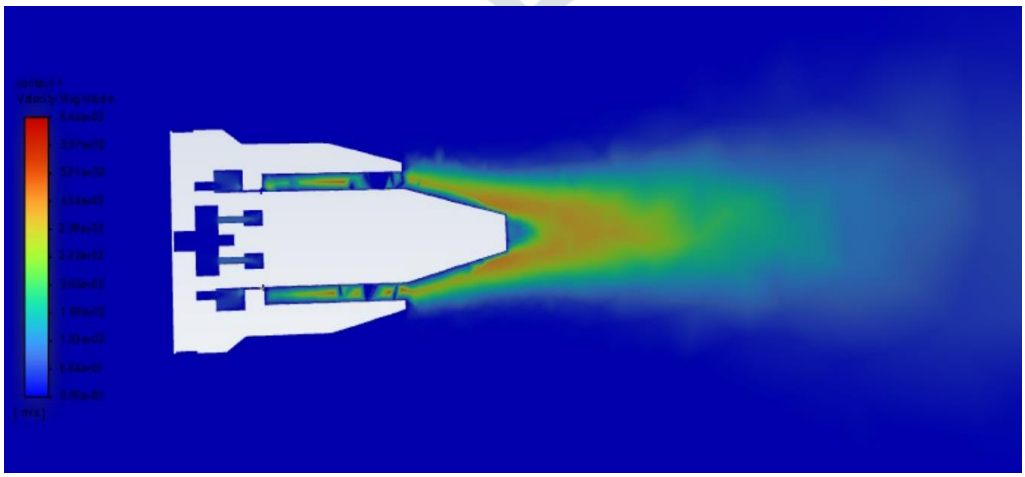


4. 40 percent Truncated Aerospike Nozzle :

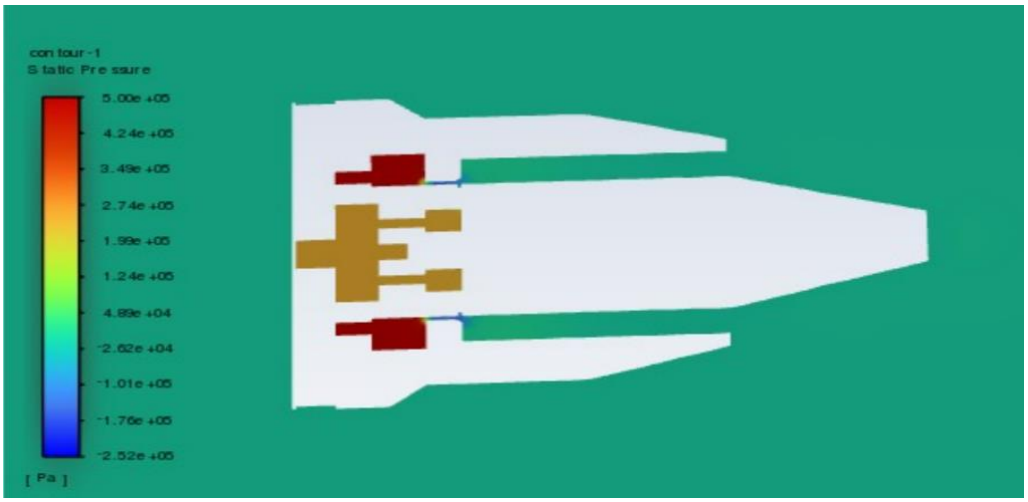


IX. CFD RESULTS OF 40 PERCENT TRUNCATED NOZZLE :

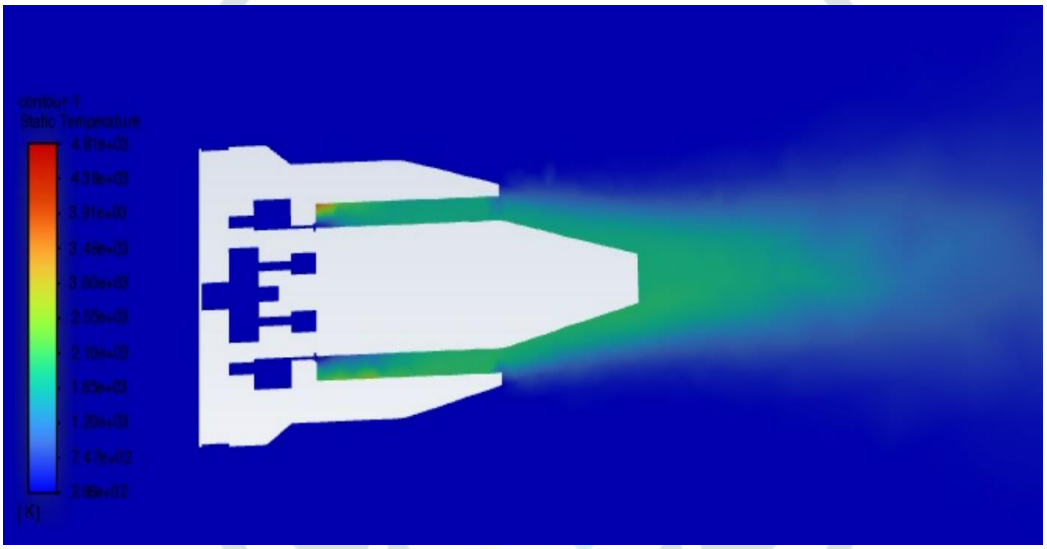
1. Velocity Contours:



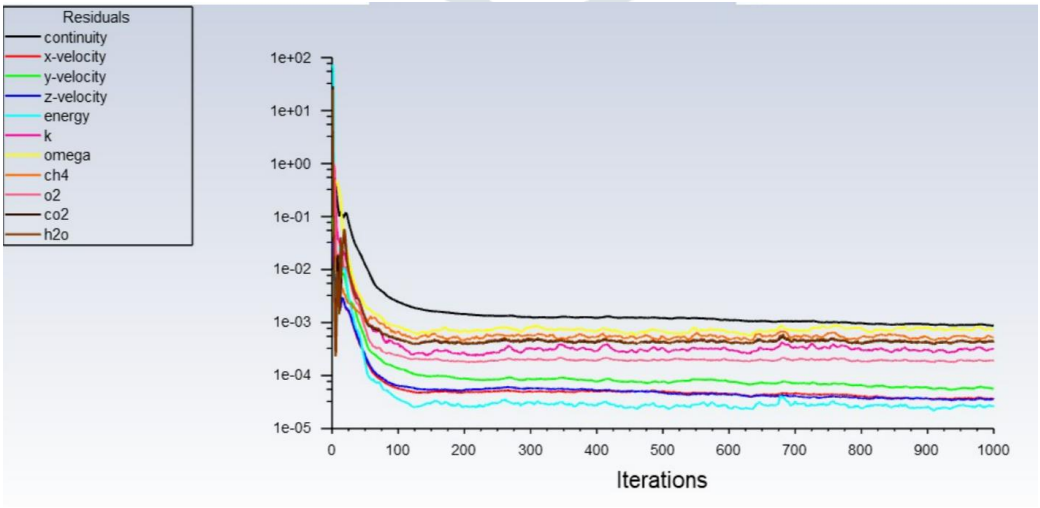
2. Pressure contours :



3. Temperature contours :



4. Scaled Residuals :



X. CONCLUSIONS :

Aerospike Nozzles	Experimental Result Suggests
1. 0 Percent Truncated Aerospike Nozzle	Complete red narrow and highly collimated flame, with low luminosity which indicates the possibility of incomplete combustion and it suggests limited visible plume expansion.
2. 20 Percent Truncated Aerospike Nozzle	Slight wider reddish-orange flame with stable combustion and increased plume expansion in comparison to 0 percent.
3. 30 Percent Truncated Aerospike Nozzle	Bright Long Flame with good stability which indicates effective flow expansion.
4. 40 Percent Truncated Aerospike Nozzle	Brightest and Longest Flame with blue core near nozzle exit which suggests stable high temperature exit plume.

Experimental results suggested that 40 percent Truncated Nozzle shows the best results which is further verified by CFD Results. It suggested that Truncation reduces the Thermal Effect and increases the Efficiency. Further refinement with sensors can be done to measure thrust, pressure, and temperature experimentally in order to compare that with the CFD results which is the Future Scope of the Research.

VII. ACKNOWLEDGMENT

We would like to thank Mr.Nikhil Gangamkote and whole Prime Tooling team for providing the platform and the essentials needed to do the Experimental testing. This work can never be possible without their support. We would also like to thank all fellow interns for assisting us in Experimental testing especially two of the interns Ansh Sharma and Harshvardhan Sarathe.

REFERENCES

[1] JohnZ.Ma, WeiminBao, Jian-pingWang. " Experimental research of the performance and pressure gain in continuous detonation engines with aerospike nozzles " ,Aerospace Science and Technology 2023

[2] K. Sankari Ashok Alshiya ⇑, M. Santhosh, V.K. Santhosh, S. Sai Gopal. " Experimental analysis of jet flow in an aerospike nozzle", Materials Today 2021

[3] .NASA Glenn Research Center. "Rotating Detonation Rocket Engine Research." nasa.gov

[4] Nazarinia. M, Naghib-Lahouti .A, and Tolouei.E, "Design and Numerical Analysis of Aerospike Nozzles with Different Plug Shapes to Compare Their Performance with a Conventional Nozzle," Aerospace Research Institute, 2003.

[5] YiyuanZhu, KeWang, ZhichengWang, MinghaoZhao, ZhongtianJiao, YunWang, WeiFan " Study on the performance of a rotating detonation chamber with different aerospike nozzles,"aerospace Science and Technology 2020

[6] Nagarajan P , Thiru.D.Kulandaivel. " Numerical Simulation of Truncated Aerospike Nozzle" International Journal of Scientific Research & Engineering Trends, 2021