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Design and Analysis on Three-Dimensional Cd Nozzle with Geometry Change

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Abstract: A CD nozzle is a propulsive device which is designed to control the rate of flow, speed, direction and pressure of stream that exhaust through it. There are various types of rocket nozzles which are used depending upon the mission of the rocket. This paper contains design and analysis over a three dimensional convergent divergent rocket nozzle with elliptical cross section which is designed using method of characteristics and CATIA v5 and stimulated with CFD analysis software ANSYS Fluent.
Keywords: Elliptical Cd Nozzle; Method Of Charactertics; Matlab; Design; Analysis

I.   INTRODUCTION

In the advancement of propulsion there are different type of nozzles get evolved with respect to the mission it has to be achieved. [1] Gustaf De Laval had invented the De Laval nozzle where it is a convergent divergent type of nozzle, generally a subsonic flow is attained in the convergent section which led to the throat where the flow get chocked and a sonic condition is occurred and while reaching the contoured divergent portion a supersonic jet velocity is achieved in the exit of the nozzle. All these nozzles are designed and fabricated in circular section, [2] the hypersonic flights nozzle is designed and stimulated with shape transition asymmetric nozzle where this evolution saves a large weight and up to Mach no six is achieved and this is done by elliptical entrance with rectangular exit in the following way this paper contain elliptical cross section of the three dimensional convergent divergent nozzle. [3] Initially the circular cross section convergent divergent nozzle geometry should be designed to optimise the supersonic flow in the divergent part which contain Mach waves that has to be properly expanded and cancelled with the use of method of characteristics. [4] The complexity of the problem is reduced by use of matlab where different area and length can be obtained by providing the no of characteristics line and corresponding inlet pressure and temperature values. The coordinates are further imported to catia and designed [5] the designed nozzle should be stimulated and flow, pressure, velocity, temperature and other parameters are checked with the help of ansys fluent

II.   METHOD OF CHARATICISTICS

The diffuser section of the nozzle propagate mach waves which can be mathematically calculated using method of characteristics which will decide the nozzle length and area ratio. And also the number of characteristics which decide the nozzle performance and efficiency. These calculation can be carried out using matlab which the code is done to solve the parameters in "tab. 1"and the corresponding coordinates is given in "fig. 1" and the "fig. 2" show the corresponding pressure and mach no in the occurrence of the position of the characteristics lines

TABLE 1. PARAMETERS OF THE PROBLEM

S.NO	PARAMETERS	VALUE
1	NUMBER OF CHARACTERISTICS LINE	15
2	THETA I	0.3
3	INLET PRESSURE	3 BAR
4	TEMPERATURE	1500 K
5	GAMMA	1.25

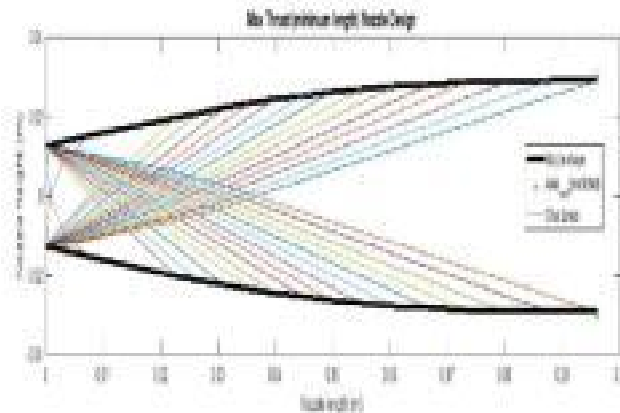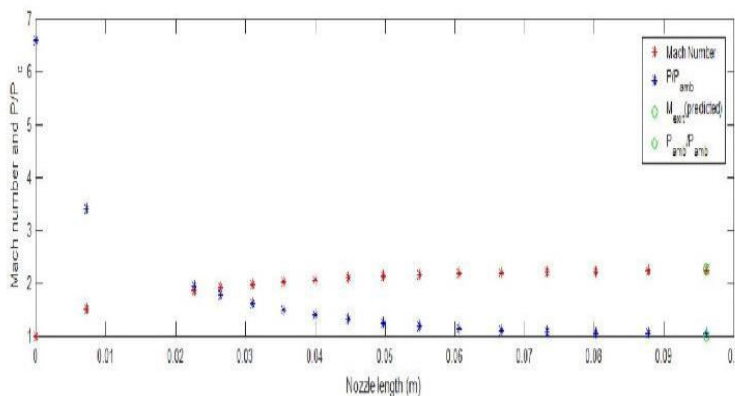Figure a1. Minimum length nozzle

Figure a1. Pressure and mach no of nozzle

III.   DESIGN

The coordinates that had got from the matlab is the optimum length for the 15 characteristics line. To design a elliptical nozzle we have to calculate eccentricity to give shape to the ellipse, so we can considered two cases in the eccentricity which is 0.3 and 0.8 using this we had made the calculation to make the coordinates to elliptical geometry. And further using the catia an elliptical contour is given to the divergent section and convergent section is calculated depending on the throat area.

Figure b1. Elliptical cd nozzle with
Eccentricity 0.3 isometric view
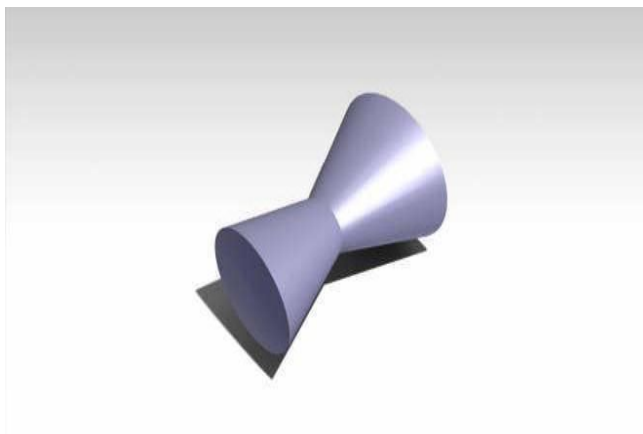
Figure b2. Elliptical cd nozzle with
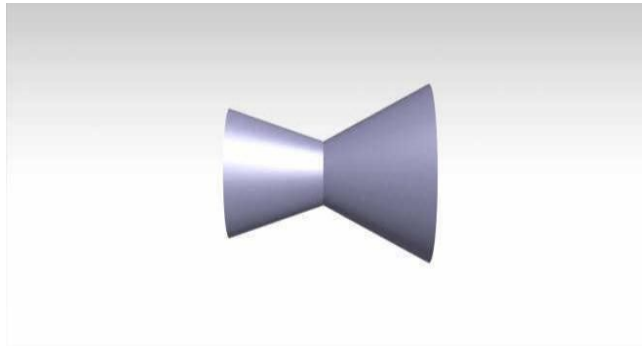Eccentricity 0.3 Side View

Figure b3. Elliptical cd nozzle with
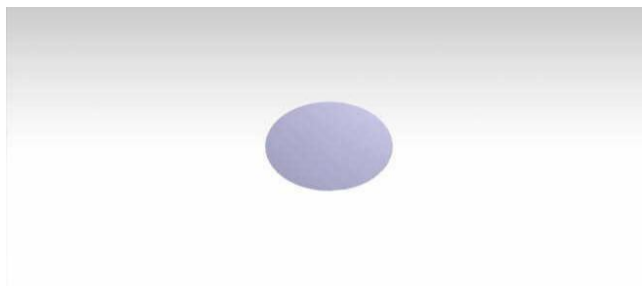Eccentricity 0.3 front view

Figure b4. Elliptical cd nozzle with
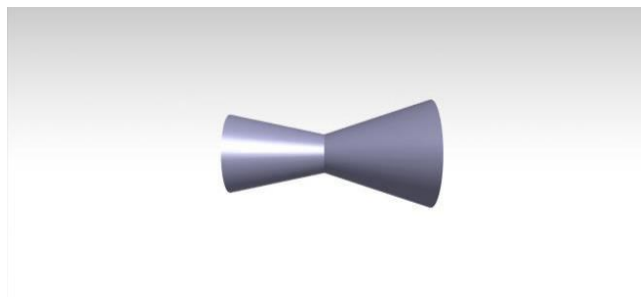Eccentricity 0.3 top view

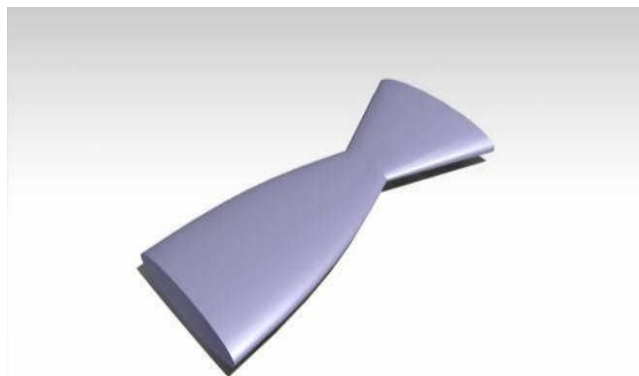Figure c1. Elliptical cd nozzle with
Eccentricity 0.8 isometric view

Figure c2. Elliptical cd nozzle with
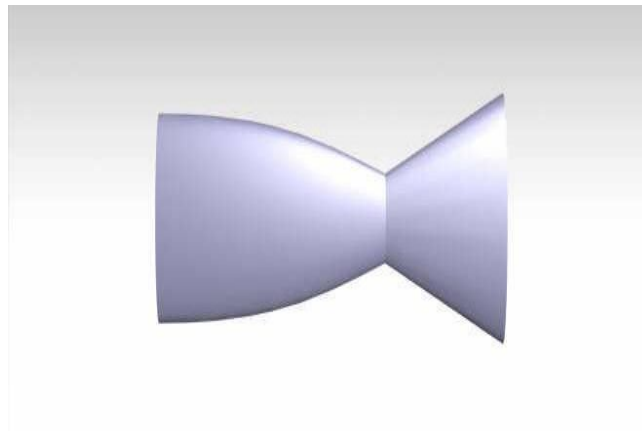Eccentricity 0.8 side view

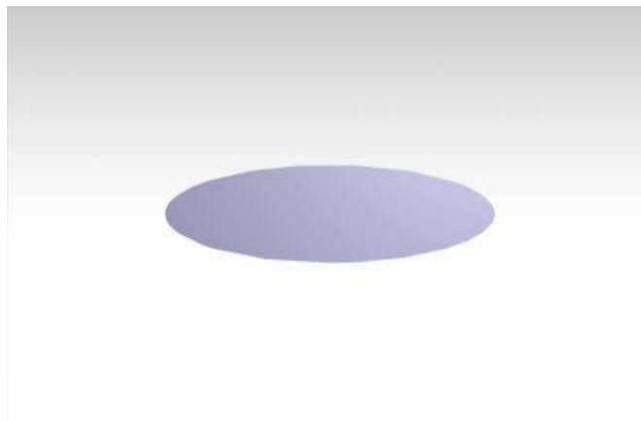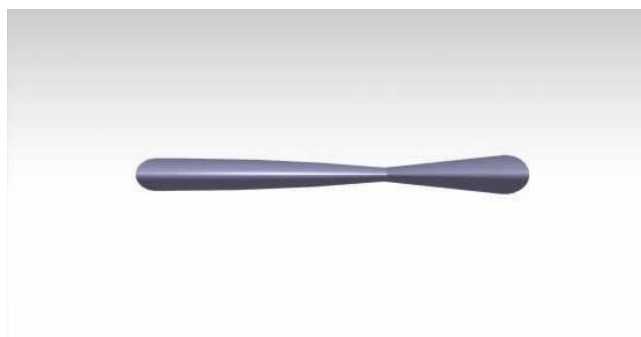Figure c3. Elliptical cd nozzle with
Eccentricity 0.8 front view

Figure c4. Elliptical cd nozzle with
Eccentricity 0.8 top view

IV. ANALYSIS

After completion of the design the model should be analyzed by the fluid either by stimulation or experimental to see the result and effects made through the design. This design of nozzle is to be analysis through stimulation which will be done by ansys fluent

A. Mesh

The number of elements and nodes is very important in the meshing as the number increases the accuracy get higher. In the nozzle the wall and exit area should have a higher amount of mesh so in that parts refinement is done.

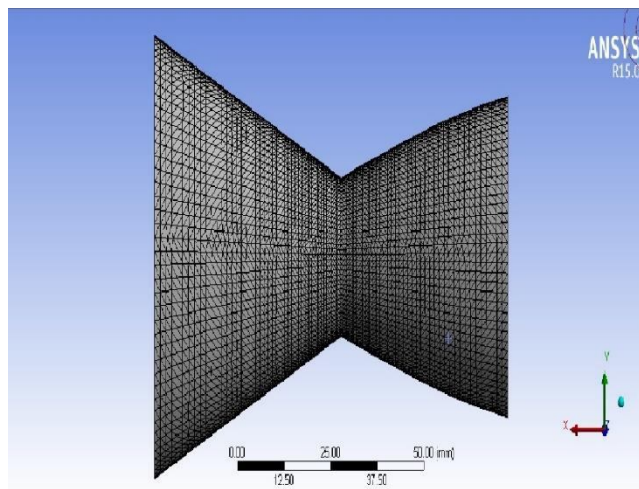Figure D1. Mesh of elliptical cd nozzle with eccentricity 0.3

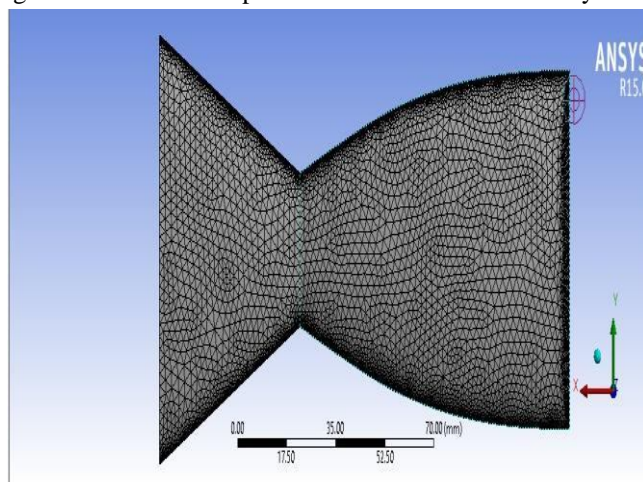Figure D2. Mesh of elliptical cd nozzle with eccentricity 0.8

Table 2. Boundary condition

S.NO	Gauge Pressure at Inlet (Bar)	Inlet Condition	Outlet Condition
1	3	PRESSURE INLET	PRESSURE OUTLET

Wall	Density	Temperature (k)
NO SLIP WALL	CONSTANT AIR DENSITY	1500

B. Setup

After meshing process is done setup should be configured to stimulate the design

Solver settings: Steady solver

                   Pressure based

                   K epsilon, wall enhanced treatment Material: working fluid was standard air

"Tab 2." Show the boundary condition required for the analyzing model

Figure E2. Velocity contour of elliptical cd nozzle with eccentricity 0.3 in xz plane
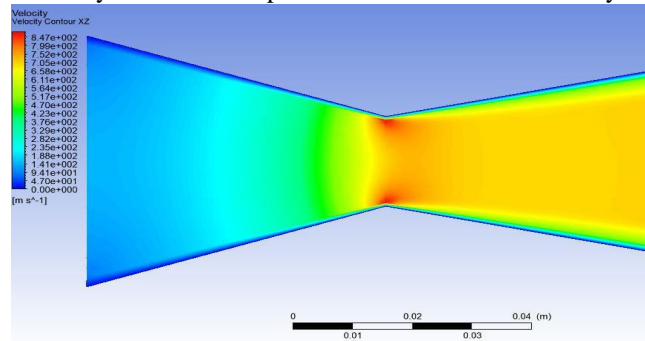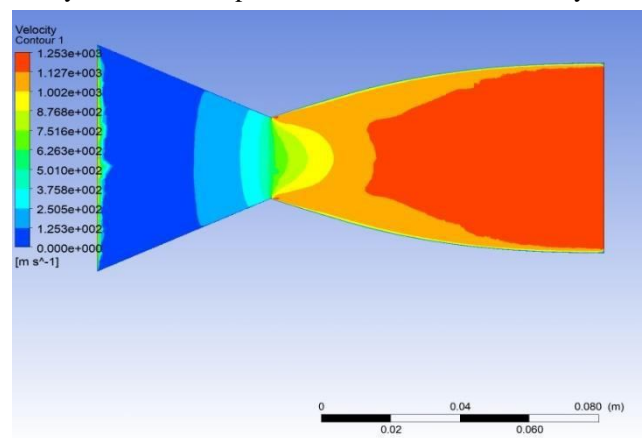

Figure E3. Velocity contour of elliptical cd nozzle with eccentricity 0.8 in xy plane

C. Solution Velocity Contours

Figure e1. Velocity contour of elliptical cd nozzle with eccentricity 0.3 in xy plane
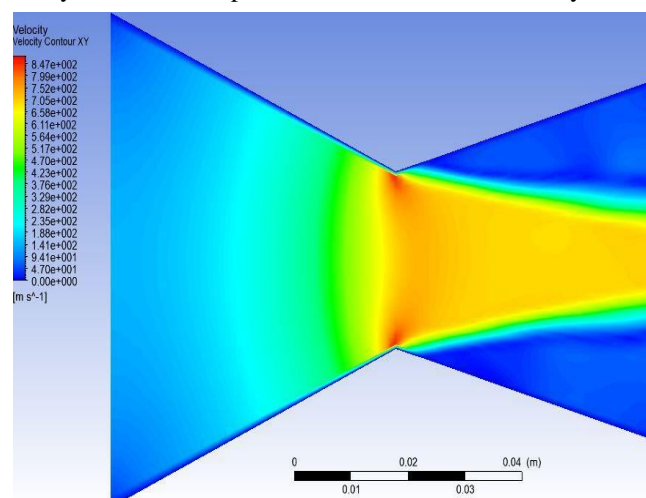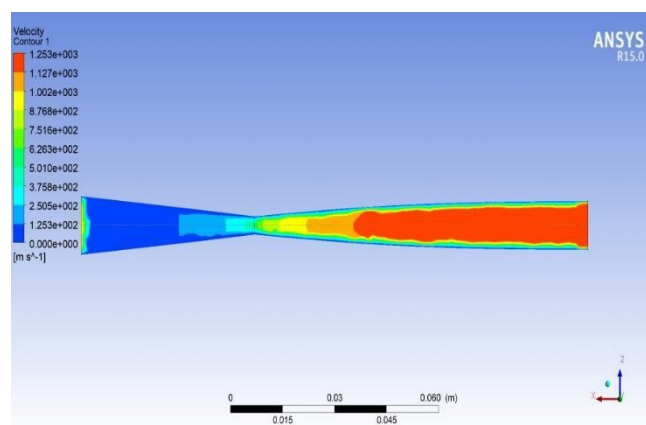
Figure E4. Velocity contour of elliptical cd nozzle with eccentricity 0.8 in xz plane

D. Pressure Contours

Figure f1. Pressure contour of elliptical cd nozzle with eccentricity 0.3 in xy plane
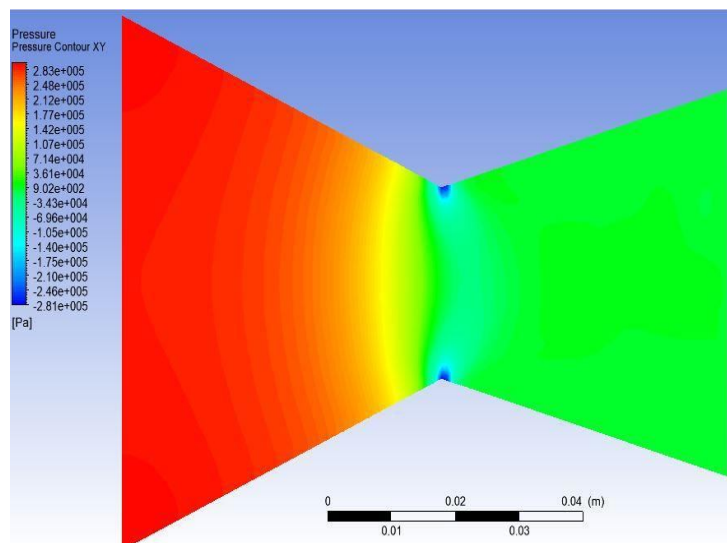

Figure F2. Pressure contour of elliptical cd nozzle with eccentricity 0.3 in xz plane
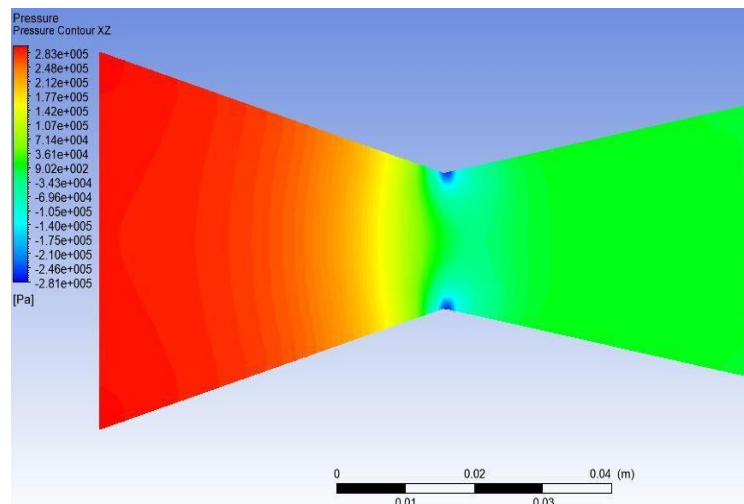
Figure f3. Pressure contour of elliptical cd nozzle with eccentricity 0.8 in xy plane
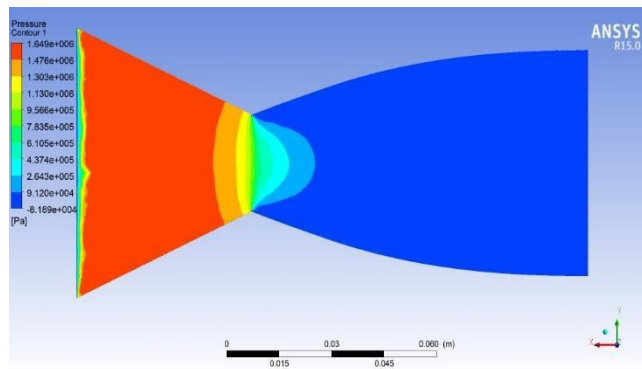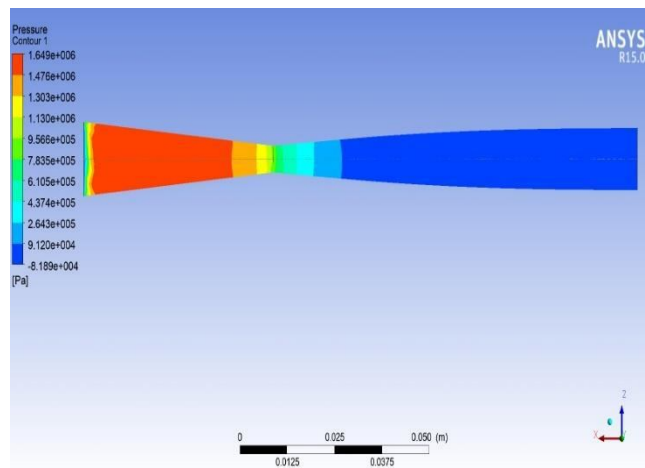

Figure f4. Pressure contour of elliptical cd nozzle with eccentricity 0.8 in xz plane

V.   RESULT

Table 3. Velocity comparsion

NOZZLE	Ave Inlet Velocity (m/s)	Ave Outlet Velocity (m/s)	Max Inlet Velocity (m/s)	Max Outlet Velocity (m/s)
CD	105.407	680.58	142.64	770.08
0.3 ELLIPTICAL	105.407	252.835	142.64	707.033
0.8 ELLIPTICAL	105.407	1127.59	142.64	1253.59

Table 4. Pressure, temperature comparsion

NOZZLE	Ave Outlet Pressure (Pa)	Inlet Temperature (K)	Ave Outlet Temperature (K)	Max Outlet Temperature (K)
CD	11000	1500	312.2	420.8
0.3 ELLIPTICAL	-891.065	1500	326.467	465.478
0.8 ELLIPTICAL	91200	1500	307.4	409

VI.   CONCULSION

The comparative data shows the higher velocity difference between the elliptical cd nozzle with eccentricity 0.8 and the other nozzle data

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