RESEARCH ARTICLE OPEN ACCESS

Aerodynamic and Acoustic Analysis of Convergent-Divergent Nozzle

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Abstract:

The Aim of this research is to perform acoustic analysis of convergent-divergent nozzle for different pressure values. In this paper, the flow over a "Convergent-Divergent Nozzle" was investigated in terms of various flow parameters such as static pressure, velocity, static temperature. ANSYS Workbench, one of the top programs for computational fluid simulation was used for acoustic analysis and CATIA V5 for modelling of the nozzle. Acoustic characteristics of Convergent Divergent (C-D) nozzle for five different pressure values have been analyzed and the most efficient pressure values for which the least acoustic power level is emitted is selected as the optimized working pressure for the designed nozzle .

Numerical analysis was conducted by using CATIA V5 for design and ANSYS FLUENT for flow analysis and the results obtained were tabulated and compared. Geometry has been imported to ANSYS FLUENT (software). Fine meshing of CD nozzle has been done. Aerodynamic and acoustic analysis with result contours has been obtained. The best operating range of pressure of the nozzle has been highlighted in the paper.

Keywords ***—Supersonic, Convergent-Divergent Nozzle, CATIA V5, ANSYS FLUENT, Acoustic noise, boundary conditions, optimized operating pressure***

I. INTRODUCTION

Nozzle is a device used to control the speed of the fluid flow, directions and flow characteristics. The design of the nozzle is considered to be a pipe with varying cross sectional areas throughout the length for altering and controlling the mass flow rate, velocity, direction of flow, pressure ratio etc. The variation of pressure difference at the inlet and outlet of the nozzle section results in the change of flow characteristics.

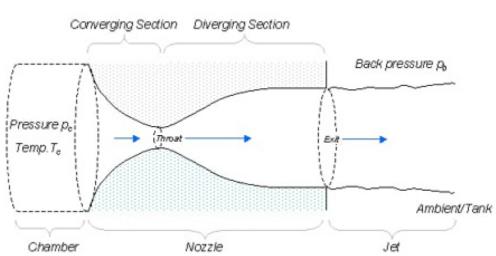

Figure 1: Convergent Divergent Nozzle configuration

Convergent-Divergent supersonic nozzles are significantly used for high speed missiles and for rocket nozzles. Depending on the nozzle applications different shapes are used. The divergent part of nozzle plays a vital role in expansion characteristics. The function of CD nozzle is to convert thermal energy into kinetic energy high speed exhaust.

The major importance of a CD nozzle in the industry is to improve the kinetic energy of flow medium at an expense of an internal energy and the pressure.

The overall objective of this paper is to examine new concepts and methods for noise reduction that have been established in the field of civil aviation and to optimize them in order to reduce the noise generated by the supersonic nozzle.

The acoustic characteristics of convergent-divergent nozzle for different pressure values has been studied.

The objectives of this research were to model the C-D Nozzle using CATIA-V5, apply the boundary conditions and analyse the different flow characteristics using ANSYS FLUENT and optimize the design.

II. C-D NOZZLE DESIGN DATA

For the flow analysis we have designed the C-D nozzle. The details of the C-D nozzle is show below.

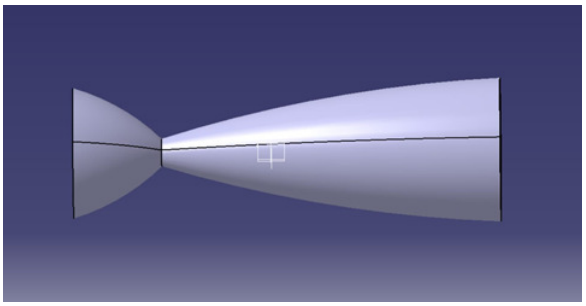

Figure 2: CATIA Model of the C-D Nozzle

Table 1: Geometrical details of the nozzle

Parameter	Dimensions
Total Length of the Nozzle	448 mm
Inlet Diameter	166 mm
Outlet Diameter	183 mm
Throat Diameter	35 mm
Convergent Angle	32 deg.
Divergent Angle	11 deg.

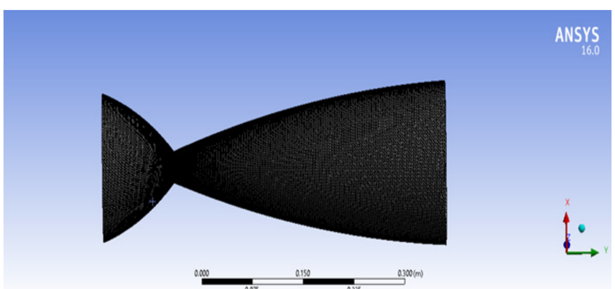

Figure 3: Meshing details of the C-D Nozzle

Table 2: Mesh Details

Physical preference	CFD
Solver Preference	Fluent
Relevance	0
Element order	Linear
Size Function	Curvature
Relevance centre	Coarse
No. of nodes	183024
No. of elements	858500

III. METHODOLOGY

Predetermining the geometrical parametersand implementing the correct measures through literature survey. Modify the design the using CATIA V5 software and import the design to ICEM CFD for grid generation.Analyse the flow over the C-D nozzle by both active and passive flow technique. Obtain the results and prove the efficiency of the modified C-D nozzle.Acoustic analysis for the different pressure values and study the result contours.

IV. AERODYNAMIC ANALYSIS

Convergent and Divergent nozzle is used to accelerate the speed of fluid (present inside the nozzle) to supersonic speed according to pressure at exit. The nozzle converts the low velocity, high pressure, high-temperature gas in the combustion chamber into high-velocity gas of lower pressure and low temperature.

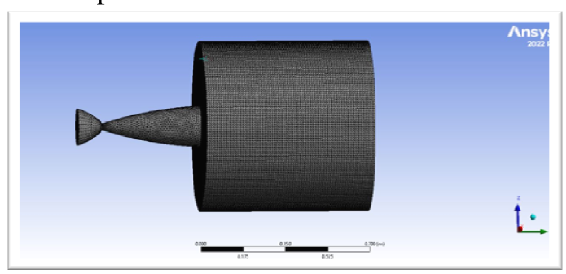

Figure 4: Domainto analyse the flow parameters

The simulation was done using FLUENT in Ansys Fluent workbench. The C-D Nozzle is modelled using CATIA V5 and the model file is imported and the boundary conditions are applied.

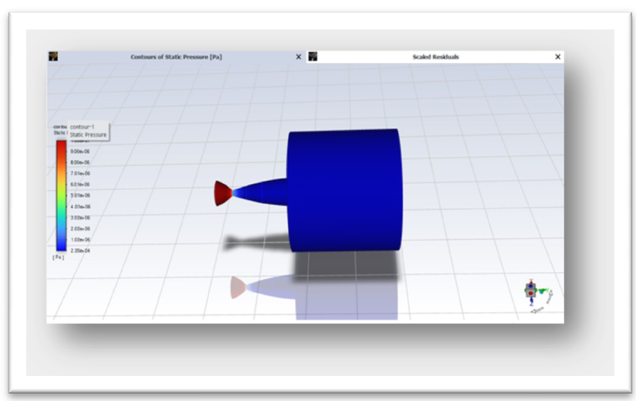

Figure 5: Contour of Static Pressure.

The figure shows the contour results of static pressure According to the contour results, the pressure at the exit of nozzle is less the velocity will be more at the exit of the nozzle.

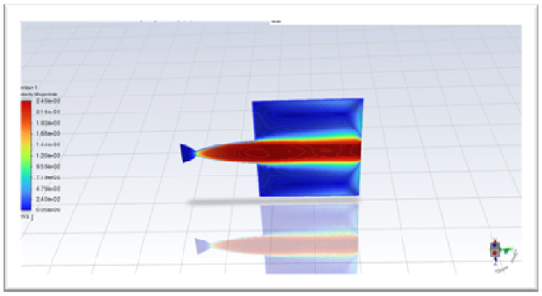

Figure 6: Contour of Velocity Magnitude

The above figure shows the contour results of velocity magnitude According to the contour results, the velocity at the Inlet of the nozzle is of minimum value this is due to the fact that at inlet the velocity will be minimum and at exit of nozzle the velocity will be of extremely high to get greater thrust.

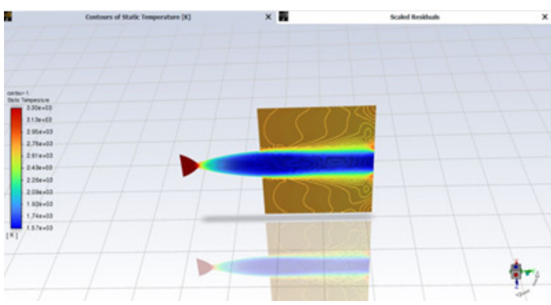

Figure 7: Contour of Static Temperature

The above figure shows the contour results of static temperature, According to the contour results, the temperature at the Inlet of the nozzle is at maximum value and having a slight variation throughout the throat where it can be seen the temperature is decreased and at the end of Nozzle the temperature reaches its minimum value.

V. ACOUSTIC ANALYSIS

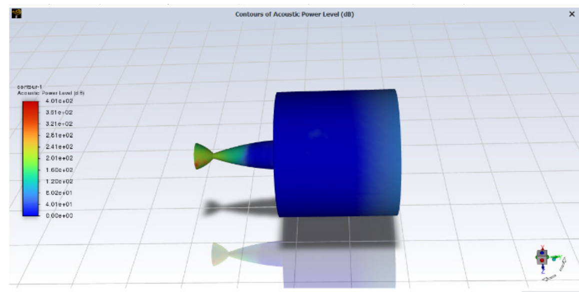

Figure 8: Contour of Acoustic for 10 bar pressure

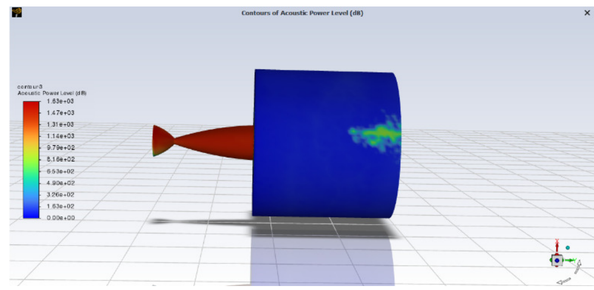

Figure 9: Contour of Acoustic for 15 bar pressure

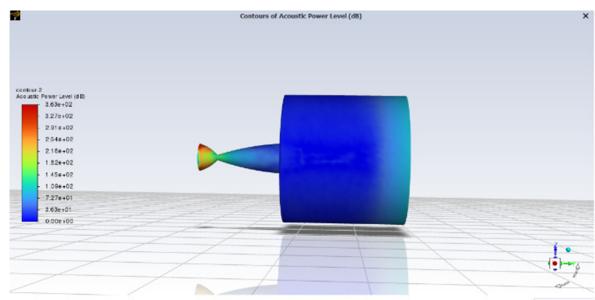

Figure 10: Contour of Acoustic for 20 bar pressure

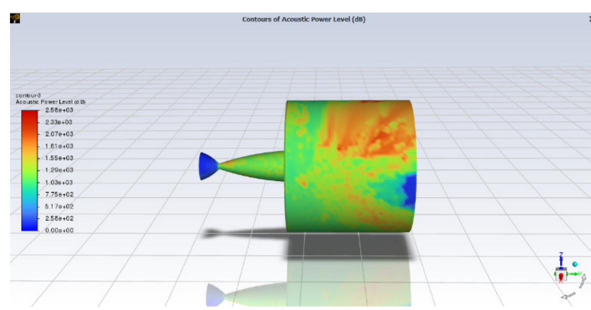

Figure 11: Contour of Acoustic for 25 bar pressure.

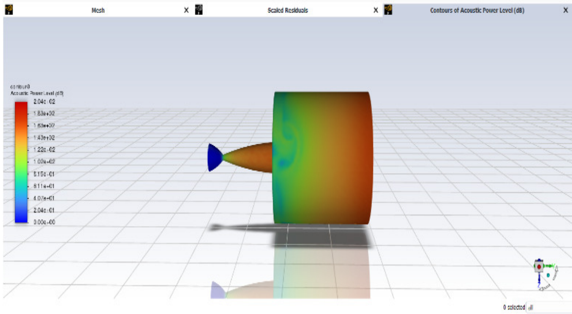

Figure 12: Contour of Acoustic for 30 bar pressure

Acoustic power for 3D Convergent-Divergent nozzle. Acoustic Power is measure of quadrupole noise source. The turbulent Intensity is influential for broad-band noise level and is presented in Figure .It is clearly shown from the result that The CD nozzle emits less acoustic power at the beginning of the exit of nozzle and then has a sharp decrease in the noise level at the rear exit of the CD nozzle and then going on decreasing. This can be explained by analysing the turbulent intensity contour.

VI CONCLUSION

Numerical analysis was conducted using CATIA V5 for design and ANSYS FLUENT for flow analysis and gave the results which has been tabulated.Geometry was imported to ANSYS FLUENT and fine meshing of CD nozzle with the domain was done. Aerodynamic and acoustic analysis with result contours has been obtained.

From the analysis, it was concluded that as the exit pressure increased the acoustics at the exit of the nozzle also increased. The operating pressure range of the nozzle was determined to be from 20 – 25 bar beyond which the noise increased.

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