Design and Analysis of Aerospike Nozzle to Improve Thrust in Hybrid Rocket Engine

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Abstract— *The Present Computational Analysis deal with improvement of momentum distribution of the high- temperature exhaust in Rocket Engine through change in profile of aero spike nozzle. Due to change of profile we can improve thrust and mass flow rate of exhaust gas. This analysis is done by using Fluent (ANSYS) on modified profile of Aero spike nozzle. The Comparison has been done with respect to mass flow rate, velocity streamline and vector between unmodified and modified profile. This Profile modification has done on basic aero spike nozzle and this CAD Model designed by CATIA V5.It has been analyzed that due to change profile in exist nozzle area. The new has improved mass flow rate of exhaust gas and also reduced non –uniform exhaust flow.*

   Keywords—*Aero spike, Mass flow rate, Velocity streamline, Velocity vector, Flow analysis.*

I. INTRODUCTION

Rocket propulsion systems are often classified per the kind of energy source(chemical, nuclear, solar), the essential function(booster stage, sustainer, perspective management, orbit), the kind of car, size, style of propellant, style of construction, or range of reaction propulsion units utilized in a given vehicle. in our own way is to classify by the strategy of manufacturing thrust. A physical science growth of a gas is employed within the majority of sensible reaction propulsion ideas. The internal energy of the gas is regenerate into the K.E. of the exhaust flow and thrust is made by the pressure on the surfaces exposed to the gas. Active development of reaction propulsion system is presently below method in additional than thirty totally different countries. a number of them have created important and original contribution to the state of the art of the technology.

II. ROCKET NOZZLE

A number of various tried nozzle configurations area unit out there these days. Nozzle and chamber area unit sometimes of circular cross section and have a converging section, a throat at the narrowest location, and a oblique section. The converging nozzle section between the chamber and therefore the nozzle throat has ne'er been vital in achieving performance. The subsonic flow during this section will simply be turned at terribly low drop and any radius.

Nozzles have a viscous physical phenomenon next to the walls, wherever the gas velocities area unit a lot of under the free stream velocities within the in gummy flow regions. The gaseous physical phenomenon contains a profound result on the general heat transfer to nozzle and chamber walls. It conjointly has an impression on the rocket performance, notably in applications with comparatively long nozzles with high nozzle space ratios, wherever a comparatively high proportion of the overall mass flow (2 to 25%) are often within the lower speed region of the physical phenomenon.

III. CAD MODEL DESIGN

CATIA V5, which stands for Computer Aided Three-dimensional Interactive Application, is the most powerful and widely used CAD software of its kind in the world. CATIA V5 was created by Dassault System.

Using the CATIA V5 software, constructed a solid Aero spike nozzle and the isometric view and the dimension of the nozzle used are given:

TABLE I: DIMENSIONS OF THE AERO SPIKE NOZZLE

| DESIGN PARAMETER	VALUES
Throat area, At	1.853 in²
Exit area, Ae	9.621 in²
Exit area ratio, Ae /At	5.192
Nozzle exit mach no, Me	2.802
Nozzle exit pressure, Pe	15.4psi
Rocket chamber pressure Pc	500psi
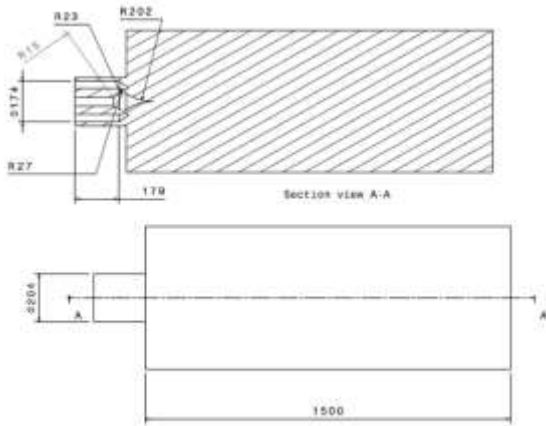
FIG 1: DRAFTING IMAGE

Now the below figure 2 reveals that the detail design of the Aero spike nozzle. Which was designed by using CATIA V5.
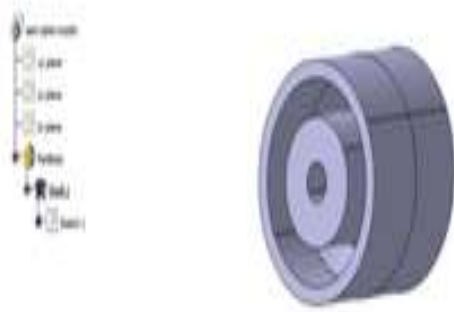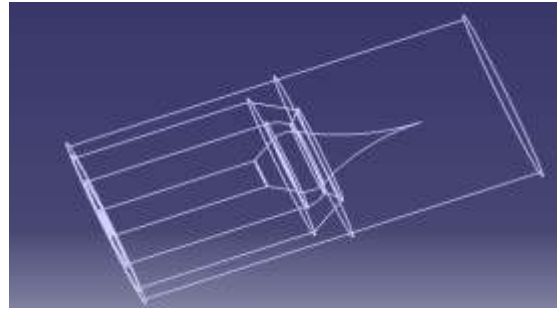

FIG 2: DETAIL DESIGN OF AERO SPIKE NOZZLE

The cross section view of the nozzle can be seen in figure three
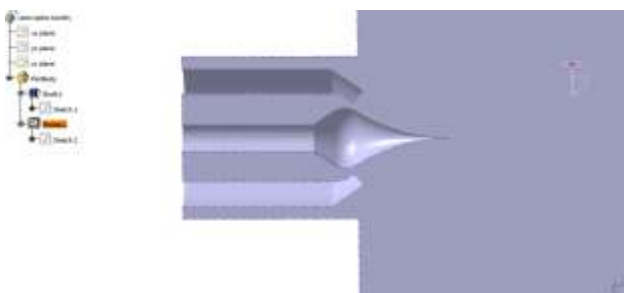
FIG 3: CROSS SECTION VIEW
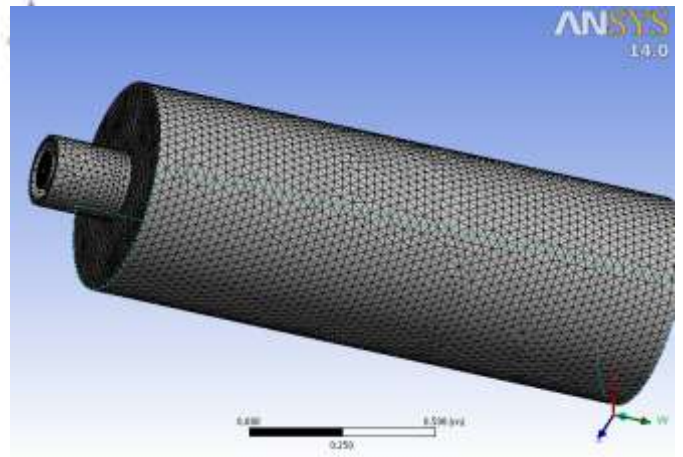

FIG 4: WIREFRAME VIEW OF AERO SPIKE NOZZLE

IV. FLOW ANALYSIS

After completing the design the next step is analysis. The process of analysis starts with the meshing. Meshing is the process of sub dividing a structure into a convenient number of smaller elements (mesh density)

V. MESH OF AERO SPIKE NOZZLE

FIG 5: MESH VIEW OF NOZZLE

TABLE II: MESH DETAILS

Mesh type	Triangular prism mesh
No. of nodes	392224
N0. Of elements	2226989
Mesh metric	Skewness(0.8575451)

A triangular prism mesh is used for this nozzle to get the convenient values.
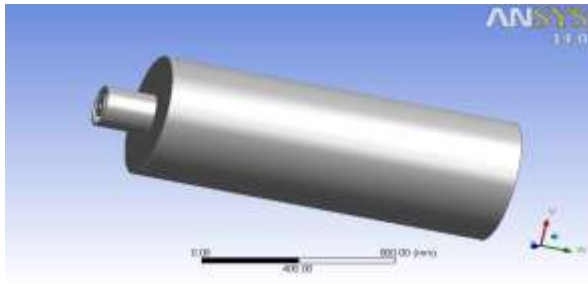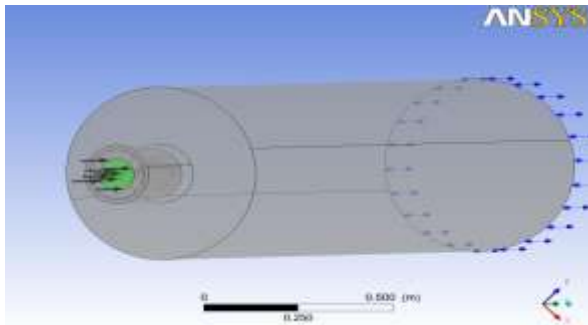
FIG 6: AEROSPIKE NOZZLE WITH CONTROL VOLUME

FIG 7: ANSYS PHYSICS PRE-PROCESS VIEW

TABLE III: DOMAIN PHYSICS FOR CFX

Domain - Default Domain	
Type	Fluid
Location	B 54
Materials	
Air Ideal Gas	
Fluid Definition	Material Library
Morphology	Continuous Fluid
Settings	
Buoyancy Model	Non Buoyant
Domain Motion	Stationary
Reference Pressure	1.0000e+00 [atm]
Heat Transfer Model	Thermal Energy
Turbulence Model	k epsilon
Turbulent Wall Functions	Scalable

After finishing the CAD modeling, ensuing step is that the analysis of nozzle. It's typically necessary to positive concerning if the mesh is pure mathematics is correct. At a similar time we've got to make sure that whether or not we tend to are having correct operative conditions and boundary conditions and

material choice for analysis. During this case there are main 3 major equations are resolved by convergent thinker particularly (continuity, energy, momentum) if the flow is viscous. We've got chosen coupled convergent thinker, second implicit, absolute speed formulation, cell primarily based gradient possibility, superficial speed porous formulation. As our flow is restricted continuity, momentum, energy equation therefore is important to ascertain them up. The fabric is chosen as air and therefore the density as perfect gas to form the answer less complicated. Once if the answer is achieved then it may be planned in graphical format. The figure may be planned between position in coordinate axis and the other operates in coordinate axis from plot command. Within the speed magnitude, speed vector, static pressure, quadcopter surface speed has been chosen.

VI. RESULT AND DISCUSSION

A. Flow analysis

From the analysis of this nozzle, it is clearly visualized the pressure and velocity and temperature streamlines during the flow.

TABLE IV: BOUNDARY CONDITIONS

Domain	Boundaries	
Default Domain	**Boundary – inlet**	
	Type	INLET
	Location	F64.54
	Settings	
	Flow Direction	Zero Gradient
	Flow Regime	Subsonic
	Heat Transfer	Static Temperature
	Static Temperature	2.5500e+03 [K]
	Mass And Momentum	Static Pressure
	Relative Pressure	3.4000e+00 [MPa]
	Turbulence	Medium Intensity and Eddy Viscosity Ratio
	Boundary - opening	
	Type	OPENING
	Location	F69.54
	Settings	
	Flow Direction	Normal to Boundary Condition
	Flow Regime	Subsonic
	Heat Transfer	Opening Temperature
	Opening	1.5500e+03 [K]

Boundary condition is usually necessary to analysis the item. It ought to lean into software system as associate degree recess condition of the matter. Hydraulic diameter is extremely necessary parameter attributable to presence of management volume. During this case we have a tendency to took recess condition as per our survey and convenient moreover.
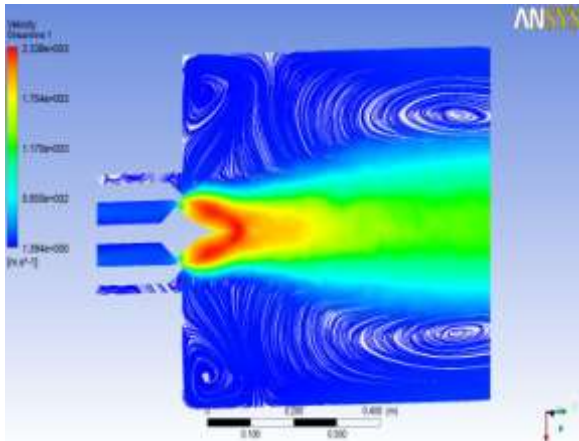
B. VELOCITY STREAMLINE OF NOZZLE

FIG 8: VELOCITY STREAMLINE

The on top of result clearly reveals that the utmost speed at initial stage that has accumulated linear manner throughout the nozzle.

The prandtl Meyer enlargement has been occurred at spike of nozzle. Owing to this reason the flow of gas is hooked up to the surface of the spike. This method ends up in will increase the flow speed.

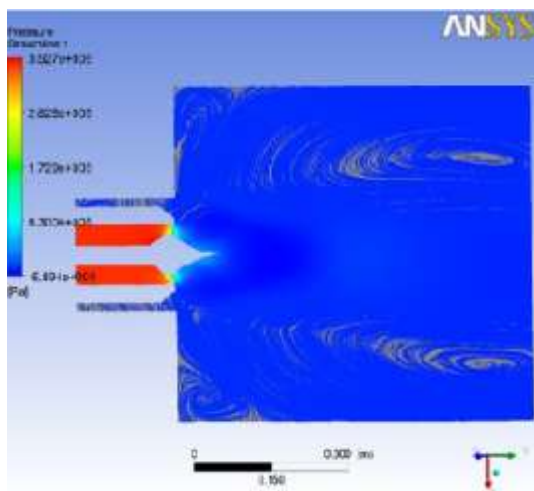## C. PRESSURE STREAMLINE OF NOZZLE

FIG 9: PRESSURE STRAMLINE

The pressure vary is a smaller amount throughout nozzle whereas it has attained its maximum (3.527e^006). From this we {are able to} determine that the pressure and speed are reciprocally proportional.

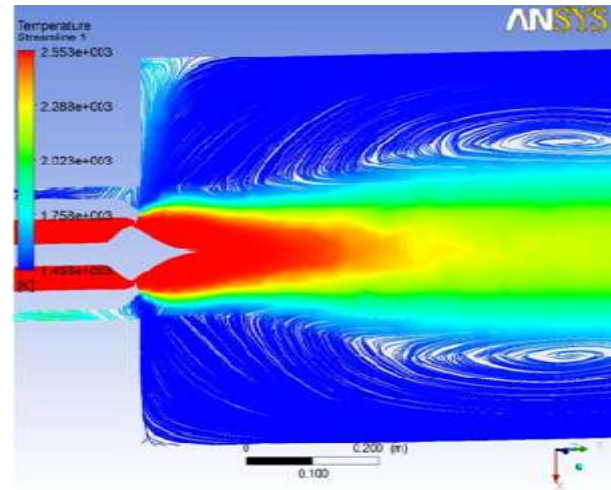## D. TEMPERATURE STEAMLINE OF NOZZLE

FIG 10: TEMPERATURE STREAMLINE

Rise in temperature level may be seen in on top of image during this case the amount of temperature is high at half portion of the nozzle that is been variable in step with nozzle diameter. Raise in temperature cause the high speed at exit of nozzle. .

TABLE V: RESULT OF AEROSPIKE NOZZLE

Parameters	Exit Area	Exit Velocity	Exit Thrust
Values	10687mm2	2832m/s	283200N

VII.SOLUTION

At the guts of ANSYS CFX package is its advanced convergent thinker technology victimization coupled pure mathematics multigrain, the key to achieving reliable and correct solutions quickly and robustly.

Its designed measurability ensures a linear increase in computer hardware time with downside size and parallel performance that's second to none. Users will follow convergence progress and dynamically monitor numerical and physical answer quantities. convergent thinker parameters, boundary conditions different parameters are often adjusted on the fly, no end the convergent thinker. The ANSYS CFX convergent thinker uses second order numeric by default, making certain users forever gets the

foremost correct predictions doable. for nearly a thousand iterations we tend to offer the convergent thinker to unravel the context, however the result's extracted most likely once the answer converges. the answer was taken on four grounds and supported this the result was extracted.

VIII. CONCLUSION

Flight research of an aero spike rocket nozzle was conducted using high power solid rockets. The lower aero spike chamber pressures and thrusts were likely to be caused by a larger actual aero spike nozzle throat area than the designed throat area. The design work on an aero spike nozzle design and associated testing hardware has been completed in preparation for a series of cold-flow tests on a truncated aero spike nozzle. The system will allow the evaluation of aerodynamic thrust vectoring and thrust augmentation through truncated aero spike base bleed. This series of tests will facilitate calibration of analytical prediction tools which include computational fluid dynamics results. Completion of cold gas testing should provide an adequate knowledge base before the project advances to hot flow testing.

ACKNOWLEDGEMENT

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