

Variable Altitude Optimal Expanded Hypersonic Nozzle Design

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ABSTRACT: In hypersonic rocket nozzles, expanding combustion gases to optimal level and gaining full energy is a tedious process. This innovative attempt quenches the universal thirst on the optimal expansion of solid rocket nozzles on all atmospheric levels which was an impossible venture of worldwide engineers since 1957. The adverse variation of pressures pushes the performance of nozzle back and forth in high amplitude and causes high reduction in its efficiency. The approach made for this optimal expanded nozzle at all altitudes is done by referring the local atmospheric conditions and optimizing the flow. Specifically a complete over expanded nozzle (till burnout condition) is designed in order to induce the external atmospheric air for achieving optimal expansion. The classic induction phenomena combined with high rammed air are induced here with number of induction ducts surrounding nozzle contour.

KEYWORDS: Nozzle, Hypersonic rocket nozzle.

I. INTRODUCTION

It had been from early times that, the problem of designing a good optimal expanding rocket nozzle especially at lower altitudes, to be in its optimal level till its burn out is a tough task. In other words from the time it starts and reaches its maximum altitude the nozzle is not optimal in expanding. It cannot manage the high pressure difference in gaining altitudes and loses its potential. Hence the efficiency achieved by an airplane nozzle cannot be attained by a rocket nozzle.

To be clearer, consider a solid rocket in 0th km altitude and it advances to some 30kms. (Note: Solid rockets have no controlled mass flow rate) For its maximum efficiency the nozzle is designed to be over expanded in sea level (where pressure is high) and continues to get optimised in altitudes as pressure goes on decreases. When it approaches say 15km the nozzle is fully or optimally expanded. But when it further proceeds, that is, when the pressure goes on decreasing, the nozzle now goes in under expansion. And when the rocket is at its 30th km altitude (in its burnout altitude) it is highly under expanded. Hence as an overall view we can get that, the nozzle is only at a particular altitude optimally expanded and at all other altitudes it loses its efficiency, a lot. This tells that the overall efficiency is low for a solid rocket nozzle at all altitudes.

II. STEPS PROCESSED

1. Nozzle configuration is studied (altitudes, pressure difference, expansion levels).
2. Over expansion contour till burnout is designed.
3. Mass flow rate introduced to make the over expansion nozzle to optimized is evaluated.
4. The place, number and size of external air induction are determined to the calculated mass flow rate.
5. Optimal expansion level is derived and verified.
6. Thrust increased is calculated
7. Nozzle efficiency is determined

8. Comparison of conventional and our nozzle is done and tabulated

III.NOZZLE BOUNDARY

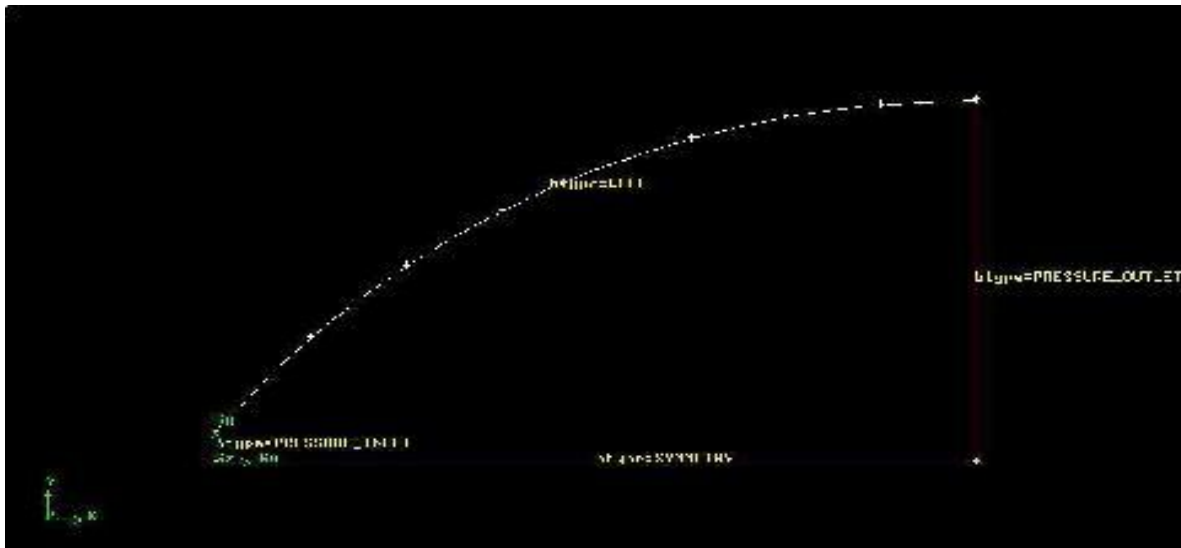


Fig.1

IV. BOUNDARY CONDITIONS

Table 1: Boundary Conditions

S.no	Boundary Type	Properties and Functions
1.	Pressure Inlet	p_0 , is related to the static pressure, p_s , through Bernoulli's equation
2.	Symmetry	symmetric about a plane to reduce computational domain
3.	Pressure Outlet	reversal (better convergence rate) values might be used during iteration and should be realistic.

V. MESHING THE GEOMETRY

A closed face is meshed with quadrilateral & Triangular grids. Because if we use quadrilateral grids we can have a better solution as the equations are solved at four points of each cell, at the same time to have finer cells at corners and to avoid forming of negative volumes at the edges we are opting for triangular grids. The meshed contour is shown in figure. To have high rate of convergence of solution we need to have a finer cells.

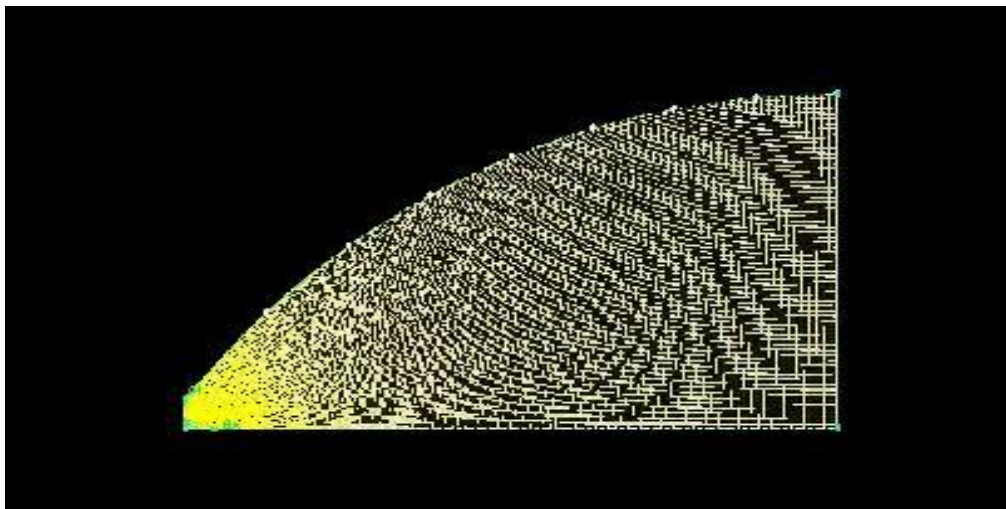


Fig. 2. Meshing

VI. FLUENT ANALYSIS

Finally the iteration is carried out with some initial values of 10, 100, 1000, etc. until all the residual monitors, force & surface monitors are displaying the unfluctuating plot throughout. Suppose the plot is not all remaining constant for long period we need to increase the number of iterations even more. This is the phase where we are going to see the results such as XY plot or contours or vectors or path lines, etc. The over expanded contour that we have designed is analysed and results are plotted.

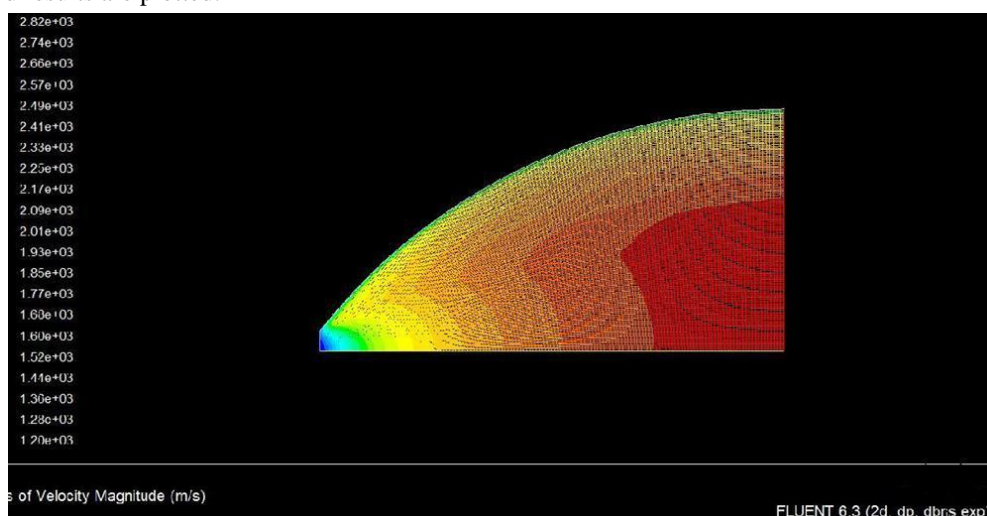


Fig. 3. Contours of velocity Magnitude

VII. INDUCTION DUCT DESIGNING

At initial state only a constant area duct is designed which is capable of producing downstream flow in subsonic regions by high pressure difference, but is in capable of producing a supersonic downstream flow at supersonic speed of rocket. As subsonic – supersonic mixing of gases is inefficient, the design is abandoned. Shown in figure

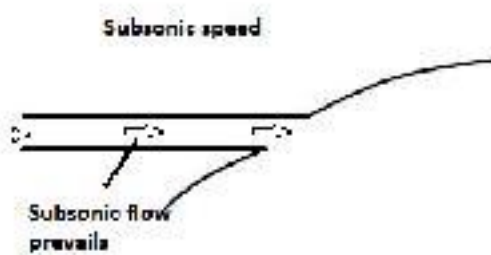


Fig.4

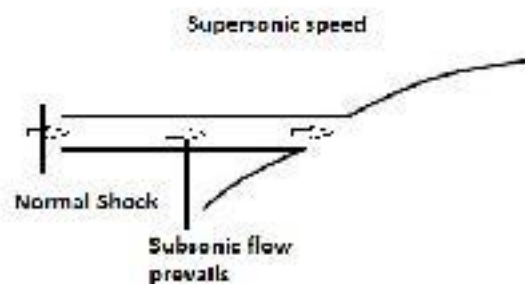


Fig.5

VIII. CONCLUSION

Seeing an overall view it can be understood that the critical condition of the behavior of this modern nozzle is at the higher altitudes (altitudes near to burnout) as here the pressure is very low leading to low over expansion level and hence the very low pressure difference. Thus we consider this altitude (say 30km of altitude) as the critical altitude and we see results there.

VIII. FUTURE DEVELOPMENTS

This idea has a high scope in future rocket technology field that the real time unsolved problem of decrement in nozzle efficiency of a rocket can be eradicated. The technical words like over expansion & under expansion will become extinct in rocket nozzles with implementation of Variable Altitude Optimal Expanded Hypersonic Nozzle (VAOE Nozzle) developed by us.

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