Redesigning and Analysis of Aerospike Nozzle by Spike Length Optimization

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Abstract- **Aerospike nozzle is named for its prominent spike located at center. This project mainly focuses on redesigning various types of nozzle such as aerospike, truncated aerospike and truncated aerospike with bleed. The commercial software Ansys 14.5 is used for analyzing. At redesigned aerospike nozzle, its operational normal condition such as velocity range of flow where analyzed. The comparison on full spike, truncated spike and truncated spike with bleed configuration are included. The increase demand for higher performance in aerospace propulsion promotes the development of nozzle with higher performance which is basically achieved in aerospike nozzle. Thus, a renewed interest into aerospike nozzle has arisen for the possible replacement of standard nozzle used for propulsion system of space vehicles.**

Keywords-Aerospike nozzle, truncated aero spike nozzle, truncated aerospike nozzle with bleed, Ansys14.5

1. INTRODUCTION

1.1 Nozzle

A nozzle is often a pipe or tube of varying cross sectional area and it can be used to direct or modify the flow of a fluid.

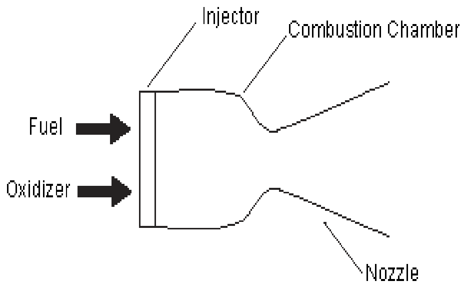

Fig 1.1 Rocket nozzle

A rocket nozzle (Fig 1.1) includes three main elements: a converging section, a throat and a diverging section. The combustion exhaust gas first enters the converging section. The gas moves at subsonic speeds through this area, accelerating as the cross sectional area decreases. In order to reach supersonic speeds, the gas must first pass through an area of minimum cross sectional area called the throat. From here, the supersonic gas expands through the converging section and then out of the nozzle. Supersonic flow accelerates as it expands.

1.2 Aerospike Nozzles

Aerospike nozzles (fig 1.2) are investigated in this paper for two reasons. The first is to demonstrate that the code developed is robust and the techniques used are applicable for designing different types of supersonic nozzles. The aerospike nozzle is considered to have better overall performance compared to the conventional bell nozzle since expansion of the jet is not bounded by a wall and the exhaust flow can adjust itself to the environment by changing the jet boundary. In addition, the nozzle performance is considered not to be influenced by the cutting off the nozzle because the base pressure compensates the loss of thrust force. The base pressure can also be increased by injecting a secondary flow at the base which may be tapped off the exhaust flow and injected.at the base.

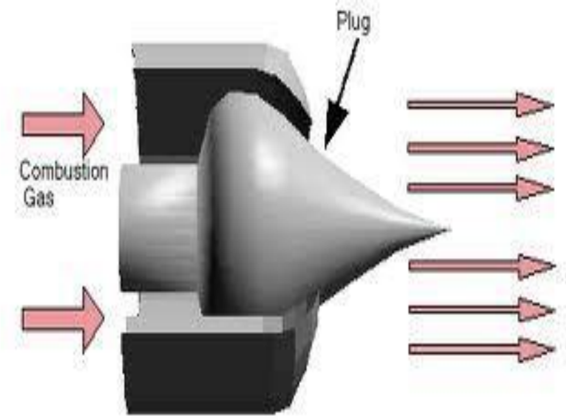

Fig1.2 aero spike nozzle

2. COMPUTATIONAL FLUID DYNAMICS

CFD is a science of predicting fluid flow, heat and mass transfer, chemical reaction and related performance by solving the set of governing mathematical equations of fluid dynamics the continuity, momentum and energy equations. These equations speak physics.

2.1 Numerical Discretization Techniques

In this process of numerical discretization each term within a partial differential equation is translated into a numerical analogue that the computer can be

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programmed to calculate. Some of the numerical discretization techniques

a. Finite Difference method
b. Finite Element method
c. Finite Volume method

2.2 Governing Equations

The governing equations are the mathematical statements of three fundamental physical principles upon which all of fluid dynamics is based.

a. Mass is conserved
b. Newton's second law
c. Energy is conserved

3. GEOMETRY DESCRIPTION AND GRID GENERATION

Geometry creation is the initial preparation in the pre-processing step of the CFD analysis. CFD analysis basically needs geometry to be analyzed, which in general created using GAMBIT software or some CAD software's like CATIA.

3.1. Modeling ofthe Nozzle Using CATIA

Modeling of the aero spike nozzle is done by the designing software CATIA V5. The dimensions of the model are represented in the figure3.1

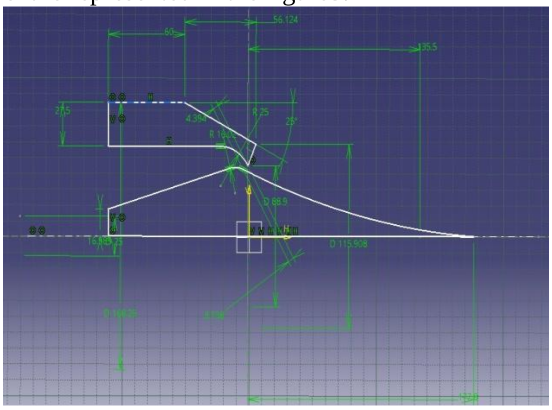

Fig 3.1 Nozzle dimensions

Aero spike nozzle designed in 3D by the dimensions is shown in the figure above, Fig (3.2,) the view is three dimensional and this is the spike basic spoke nozzle

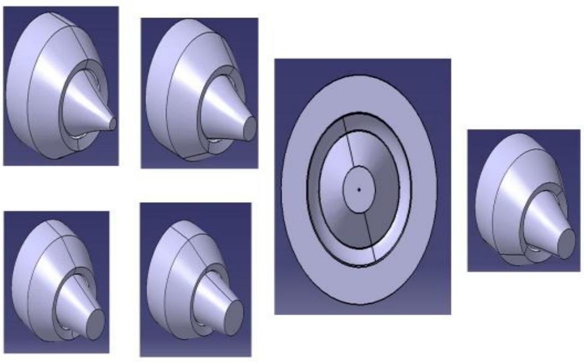

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Fig 3.2variousaero spike nozzle models

Nozzle ratios-For normal spike;

- Ratio 1 = 150 % of throat diameter
- Ratio 2 = 200 % of throat diameter
- Ratio 3 = 250 % of throat diameter
- Ratio 4 = 300 % of throat diameter

For truncated and with bleed types nozzles;

- Ratio 1 = $\frac{1}{2}$(150 % of throat diameter)
- Ratio 2 = $\frac{1}{2}$ (200 % of throat diameter)
- Ratio 3 = $\frac{1}{2}$ (250 % of throat diameter)
- Ratio 4 = $\frac{1}{2}$ (300 % of throat diameter)

Grid Generation- Grid generation is the next logical step to the geometry creation in the CFD analysis is shown in fig 3.3 by means of mesh.

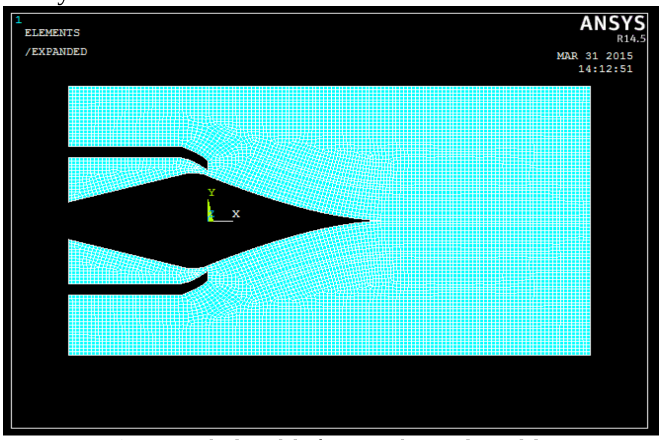


Fig 3.3 Meshed model of Aero spike nozzle model

Boundary condition for flow analysis is mentioned at 20000m altitude and velocity is mentioned to the inlet is subsonic flow. In aero spike nozzle flow analysis is made for above conditions for above meshed geometry.

4. RESULTS AND DISCUSSIONS

4.1. CFD Results for Normal Spike Nozzle

Normal spike nozzle is subjected to an exhaust flow in subsonic speed and increased to sonic at the throat and into the supersonic velocity. The nozzle lengths are assigned as the 150 per cent of then the diameter of the throat and

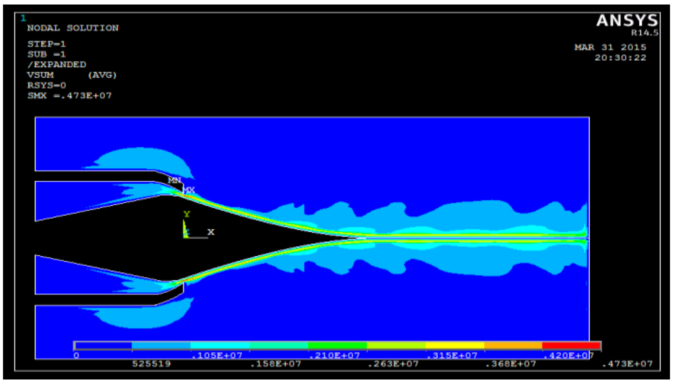


Fig 4.1 Aerospike nozzle ratio 1

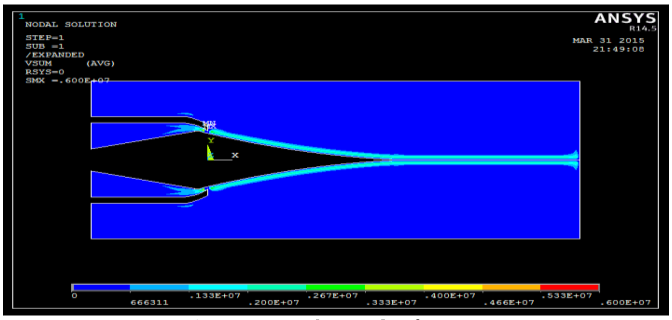


Fig 4.2 Aerospike nozzle of ratio 2

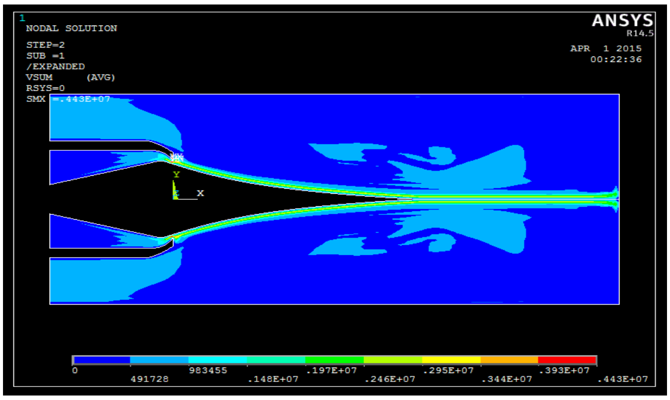


Fig 4.3 Aerospike nozzle ratio

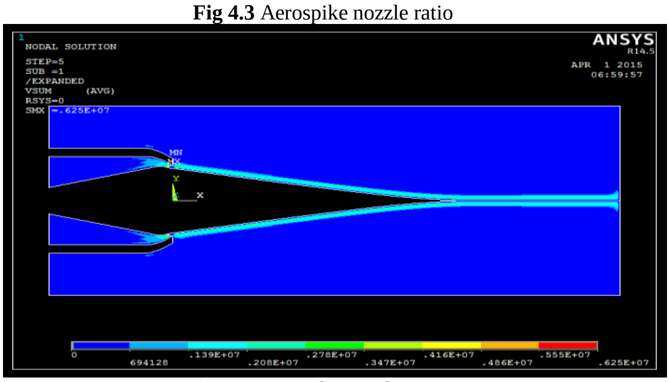


Fig 4.4 Aerospike nozzle ratio 4

4.2. CFD result for truncated aerospike nozzle

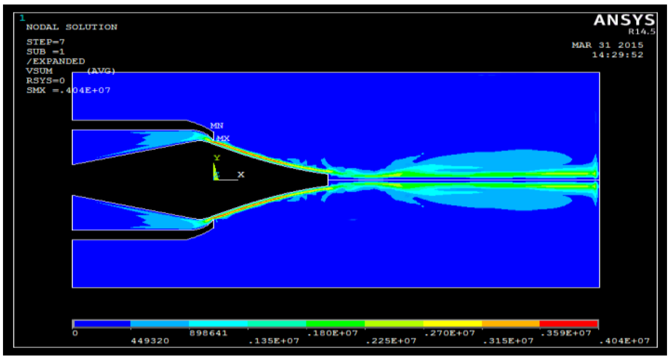


Fig 4.5 Truncated aero spike nozzle ratio 1

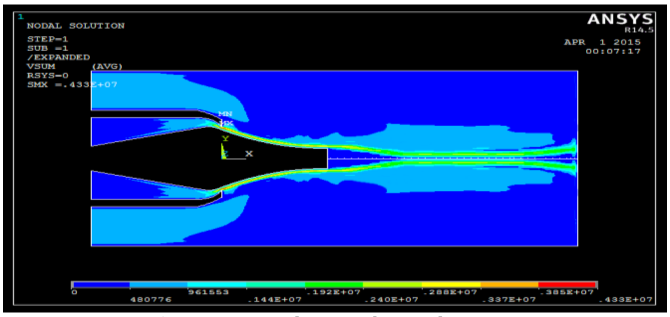


Fig 4.6 Truncated aero spike nozzle ratio 2

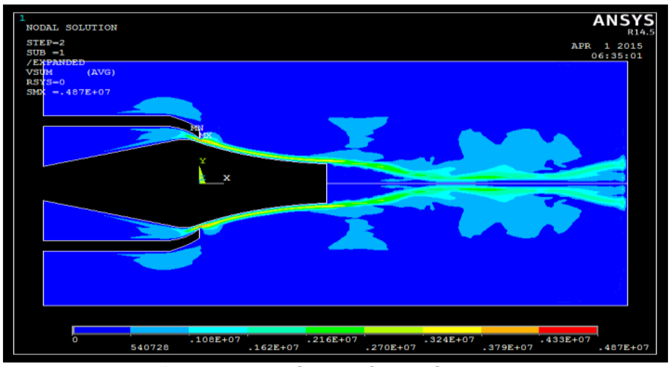


Fig 4.7 Truncated aerospike nozzle ratio 3

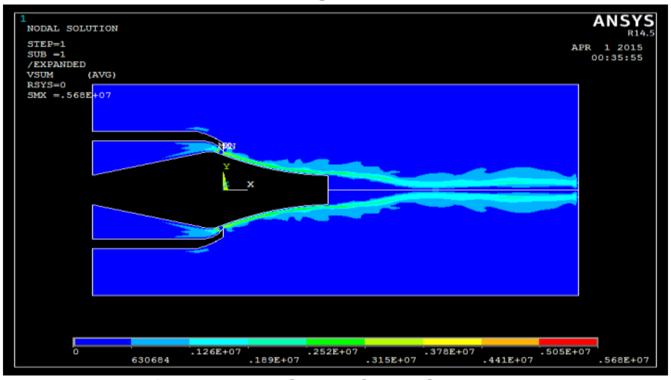


Fig 4.8 Truncated aerospike nozzle ratio 4

4.3 CFD analysis of truncated aerospike nozzle with bleed

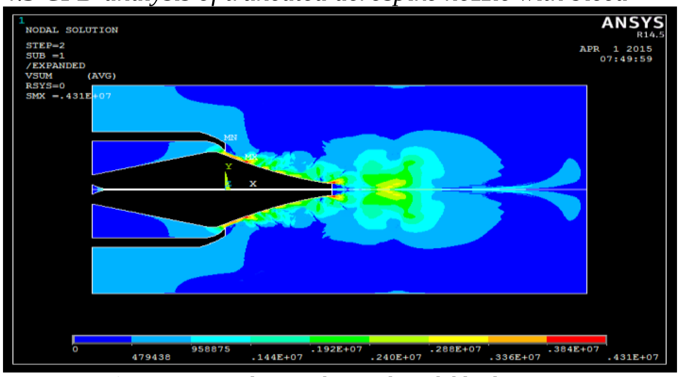


Fig 4.9 Truncated aerospike nozzle with bleed ratio 1

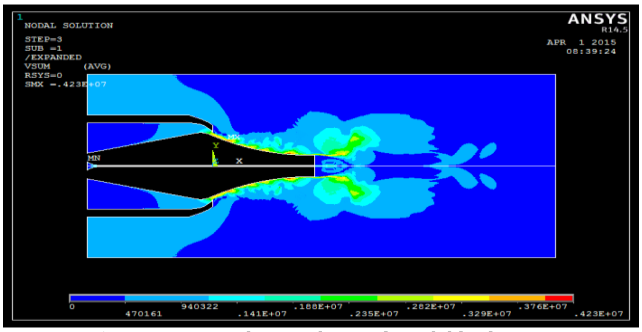


Fig 4.10 Truncated aerospike nozzle with bleed ratio 2

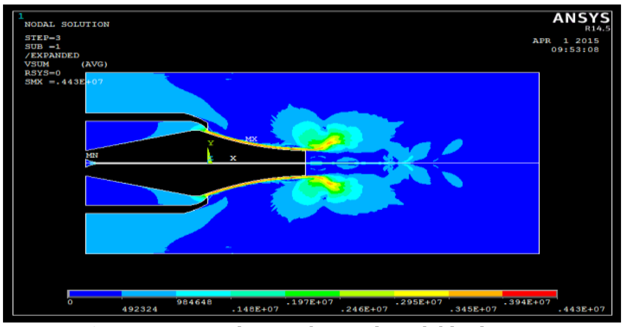


Fig 4.11 Truncated aerospike nozzle with bleed ratio 3

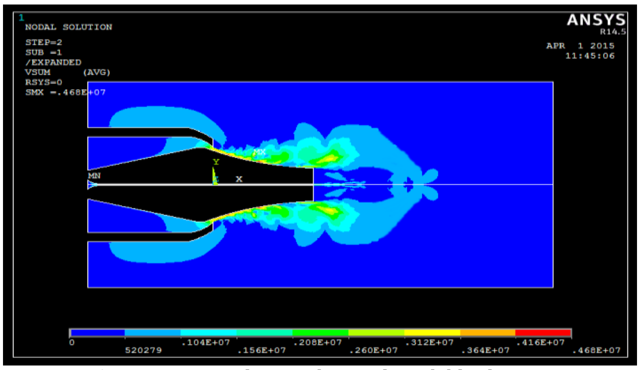
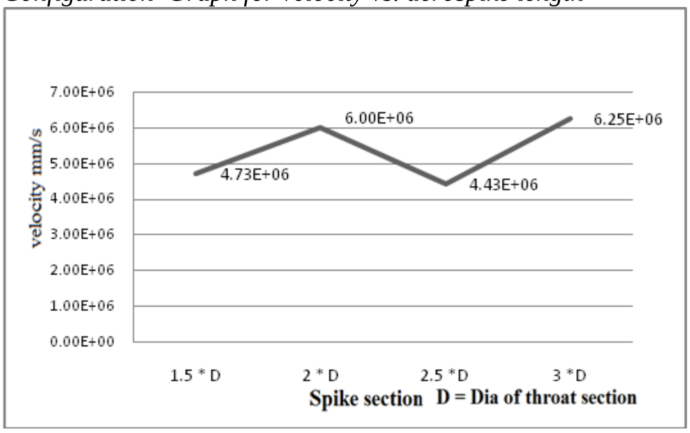


Fig 4.12 Truncated aerospike nozzle with bleed ratio 4

4.4. Comparison Of Performance With Different Configuration

Graph for velocity vs. aerospike length

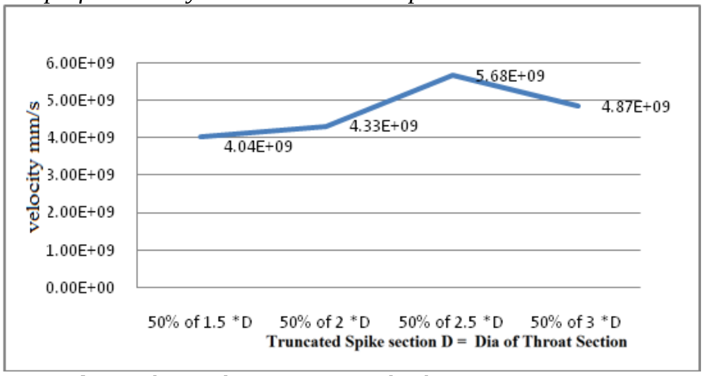


Graph 4.1 Exhaust velocitiesvs. spike section at 20,000 m altitude

Maximum velocity producing length = 3*D Velocity = 6.25E + 06

This graph is of the aerospike nozzle which is changed the length of the spike as per the percentages

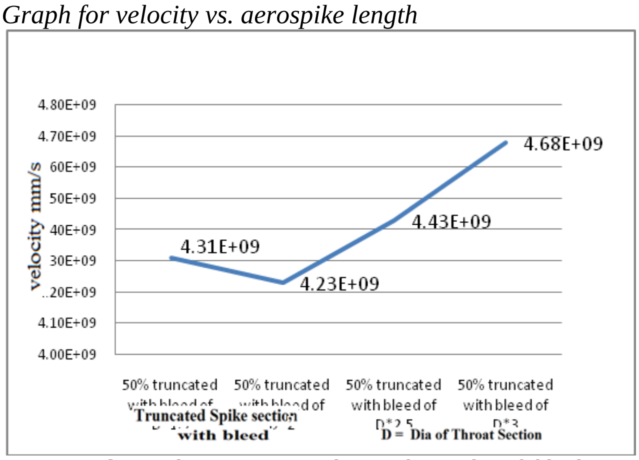
Graph for velocity vs. truncated aerospike nozzle:



Graph 4.2 Exhaust velocitiesvs. truncated spike section at 20,000m altitude

Maximum velocity producing length = 50% of 2.5*D Velocity = 5.68E + 09 mm/sec

Graph for velocity vs. aerospike length



Graph4.3 Velocity vs. truncated aerospike nozzle with bleed

Maximum velocity producing length = 50% of 3*D Velocity = 4.68E + 09 mm/sec

CONCLUSION

the aerospace application. Researches have to be done in these nozzles to see the atmospheric conditions at various altitudes. Modification of an aerospike nozzle has to be made for the accurate optimum values. The spike nozzle design is modified with cluster arrangement at throat section. It is believed that nozzle would achieve an even higher performance by making an optimal use of the flow. After a successful implementation of spike nozzle in above mentioned model with various analysis carried out with different altitude, pressure and also various parameter such as chamber pressure, sea level thrust for time and altitude will be identified.

Design and analysis of aerospike nozzle has been analyzed successfully by modifying its contour length. This aerospike nozzle give efficiency as same as in all altitude limits. By reducing the weight of the aerospike nozzle, the mass of the body reduces at a certain level which increases the thrust when compared to normal aerospike nozzle. By knowing normal flow range characters we have designed a reduced nozzle length, at that point we analyzed all the properties of nozzle to attain high range of thrust efficiency by using ANSYS 14.5 software. Thus, a renewed interest in aerospike nozzle has arisen for the possible replacement of standard nozzle used for propulsion system in space vehicles.

FUTURE WORK

The simplicity of aerospike design coupled with its altitude compensating properties makes it the best option in

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