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CFD ANALYSIS OF DUAL THROAT THRUST VECTORING WITH CHEVRON NOZZLE

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Abstract - *Thrust vectoring is a moderate concept that it can give present day military aircrafts with various point of buffs such as enhanced manuvervarability, shorter take off distance etc., fluidic thrust vectoring is a concept that doesn't use mechanical parts for vectoring. of many fluidic thrust vectoring nozzles we have chosen the dual thrust vectoring nozzle for this project because it is the better option to change exit nozzle shape and study. Chevron nozzle is a pretty much new concept used by boeing in its engine to reduce the noise. we are going to use the chevron shaped nozzle in normal dual throat nozzle and analyse the performance of chevron in this thrust vectoring method and compare the results of normal and chevron exit nozzles.*

***Keywords*—thrust vectroing, dual throat nozzle, chevron nozzle**

1. INTRODUCTION

Thrust vectoring is a concept that is used in aircraft and rockets to control the direction of thrust and manuver the aircraft using that directional control. Thrust vectoring is of two types 1. Mechanical thrust vectoring 2. Fluidic thrust vectoring.

Fluidic thrust vectoring is a type of thrust vectoring which uses fluid from the engine to control the direction of thrust instead of using normal mechanical actuators. There have been serious efforts to develop light weight and fixed geometry nozzles with fluidic thrust vectoring for unamanned and stealth air vechicles. Fluidic thrust vectoring uses various concepts to control the out flow such as subsonic skewing, shock thrust vector control, fluidic throat skewing etc,..

Fluidic thrust vectoring has less weight and no movable parts and easy to integrate and less expensive. It's aerodynamically efficient and has rapid response capability than the mechanical thrust vectoring. It is more suitable for stealth as it has low observable shaping with less IR signature.

Dual throat thrust vectoring is still a developing concept which is based on the throat method with enhanced separation. This method has another inlet in the divergent throat to control the directional vector of the exhaust gases. The second injection that occurs in the divergent portion while the flow is still subsonic and able to change the direction of the flow without creating efficiency reducing shocks.

To vector air is injected at or near one vertex of the first throat the main engine flow is deflected. The second throat will necessarily have to be larger than the first throat to allow for the increased air flow to the bleed flow as well as the loss in the total pressure to ensure that the controlling throat to insulate the main engine working during the vectoring process. This method achieves higher System thrust ratios than other methods. Compared to other methods this method has less weight and much easier to design.

Chevron nozzle is a new concept used by boeing company in its aircrafts to reduce the noise produced by the nozzle to a certain extent. Chevron nozzle has several saw tooth shaped structure in its ends. This technology has potential for reducing the turbulent mixing noise which is the main reason noise in the various engines. By the very shape of chevron nozzle the airflow converges to the center of every saw tooth apex there by reducing the noise of the engine. This concept was now used by boeing in its flight to reduce engine noise.

2. METHODOLOGY

2.1. MODELLING

In order to study the thrust vectoring produced by dual throat nozzle and properties the base design of the thrust vectoring nozzle is designed first and the design is validated using the previous solutions provided in the published journals. Chevron type nozzle model is the modification made in the further modelling. Chevron nozzle is designed with 8 cuts or lobes with the depth of 8mm and 45^0 angle.

The modified design which contains the chevron nozzle is being optimized by changing the exit convergent section of the existing design of the normal dual throat nozzle using the CATIA V5R20 software. The secondary injector has been drawn in the upper surface for both the normal and the optimized design.

2.2 CFD ANALYSIS

The geometric model is designed in the CATIA V5R20 software and converted the file into IGS file to import in the ANSYS 18.0 FLUENT. Before analysis to be grid validation is done and the grid independence is studied for the model. Then analysis is to be done in fluent and results are taken and compared for normal with chevron nozzle and effect of chevron nozzle in the thrust vectoring is studied.

This study focuses on different conditions given for the dual throat and the chevron type nozzle under several parameters and the results of these were studied.

As this project explains about the concept of thrust vectoring in the nozzle without using the external mechanical parts and computational results of velocity contour , pressure contour and acoustics contours for the normal and the optimized design were taken and compared with each other ,then the efficiency of one over the other is calculated.

3. GEOMETRIC MODELLING

3.1: 2D design

The nozzle geometric design variables cavity divergence angle (θ 1=10^0), cavity convergence angle (θ 2= 20^0),upstream minimum height (hut=1.15 in)and down stream minimum height (hdt=1.15 in). Design validation is done using the 2d reference model. Ansys design modeler is used to create the 2d design without flow domain to capture the exhaust flow and the grid study is also done using the 2d model with structured mesh.

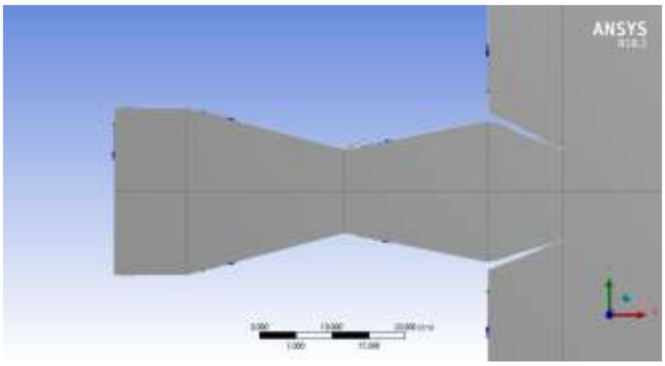

Fig - 1: 2D design in ANSYS 18.1.

3.2 3D design

The geometry of the 3d model is designed in catia wireframe and the open surfaces are closed for fluid flow analysis. At first the normal DTN is designed in the wireframe and then chevron DTN is designed using wireframe and part design. Chevron is designed as triangular tooth shape cut with the depth of 10mm and angle of 45^0.

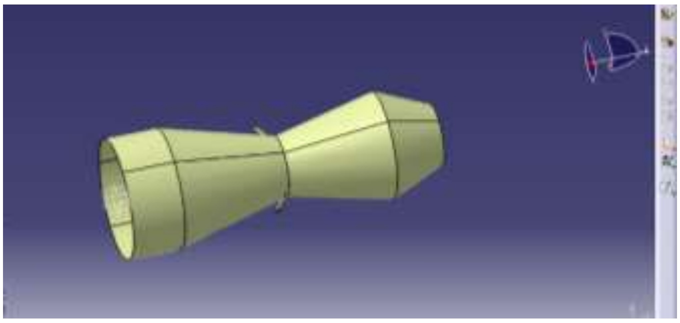

Fig - 2: 3D normal dual throat nozzle.

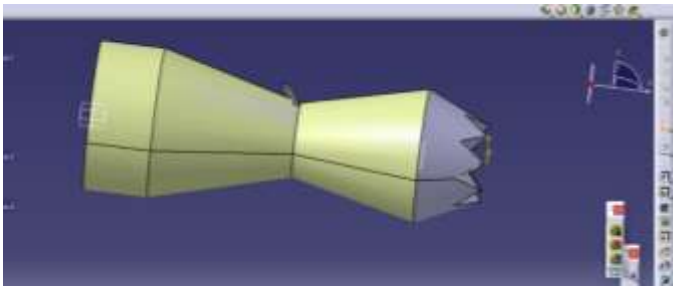

Fig - 3: 3D chevron dual throat nozzle

4. MESHING

2d model is meshed with structured mesh using face mesh. Grid generation study is also done for 2d model varying the no of cell divisons in the mesh. Grid generation study is done for the upper wall pressure of the model by varying the no: of the cells upto 50%.

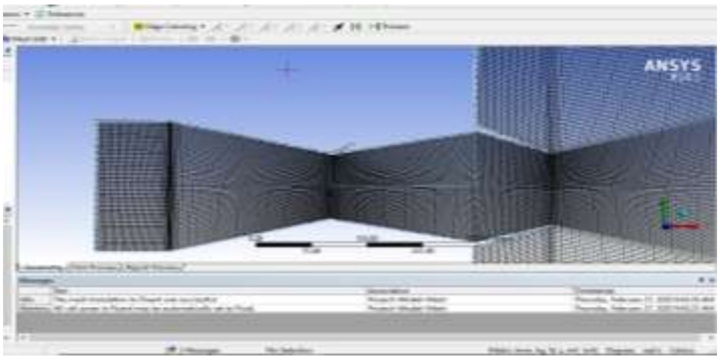

Fig - 4: meshing of 2d model.

3D Meshing is done with ANSYS FLUENT and the internal structure is considered as fluid for the fluid flow to be efficient. The mesh is done with fine relevant center and the minimum cell size and maximum size is given in mm and hex dominant method is used.

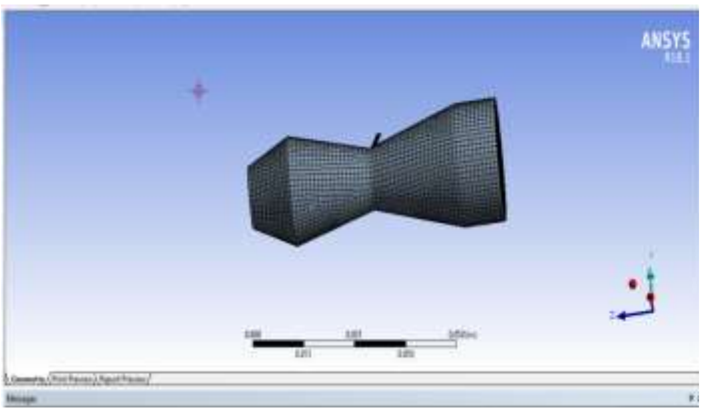

Fig - 5: Meshing of normal Dual throat nozzle

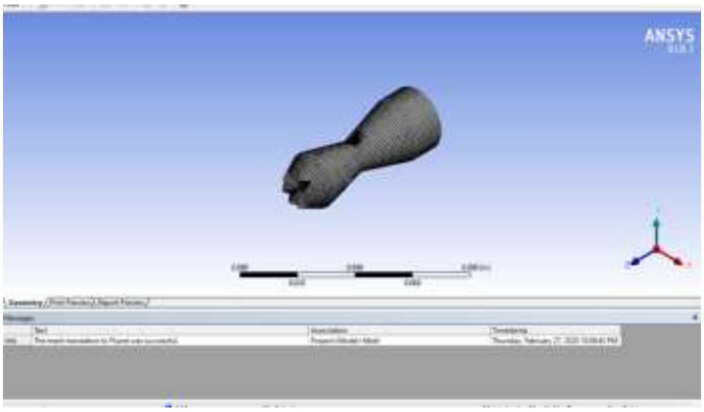

Fig - 6: Meshing of chevron dual throat nozzle

5. ANALYSIS AND RESULTS

ANSYS FLUENT SOLVER is used for the analysis of the project. There are two different solvers within Fluent, pressure based and density based. The pressure-based solver is normally used for lower speeds and the density-based solver is used for higher speeds and is recommended for compressible flow problems. Therefore, a steady state pressure-based solver was used for this study.

Fluid is given as air with ideal gas configuration Inlet is given as pressure inlet with pressure at the altitude of 11 km and operating pressure is taken for zero and outlet is taken as pressure outlet and the secondary inlet is also given as the pressure inlet with 5% of the injection. Other boundaries are given for pressure farfield.

The boundary conditions are given for certain condition and the calculations are calculated for upto 10000 iterations or until the solution si converged. Results are taken for pressure, Mach number and acoustics contours for various nozzle pressure ratios.

5.1 RESULTS

5.1.1 ACOUSTICS CONTOURS

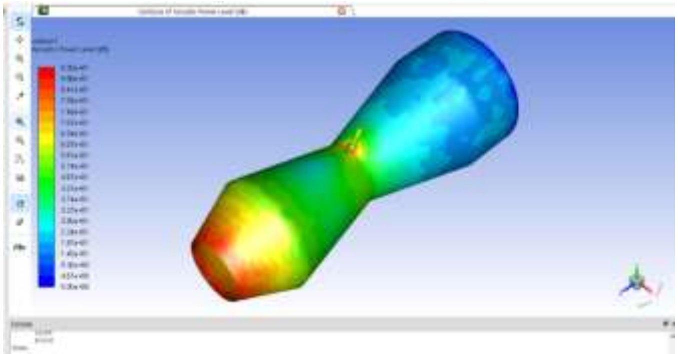

Fig - 7: Acoustics of Normal DTN

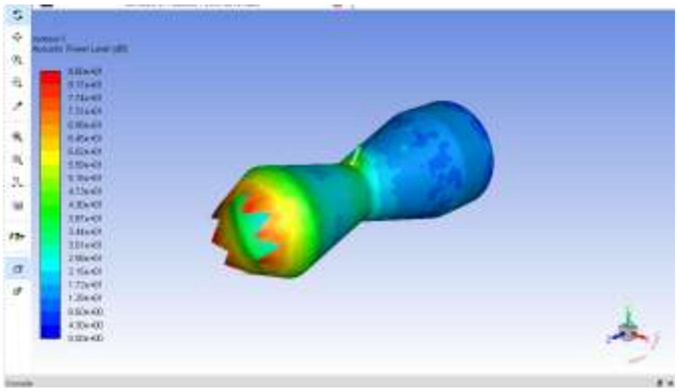

Fig - 8: Acoustics of chevron DTN

5.1.2 STATIC PRESSURE CONTOURS

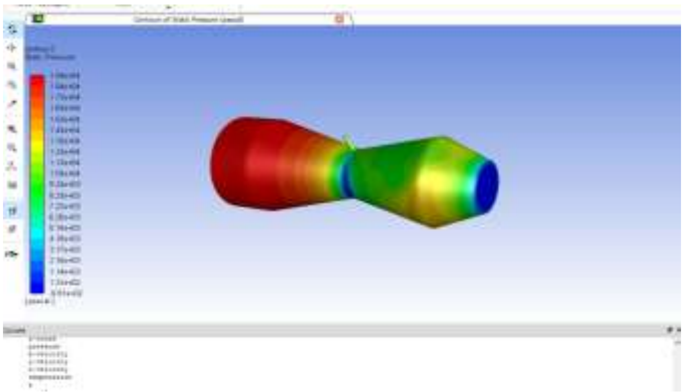

Fig - 9: static pressure distribution in normal DTN

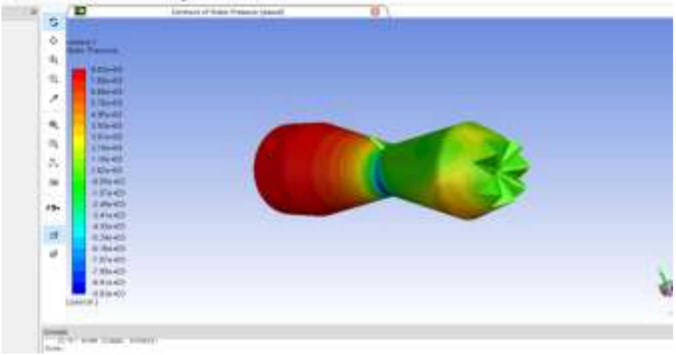

Fig - 10: static pressure distribution of chevron DTN

5.1.3 TOTAL PRESSURE CONTOURS

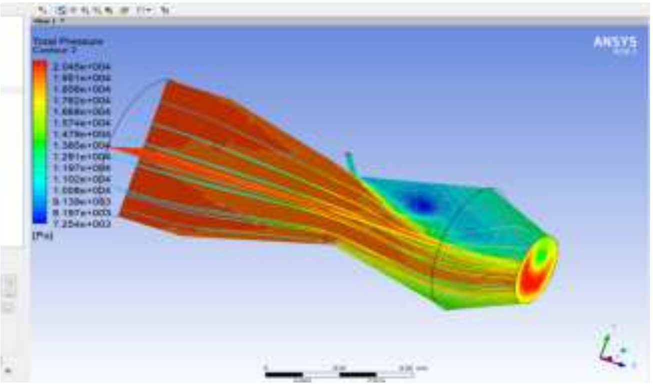

Fig - 11: total pressure distribution on normal DTN

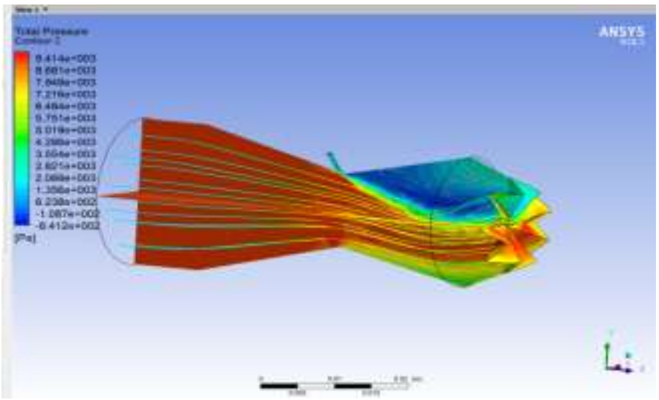

Fig - 12: total pressure distribution of chevron DTN

5.1.4 MACH NUMBER CONTOURS

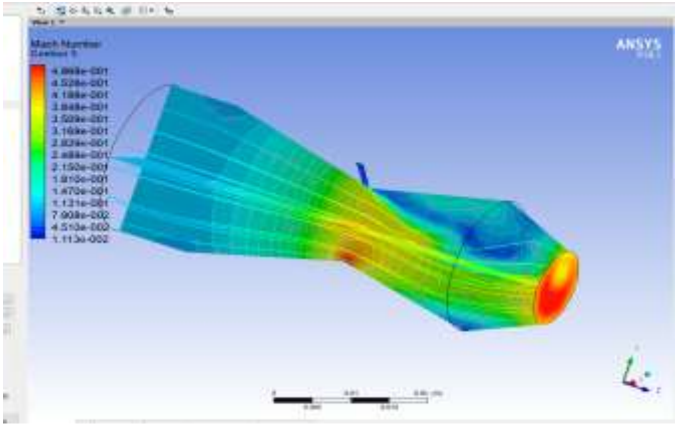

Fig - 13: Mach number distribution in normal DTN

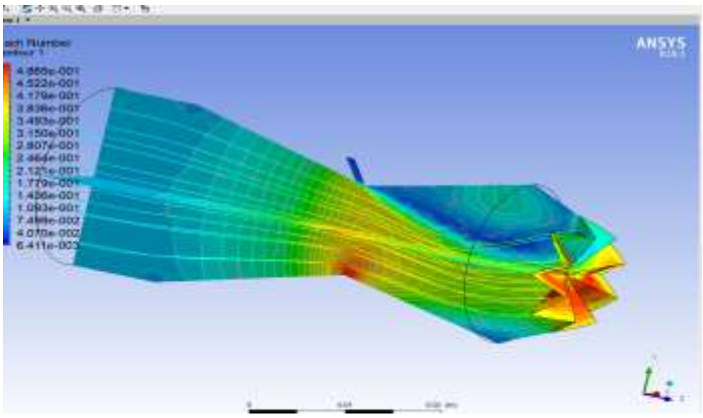

Fig - 14: Mach number distribution in chevron DTN

5.1.5 COMPARISON TABLE WITH NORMAL DTN

Table - 1:

Nozzle type	Velocity	Mach Number	Acoustics (sound)
Chevron DTN	DECREASE by 3 %	DECREASE by 0.6%	DECREASE by 7 %

6. CONCLUSION

It is found out in comparison with both the nozzle designs there is reduction in noise level in chevron type nozzle. Even though there is minor change in the velocity and pressure it is accepted as it can be neglected and does not affect the efficiency of thrust vectoring. Acoustics characteristics were studied for different main flow parameters such as pressure and velocity to find the effective design. The computational results shows that there is considerable reduction in the noise level in the chevron type nozzle which does not affect the performance of the nozzle.

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