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# Numerical Investigation of Jet Noise Prediction in Exhaust Nozzle by Passive Control Techniques

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**ABSTRACT**
The project mainly focuses on the reduction of jet noise emission in the exhaust nozzle of TURBOFAN ENGINES. Reduction of noise in the exhaust system is done by attaching chevrons with particular parameters in the nozzle exit. Numerical investigations have been carried out on chevron nozzles to assess the importance of chevron parameters such as the number of chevrons like (chevron count), chevron penetration and the mixing characteristics of co flow jet. Chevron count is the pertinent parameter for noise reduction at low nozzle pressure ratios, whereas at high nozzle pressure ratios, chevron penetration is crucial. The results illustrate that by careful selection of chevron parameters substantial noise reduction can be achieved. The sound pressure level (SPL) can be calculated from that we determined the noise level at nozzle exit section. After assessing the chevron parameters we are going to modify the chevron shapes in order to get maximum noise reduction along with very negligible thrust loss. Modification of chevron is based on aspect of increasing the mixing of cold jet and the hot jet in order to decrease the noise emission. ANSYS-Fluent is a commercial CFD code which will be used for performing the simulation and the simulation configuration contains three different velocities (100,150,200) with two different nozzle model(plain & chevron nozzle). The simulation results are evaluated to find out nozzle noise level in the engine exhaust system.
**Keywords** – Plain nozzle, Chevron, Noise level(db),Nozzle pressure(pa),velocity(m/s)

## I. INTRODUCTION

Numerical investigations can be carried out on chevron nozzles to assess the importance of chevron parameters such as the number of chevrons like (chevron count) and chevron penetration. The noise emitted by a jet engine has many sources. These include, in the gas turbine engines fan, compressor, combustor, turbine and propelling jet's .The propelling jet produces jet noise which is caused by the violent mixing action of the high speed jet with the surrounding air. in the subsonic case the noise is produced by eddies and in the supersonic case by mach waves. The noise generation from high-speed jets, several passive and active flow control techniques will be used. Passive control is accomplished by modifications of the nozzle geometrical shape (e.g. serration, beveling, tab's, saw tooth). Active control is accomplished by adding mass or energy to the flow in order to excite flow instabilities or affect the flow through the generation of new flow structures (e.g. stream wise vortices) further divided into two categories: open-loop and closed-loop Sound pressure level (SPL) will be discover from nozzle pressure at exit section. Acoustic power index has been calculated to quantitatively evaluate the performance of the various chevron nozzles. Chevron count is the pertinent parameter for noise reduction at low nozzle Pressure ratios, whereas at high nozzle pressure ratios, chevron penetration is crucial. The results illustrate that by careful selection of chevron parameters substantial noise reduction can be achieved. The rate of mixing of the jet and the surrounding fluid can be increased by the presence of small tabs on the nozzle. Unfortunately, the increased mixing, while reducing low frequency noise, generates excessive high-frequency noise that may overwhelm any acoustic benefit. In addition, tabbed nozzles always result in thrust loss. As an alternative to tabbed nozzles, serrated nozzles edge or chevrons, have been recently proposed. These devices are the current state of the art in jet-noise mitigation technology for medium- and high-bypass turbofan engines. Analogously to tabs, the triangular serrations in the nozzle trailing-edge induce stream wise vortices into the shear layer that leads to increased mixing and reduced length of the jet plume. However, since the penetration into the flow is lower than that occurring with tabs, the mixing enhancement occurs with a minimal engine performance penalty. Experimental tests show a complex dependence of the noise benefits from a series of geometrical parameters.

## II. JET EXHAUST NOISE REDUCTION

Jet exhaust consists of the fan stream and the core/combustion stream. The core flow stream is typically at a higher speed than the fan stream. As the two flow streams mix with each other, noise is created in the surrounding air. Of particular difficulty, the jet exhaust noise is actually created after the exhaust leaves the engine. This means that jet noise cannot be reduced where it is created, but must be addressed before the exhaust leaves the engine. Theory of noise generation is being studied and computer codes that can simulate the theory are being developed. The final goal of this effort is to have a computer model for jet noise that will predict the source of the noise and how it is sent into the surrounding air.

Theoretical understanding of jet noise is used to develop ideas for noise reduction concepts that are tested in model scale. Ideas that have already been tested or will be tested include mixer devices to combine the flows quickly, which reduce the noise generation area.

- To reduce the jet noise level at the nozzle exit.
- To reduce jet noise with minimum thrust loss.
- To study the mixing characteristics of a co-flow exhaust nozzle**.**
- By varying the geometries at nozzle exit to get the proper noise reduction.
- Formula used for calculating noise level

Conservation of mass

$\dot{m} = \rho AV =$ constant

$SPL = 20\times\log_{10} (p / p_{ref})$ in dB

$p_{ref} = 20\times10^{-6}$ pa

Human Hearing Range (64-23,000 Hz =0.00002pa)

for subsonic flow (M<1)increase in area causes flow velocity to decrease.

for supersonic flow (M>1) increase in area cause flow velocity to increase.

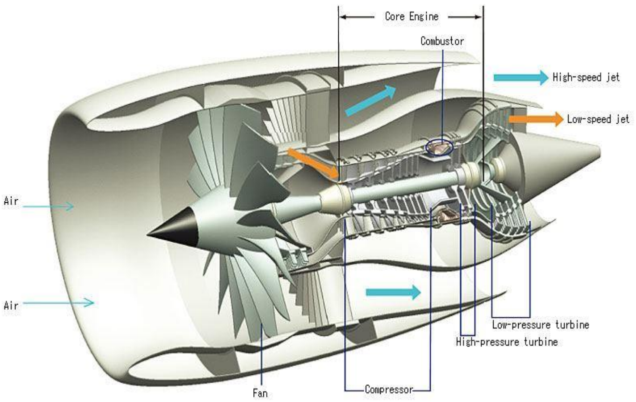


**Fig.1: Turbofan engine parts**

- Isentropic compression in diffuser
- Isentropic compression through compressor
- Constant pressure heat addition in combustion chamber
- Isentropic expansion through turbine
- Isentropic expansion in nozzle

## III. LITERATURE SURVEY

P.S. Tide, K. Srinivasan (2009),This work have been carried out on chevron nozzles to assess the importance of chevron parameters such as the number of chevrons and chevron parameters.

P.S. Tide, V. Babu For the baseline nozzle without chevrons, predicted trends of sound pressure levels for the cold jet is poor for observers located at angles less than 50% and good for other observers, while the predictions for the hot jet are in excellent agreement with experimental trends. However, the absolute values for the overall SPL are severely under-predicted

A.R.Saravanan , S.Thanigaiarasu , Christy Oommen Jacob, S. Prashanth(2014)The CFD results clearly indicate the overall sound pressure level (OSPL) of various configurations of chevron nozzles in dB. From that values chevron with 2mm diameter hole gives good acoustic sound pressure level. It reduces the sound level up to 2dB. For the future commercial aircraft (Turbofan) engines the chevron nozzle produces the minimum sound level compare to other nozzles. It helps to reduce the second major problem (sound) in our country.

Philip J Morris, K.B.M.Q.Zaman, (2009) This work describes an experimental investigation of a statistical properties of turbulent velocity fluctuations in an axisymmetric jet. the focus is on those properties that are relevant to the prediction of noise.

Mattihas meinke, Seong ryong koh, (2009) the generation of noise in subsonic high Reynolds number single and co axial turbulent jet is analyzed by hybrid method.

## IV. 3D MODEL AND ANALYSIS

CATIA (Computer Aided Three Dimensional Interactive Application) modeling software widely use to create three dimensional exhaust nozzle design model. After completing model go for analysis by fluid flow meshing tools & solver. ANSYS software use to mesh and FLUENT use solver for require model.

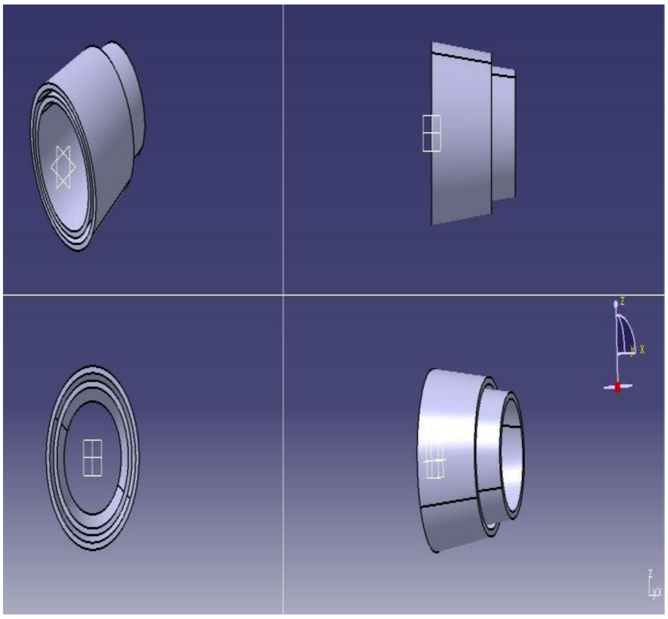

**Fig. 2: Plain nozzle model**

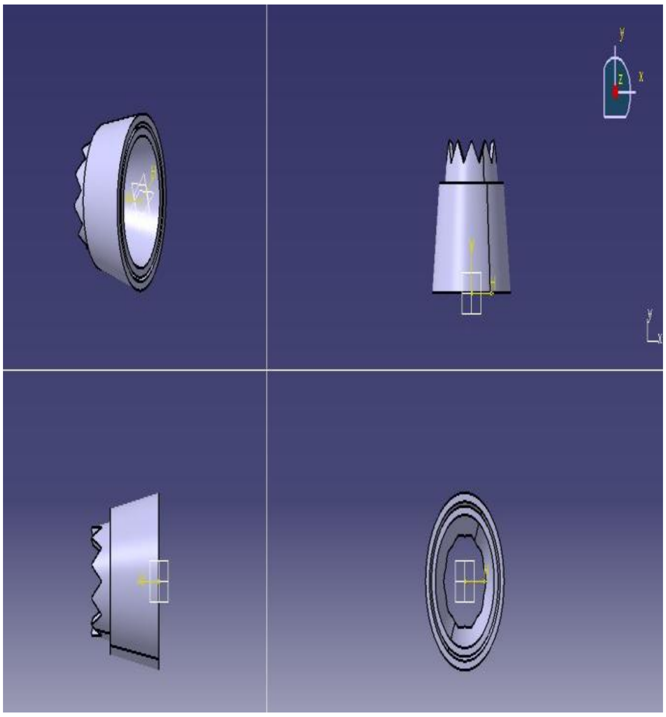

**Fig. 3: Single chevron nozzle model**

| No. | Fan nozzle inlet Velocity (m/s) | Core nozzle inlet Velocity (m/s) | Bypass nozzle (m/s) | core nozzle (m/s) |
|---|---|---|---|---|
| 1 | 80 | 100 | 158 | 163 |
| 2 | 80 | 150 | 237 | 244 |
| 3 | 80 | 200 | 316 | 326 |

**Table 1: Inlet boundary conditions**

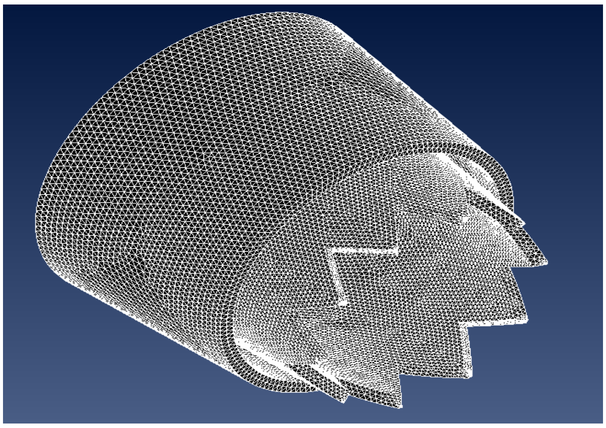

**Fig.4 Nozzle meshing**

**ANALYSIS**

**Mesh Type** : Tetrahedral & Prism
**Iteration** : 800
**Elements** : 19,00,000
**Tool** : ANSYS & FLUENT
**Viscous model** : K-Epsilon
**Domain Size** : 1m (1000mm)

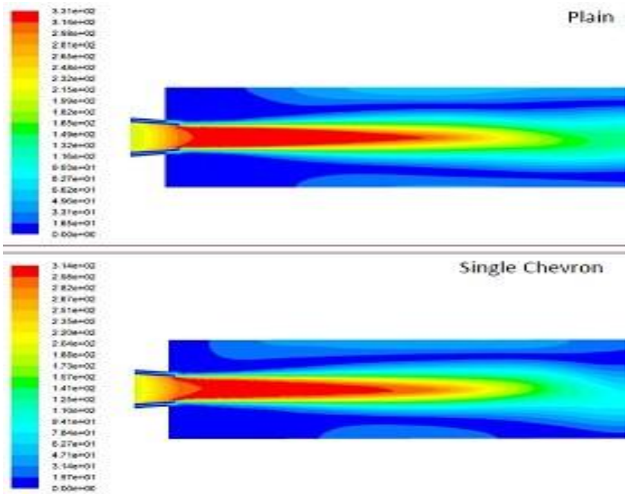


**Fig.5 Velocity 100 m/s contour**

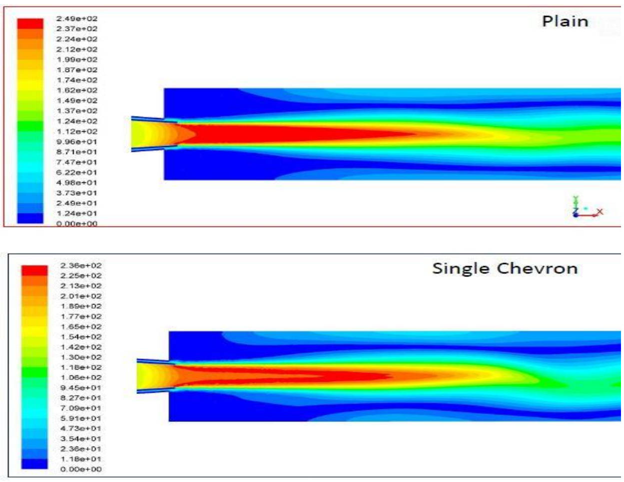


**Fig.6 Velocity 150 m/s contour**

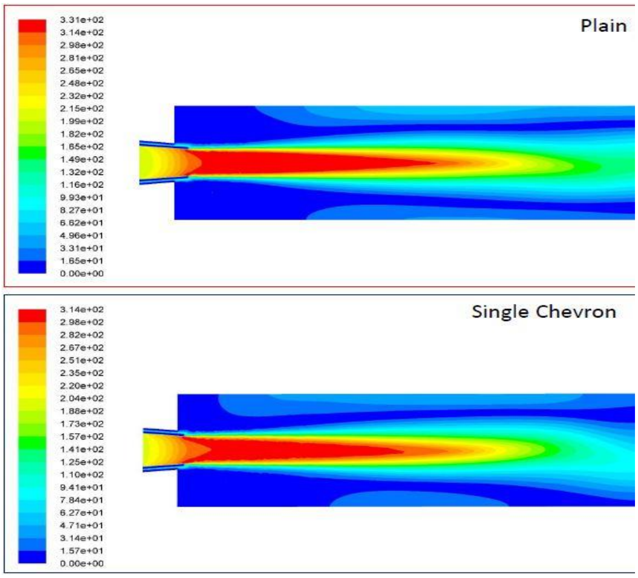


**Fig.7 Velocity 200 m/s contour At 100 m/s:**

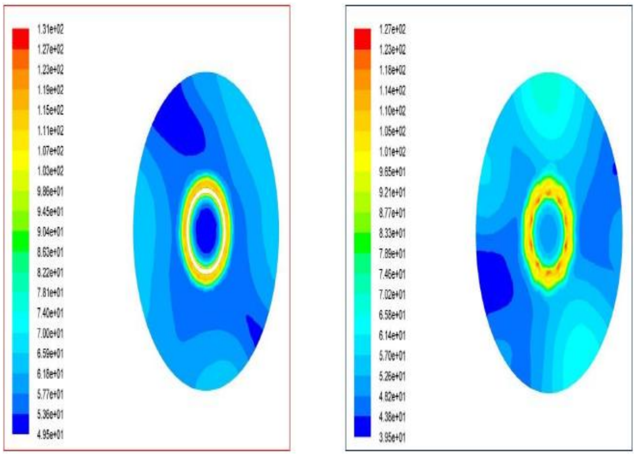

**Fig.8 Acoustic power(db) in plain & chevron 35mm**

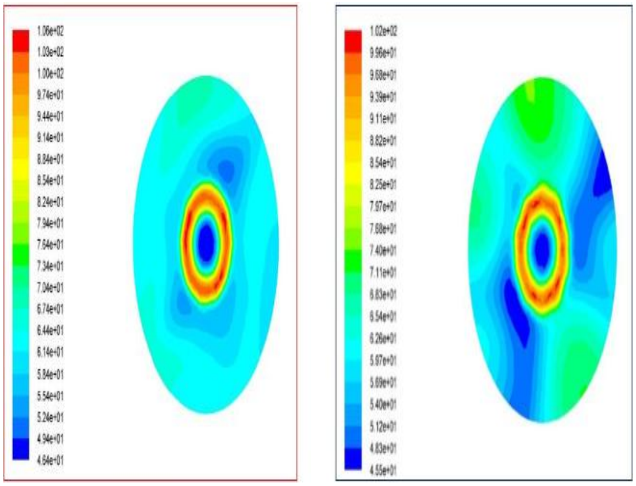

**Fig.9 Acoustic power(db) in plain & chevron 50mm**

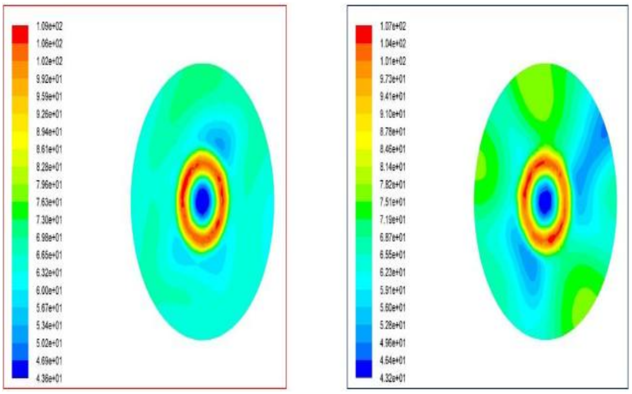

**Fig.10 Acoustic power(db) in plain & chevron 60mm**

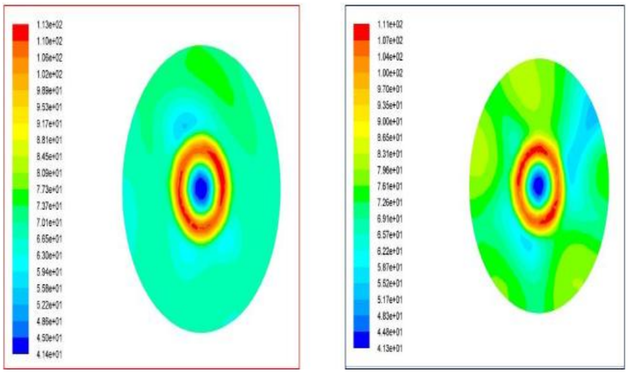

**Fig.11 Acoustic power(db) in plain & chevron 70mm At 150 m/s:**

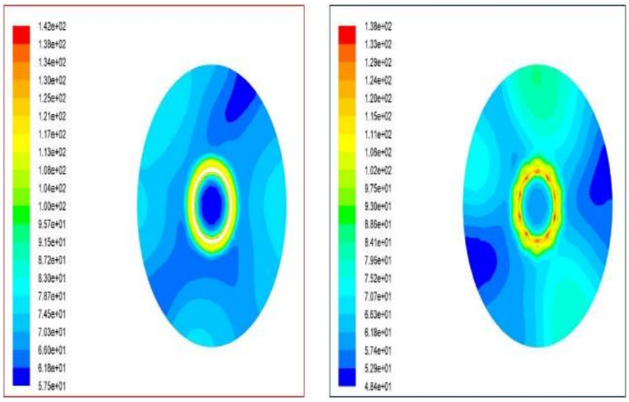

**Fig.12 Acoustic power(db) in plain & chevron 35mm**

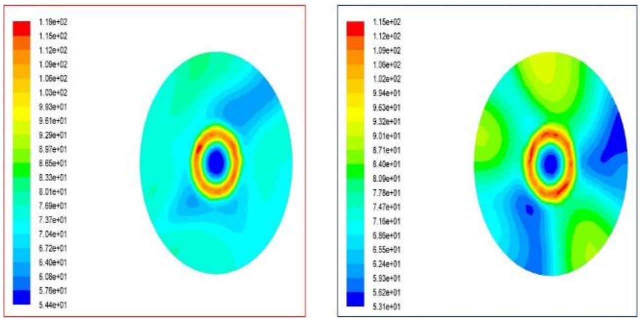

**Fig.13 Acoustic power(db) in plain & chevron 50mm**

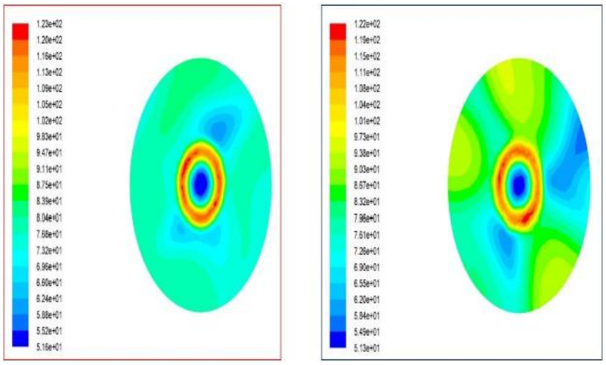

**Fig.14 Acoustic power(db) in plain & chevron 60mm**

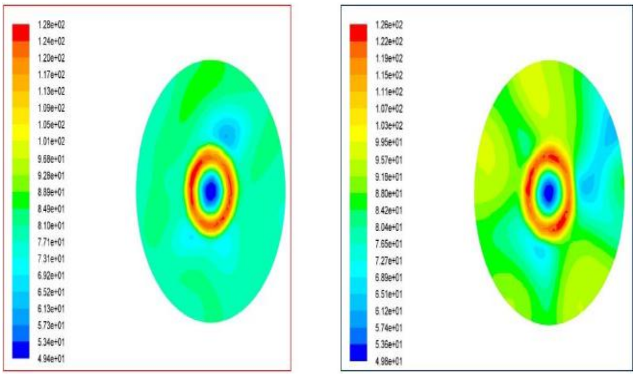

**Fig.15 Acoustic power(db) in plain & chevron 70mm**

**At 200 m/s:**

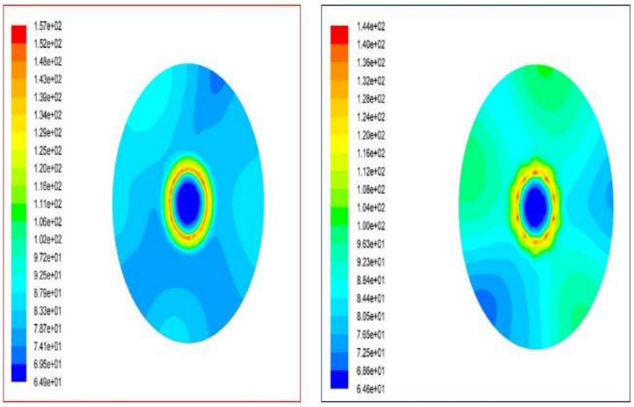

**Fig.16 Acoustic power(db) in plain & chevron 35mm**

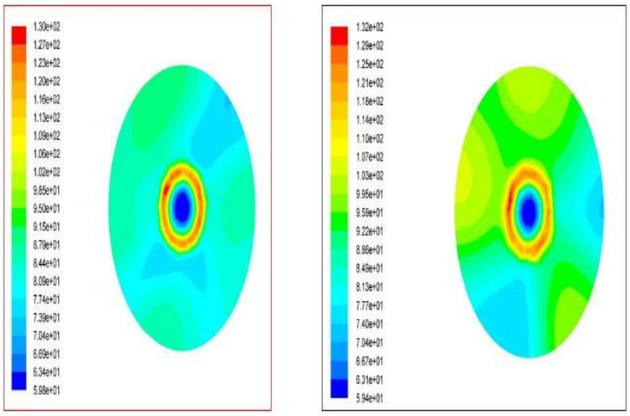

**Fig.17 Acoustic power(db) in plain & chevron 50mm**

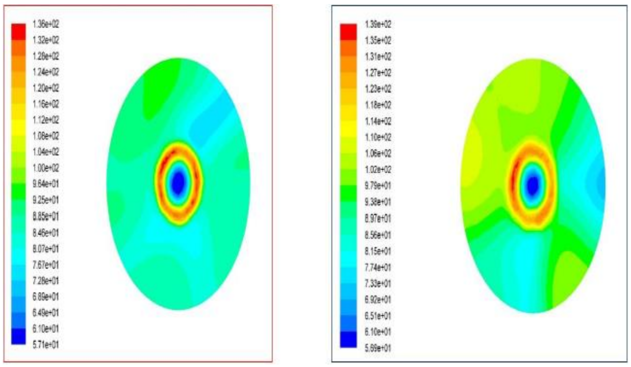

**Fig.18 Acoustic power(db) in plain & chevron 60mm**

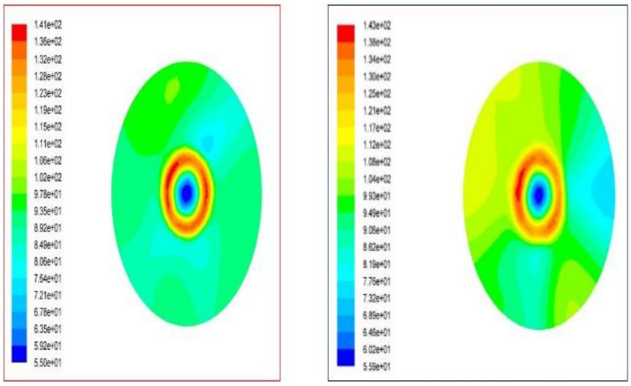

**Fig.19 Acoustic power(db) in plain & chevron 70mm**

Exhaust nozzle Acoustic values are shown possition at 36mm and velocity inlets 100m/s Fig.20 plain nozzle has 120db and chevron 117db similarly Fig.21 and Fig.22

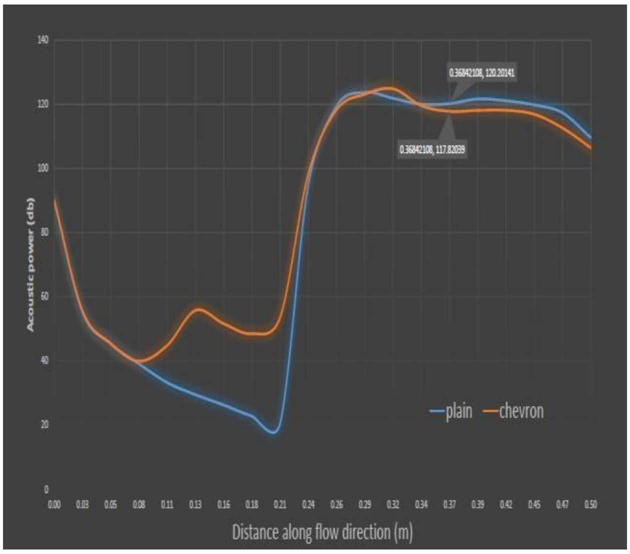


**Fig.20 Plain and chevron 100 m/s**

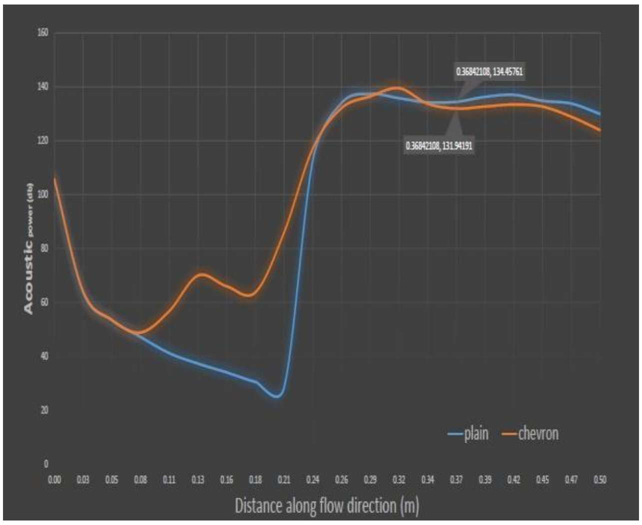


**Fig.21 Plain and chevron 150 m/s**

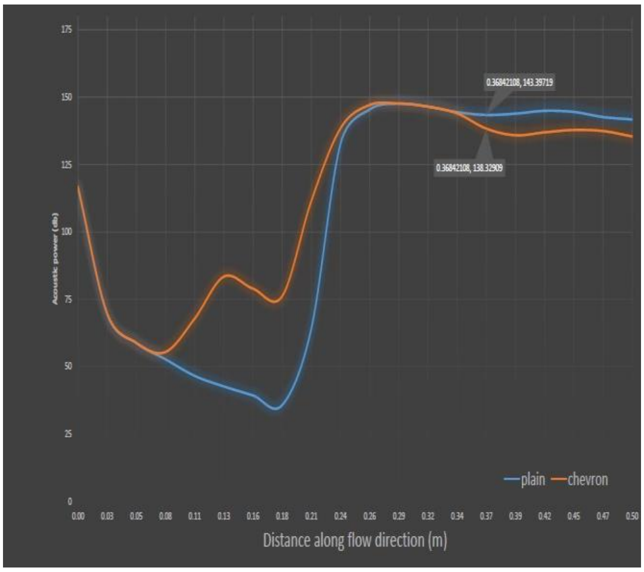


**Fig. 22 Plain and chevron 200 m/s**

| S.No | Velocity Variations (m/s) | Plain nozzle noise level (db) | Chevron nozzle noise level (db) |
|---|---|---|---|
| 1 | 100 | 120 | 117 |
| 2 | 150 | 134 | 131 |
| 3 | 200 | 143 | 138 |

**Table.2 Noise level at nozzle exit**

## V. CONCLUSION

The CFD results clearly indicate the sound pressure level (db) of various configurations of plain nozzle and chevron nozzles. From that values chevron model gives good acoustic sound pressure level compare to plain model. It reduces the sound level nearly to 3db. For the future commercial aircraft (Turbofan) engines the chevron nozzle produces the minimum sound emission level compare to plain and other nozzles. It helps to reduce the transport engine (noise emission) in our country.

**COMPARISON:**

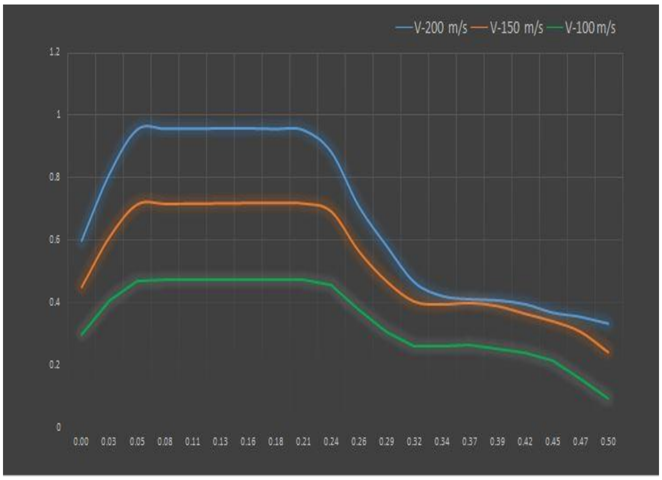


**Fig.23 Plain nozzle at different velocities**

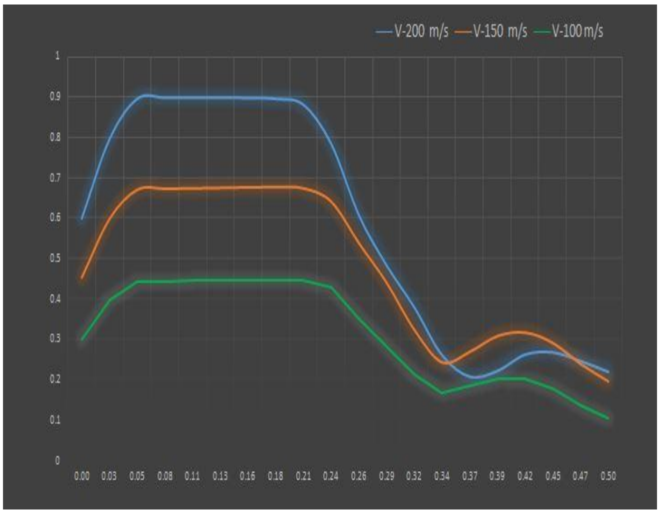


**Fig.24 Chevron nozzle at different velocities**

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