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MODELLING NOZZLE IN CFD – A NEW APPROACH

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***Abstract*— The nozzle design was modeled using commercial modeling software Catia V5. In catia software part design was selected and the coordinate points were given as inputs and the points were joined using lines, spline, etc. Finally all the 12 individual nozzle models were modeled and saved as IGES file, so that they can be imported to meshing software. It was observed that the Mach number at the exit varied to an extent of 10% from the design criteria. And since this trend was same for all the nozzle designs, it was ignored and more focus was given to the objective of the project, which is to find out a design which produces more uniform flow at the nozzle exit.**

***Index Terms*—Catia V5, Nozzle Model 8, Nozzle Exit**

I. INTRODUCTION

Convergent nozzles are used in applications where only sonic speed of fluid is needed. In this type the walls of the nozzle keep converging towards the axis of the nozzle. Convergent nozzles are used on many jet engines. If the nozzle pressure ratio is above the critical value a convergent nozzle will choke, thus accelerating the fluid to sonic speeds.

In Divergent nozzle the walls of the nozzle keep diverging apart from the axis of the nozzle. The supersonic speed of the air flowing into a scramjet allows the use of a simple divergent nozzle.

A CD nozzle has both a convergent as well as a divergent section. This type of nozzles is used to accelerate fluids from subsonic speeds to supersonic speeds. Engines capable of supersonic flight have convergent-divergent exhaust duct features to generate supersonic flow which are areas where CD nozzles are used. A diagrammatical representation of the physical flow of a nozzle is shown in Fig.1.

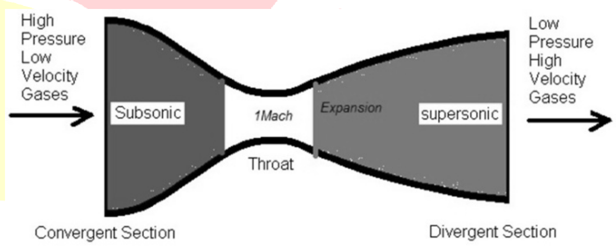

Fig.1. De Laval Nozzle

Basically there are three types of nozzles namely

1. Conical Nozzle
2. Bell Nozzle
3. Plug Nozzle

The conical nozzle represents a compromise of the length, thrust, and ease of manufacturing design criteria weighted somewhat in favour of the last factor. A conical nozzle consists of two truncated cones (Fig 1.3), joined top to top along their axis by a suitable radius to form the nozzle throat. The combustion chamber is similarly faired into the convergent nozzle section. The converging contour of the nozzle is not critical as regards the flow, and a rather rapid change in cross section is permissible here with a conical apex half-angle on the order of 400 commonly used. The divergence angle of the supersonic portion of the nozzle, however, is limited by flow separation considerations and must not exceed a value of about 150. For divergence angles too much greater than 15 deg, the flow will separate from the nozzle walls short of the exit even though the nozzle is operating at design altitude. Conversely, for a given divergence angle, the flow will separate if the nozzle back-pressure ratio Pa/Pe is too high in place of normal shocks near the exit section.

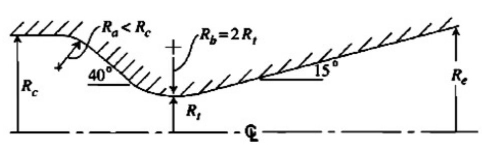

Fig.2. Conical CD Nozzle

The bell-shaped nozzle of the Atlas sustainers engine (Fig.2.) is designed to reduce the thrust and length disadvantages of a conical nozzle. To reduce length, a bell-shaped nozzle employs a high divergence angle at the throat with a very rapid expansion of the gases from the throat. The flow is then turned rather abruptly back toward the axial direction. The bell-shaped contour is used on several current engines. The bell-shaped nozzle on the H-I Saturn 1B engine has a length 20% less than the length that would be required for a 15-deg conical nozzle with the same 8: l area ratio.

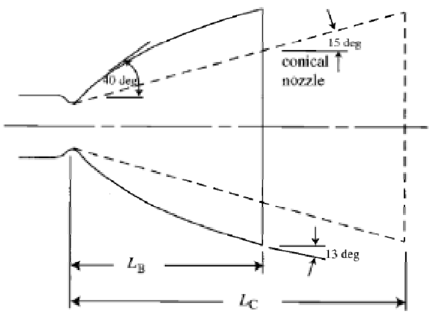

Fig.3. Bell-Shaped Nozzle

It is possible, however, to design a nozzle so that the expanding flow is not bound by immovable solid walls. In such free-expansion nozzles, the expanding flow is bound by a solid surface and a free-to-move slip-line expansion surface. The adjustable slip-line boundary, in effect, produces a variable area ratio nozzle that accommodates itself to changing nozzle pressure ratios. Free-expansion nozzles, therefore, tend to operate at optimum expansion, with the ratio of thrust-to-optimum-thrust being quite insensitive to altitude variations. The free-expansion nozzles shown in (Fig.3.) have been dubbed "plug nozzles." The improved performance of the free-expansion type of nozzle over the bell nozzle at lower off-design altitudes is evident. The absence of large thrust losses at lower altitudes suggests that a free-expansion-type nozzle would be particularly suited for use in both boosters or in single-stage ballistic missiles.

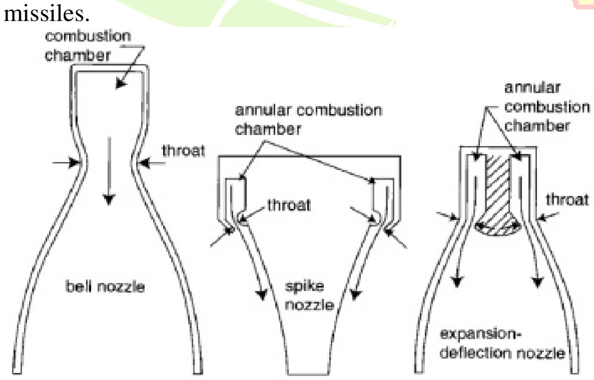

Fig.4. Plug Nozzle

The different types of nozzles, their shapes and their sizes are compared in the given below in Fig.4.

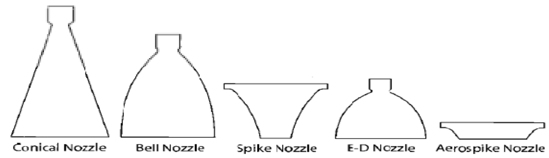

Fig.5. Nozzle types and size comparison

[1] used nitric oxide PLIF to visualize the flow at the exit of a hypersonic conical nozzle, to determine operating conditions that would allow more uniform nozzle flow than that of and to explain the mechanism most likely to be responsible for the non-uniform flow. Two nozzle throat inserts were fabricated: one with a converging conical end-wall, having a half angle of 30° and the other with a flat end-wall. Possible causes for the non-uniformity were outlined and investigated and the problem was shown to be due to a small step at the nozzle throat. They postulated that the cause of the flow non-uniformity was the entrainment of cooler gas from the boundary layer into the free stream caused by flow separation at the throat. Upon modifying the nozzle throat, images were significantly more uniform and the standard deviation in average signal between tunnel runs reduced from 25% to 15%. Christo Ananth et al. [4] proposed a system, this fully automatic vehicle is equipped by micro controller, motor driving mechanism and battery. The power stored in the battery is used to drive the DC motor that causes the movement to AGV. The speed of rotation of DC motor i.e., velocity of AGV is controlled by the microprocessor controller.This is an era of automation where it is broadly defined as replacement of manual effort by mechanical power in all degrees of automation. The operation remains an essential part of the system although with changing demands on physical input as the degree of mechanization is increased.

II. PROPOSED SYSTEM

The modeled nozzles for mach numbers 2, 3 and 4 are shown in Fig.6, Fig.7. and Fig.8. respectively.

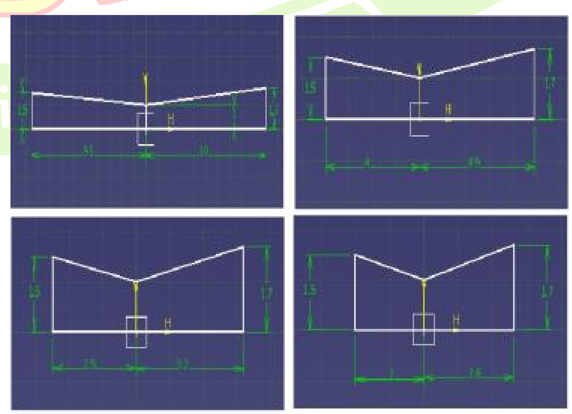
Fig.6. Nozzle Model of Mach 2

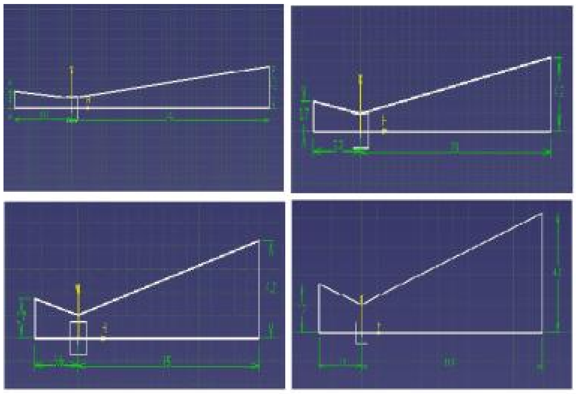

Fig.7. Nozzle Model of Mach 3

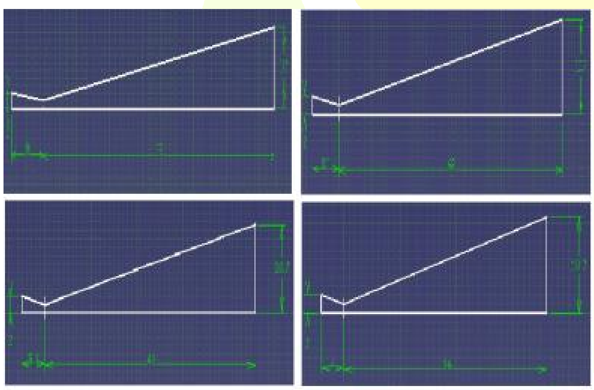

Fig.8. Nozzle Model of Mach 4

After creating the geometries of the nozzles, they were imported by the software Ansys Gambit, which was used to generate the grids. In order to mesh geometry in Ansys Gambit, first it is necessary to mesh the edges and then mesh the face.

For the four edges considered (inlet, exit, axis and wall), the grid grading scheme chosen were different. For the axis and the wall, the grading scheme was constant with 200 intervals uniformly distributed from inlet to exit of the nozzle.

IV. CONCLUSION

The nozzle design was modeled using commercial modeling software Catia V5. In catia software part design was selected and the coordinate points were given as inputs and the points were joined using lines, spline, etc. Finally all the 12 individual nozzle models were modeled and saved as IGES file, so that they can be imported to meshing software. It was observed that the Mach number at the exit varied to an extent of 10% from the design criteria. And since this trend was same for all the nozzle designs, it was ignored and more focus was given to the objective of the project, which is to find out a design which produces more uniform flow at the nozzle exit.

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