

Numerical Analysis of Chevron Nozzle with Various Configurations for Noise Reduction

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ABSTRACT: The project mainly focuses on the reduction of jet noise emission in the exhaust nozzle of turbofan engines. Numerical analyses have been carried out on various configurations of chevron nozzle to assess the importance of chevron parameters. The sound pressure level 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 chevrons in order to get maximum noise reduction along with very negligible thrust loss. ANSYS-Fluent is a commercial Computational Fluid Dynamics code which will be used for performing the simulation with five different nozzle models-plain and chevron nozzle. The simulation results are evaluated in order to be able to discover the design of chevron nozzle regarding the acoustic power level emitted.

KEYWORDS: Chevron Nozzle, Chevron Parameters, Sound Pressure Level, Noise Reduction, ANSYS-Fluent.

I. INTRODUCTION

Today's jetliners are significantly more efficient and quieter when compared to commercial jetliners of the 1960s and 1970s. Even so, the goal of reducing noise from aircraft in communities surrounding airports continues to exist. Aircraft manufacturers are motivated more and more by stringent noise abatement regulations in airport communities. Traditionally, much of the noise heard during take-off and landing comes from the aircraft's engines. Jet noise is produced by the shear layers of the jet plume: the core stream, fan stream, and free stream. Much research has been exerted on jet engine nozzles to hasten the mixing of the shear layers without significantly reducing performance.

II. LITERATURE SURVEY

Different researchers have discussed the noise emission in numerous ways. They are summarized below

I.A Brailko, S.Yu. Krasheninnikov (2004) the jet flow fields are presented in the form of Mach number contours. It should be noted that the results of the calculations for an axisymmetric jet using the program developed for three-dimensional flows are in good agreement with the available data for turbulent jets. Due to the displacing effect of the inward-bent chevrons, the stream is expelled, thus creating an intense transverse flow.

Abhimanya Kohli, Nittin Sharma, Poonampreet kaur, Vikrant Goyal (2012) is shown that the noise generated by Turbofan Engine is due to the ejection of hot burnt gases at the exhaust outlet when the high pressure gases are converted to high speed according to Bernoulli's theorem. A chevron nozzle reduces noise to a considerable extent but this reduction in noise is also accompanied by the reduction in thrust

Daniel Crunteanu, Petre-Claudiu Cojan (2013) present a comparison between different types of chevrons and their influence on the acoustic power level radiated by the flow over them. The comparison was performed using a two-dimensional simulation of the flow over four different shapes of chevrons resulting propagation of the acoustic waves for each shape. Acoustic characteristics were revealed studying the main flow parameters (pressure, velocity, kinetic energy) in order to be able to discover the most efficient shape of chevron regarding the acoustic power level emitted.

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III. METHODS

The 3D modelling of a chevron nozzle is conventionally done using CAD software's like CATIA V5 R20.

1. Problem definition.
2. Generate the 3-dimensional computer model
3. Prepare finite element model of the 3D computer model
4. Pre-process the 3D model for the defined geometry
5. Mesh the geometry model and refine the mesh considering sensitive zones for results accuracy
6. Post process the model for the required evaluation to be carried out
7. Determine the turbulence intensity and acoustic power level of the chevron nozzle.
8. Conclude the results.

I. MODELING

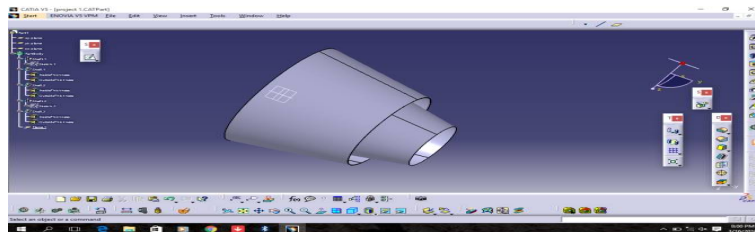


Figure 1: Baseline nozzle

The figure 1 shows the baseline nozzle or plain nozzle. This nozzle was used in the earlier turbo fan engines. It produces the high velocity and thrust at the same time and produces higher acoustic power level due to high turbulence at the exit of nozzle.

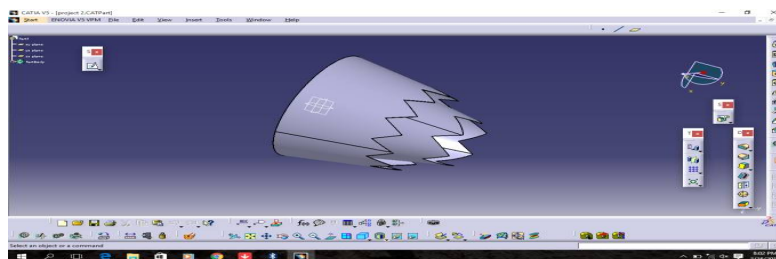


Figure 2: Chevron nozzle with triangular pattern on fan and core

The figure 2 shows the chevron nozzle with triangular pattern on fan and core. This type of chevron nozzle is commonly used in the commercial aircrafts with turbo fan engine. It reduces the acoustic power level with low thrust loss.

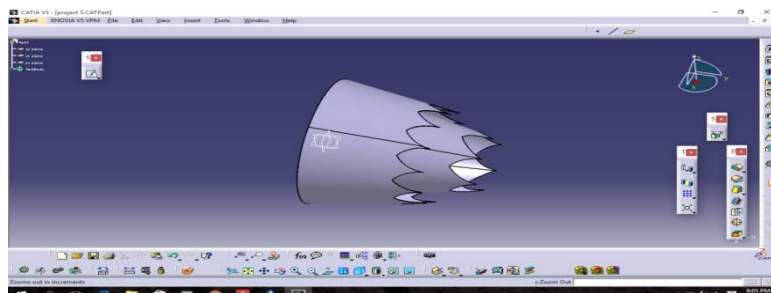


Figure 3: Chevron nozzle with petal pattern on fan and core

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The figure 3 shows the chevron nozzle with petal pattern on both fan and core. The petal pattern chevron is modelled in order to analyse it for the acoustic power level and velocity at the exit of the nozzle in order to increase the efficiency of the engine and to reduce noise level.

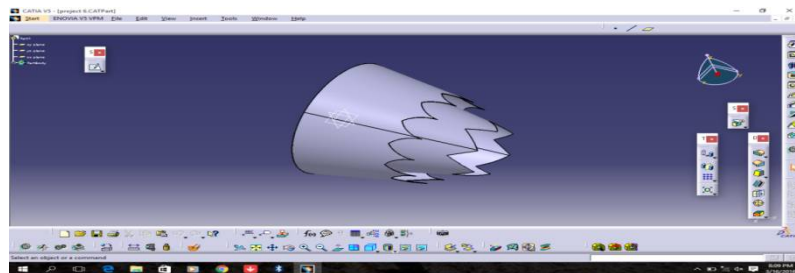


Figure 4: Chevron nozzle with triangular pattern on core and petal pattern on fan

The figure 4 shows the model of chevron nozzle with triangular pattern on core and petal pattern on fan. In this nozzle there is combination of chevron patterns. It was the concept that has been introduced in this project for reduction of acoustic power level.

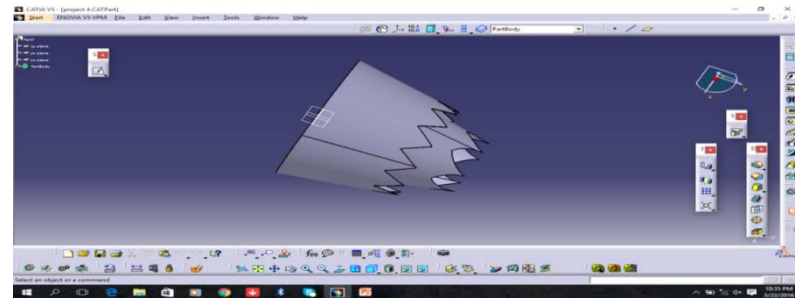


Figure 5: Chevron nozzle with petal pattern on core and triangular pattern on fan

The figure 5 shows the chevron nozzle with triangular pattern on fan and petal pattern on core. The above nozzle shows the combination of triangular pattern and petal pattern on core and fan in order to reduce the acoustic power level and increase the velocity at the exit of the nozzle.

II. MESHING

Element type

- 2D – Tria element
- 3D – Tetra element
- Boundary layer mesh – Penta element

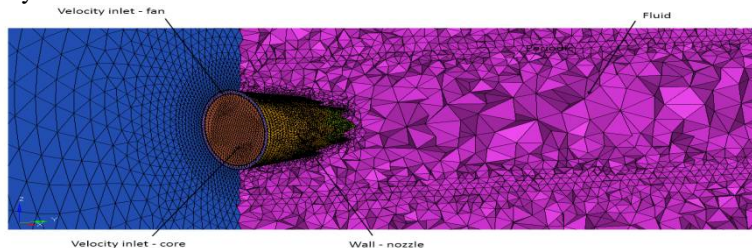


Figure 6: Boundary conditions applied in meshed model

The figure 6 shows the mesh of the designed model. The model have been meshed using hypermesh software. The tria element is used for 2D surface and tetra element is used for the 3D surface and penta element is used for the boundary layer applied.

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III. BOUNDARY CONDITIONS

Table 1: Boundary Conditions

Fan nozzle inlet velocity	Core nozzle inlet velocity	Fan nozzle inlet pressure	Core nozzle inlet pressure
270.85 m/s	363 m/s	67120.525 Pa	49238.6 Pa

The table 1 shows the boundary conditions that are applied in the meshed model. In the five different types of nozzle designed the boundary conditions applied are shown in the table. The boundary conditions given are the pressure inlet of fan and core and velocity inlet of fan and core.

IV. VELOCITY MAGNITUDE

The chevron shape does not have quite an influence regarding air flow velocity. So, taking into consideration that the noise magnitude is proportional with the air flow velocity, for now we cannot tell which of the shapes is more efficient.

The contours of velocity magnitude for five different types of nozzle are shown below

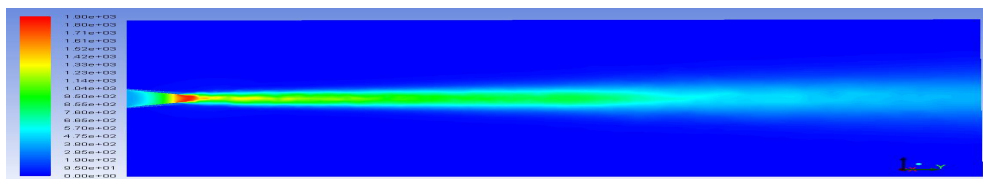


Figure 7: Base line Nozzle

The figure 7 shows the velocity magnitude of a baseline nozzle or plain nozzle in which the acoustic power level is high compared to the other four types of nozzle with chevron patterns. The plain nozzle is that produces higher velocity at the exit of nozzle.

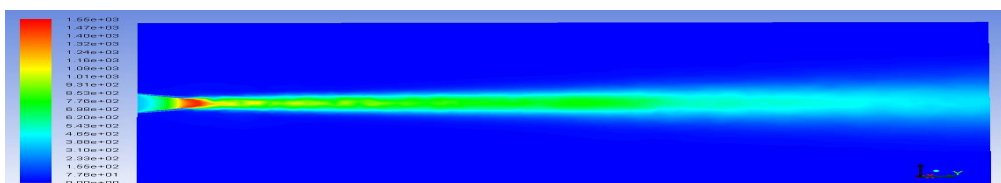


Figure 8: Chevron nozzle with Triangular pattern on both fan and core

The figure 8 shows the velocity magnitude of the chevron nozzle with triangular pattern on both fan and core it produces velocity lesser than the velocity at baseline nozzle. Velocity is slightly reduced and it causes thrust loss but it is negligible.

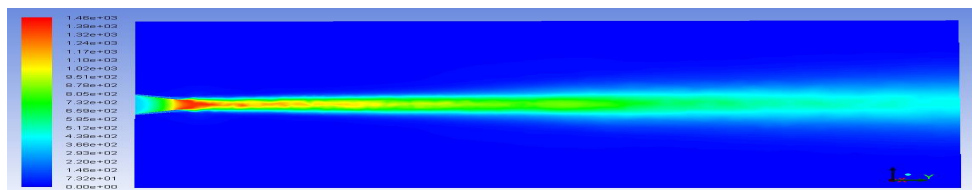


Figure 9: Chevron nozzle with Petal pattern on both fan and core

The figure 9 shows the velocity magnitude of the chevron nozzle with petal pattern on both fan and core. It produces velocity less than the velocity produced by the nozzle with triangular pattern on both fan and core and it also reduces the thrust.

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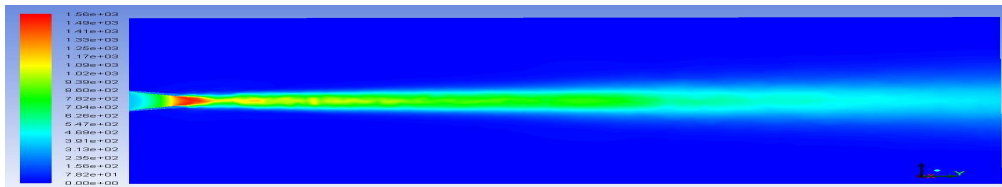


Figure 10: Chevron nozzle with Petal pattern on fan and Triangular pattern on core

The figure 10 shows the velocity magnitude of chevron nozzle with petal pattern on fan and triangular pattern on core. This type of nozzle is that produces velocity greater than the velocity produced by chevron nozzle with triangular pattern on both fan and core.

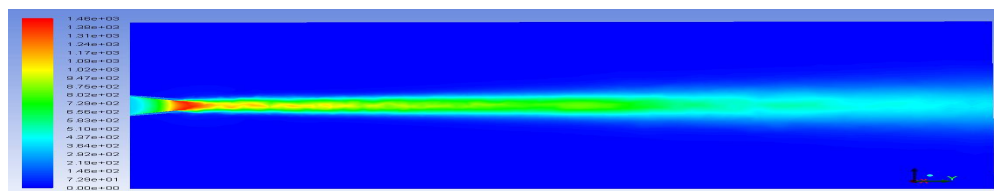


Figure 11: Chevron nozzle with Triangular pattern on fan and Petal pattern on core

The figure 11 shows the velocity magnitude of chevron nozzle with triangular pattern on fan and petal pattern on core. This nozzle produces the velocity greater than the velocity produced by chevron nozzle with petal pattern on both fan and core but velocity less than the velocity produced by chevron nozzle with petal pattern on fan and triangular pattern on core.

V. ACOUSTIC POWER LEVEL

Sound power or acoustic power is the rate at which sound energy is emitted, reflected, transmitted or received, per unit time. The SI unit of sound power is the watt (W).

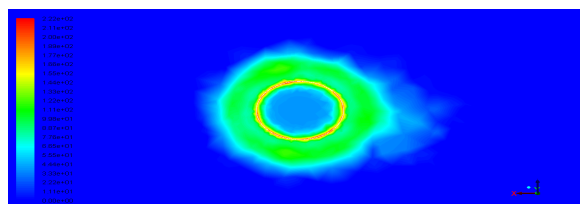


Figure 12: Baseline Nozzle

The figure 12 shows the acoustic contour of baseline nozzle or plain nozzle. It shows the acoustic power level and it indicates that the acoustic power level at the end of the nozzle is 222 dB. This noise level is that produced in the turbo fan engine without chevrons.

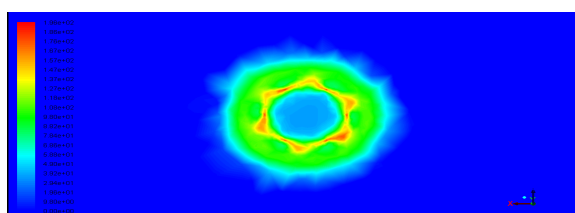


Figure 13: Chevron with Triangular pattern on both fan and core

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The figure 13 shows the acoustic contours of chevron nozzle with triangular pattern on both fan and core. It shows the acoustic power level at the end of the nozzle is 196 dB. The noise level produced by the nozzle is reduced to about 26 dB than the noise produced by the baseline nozzle.

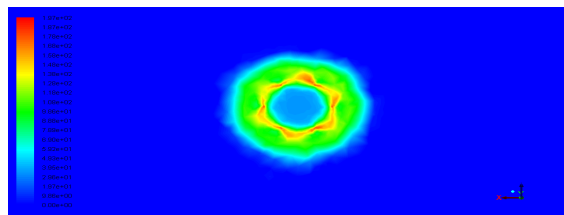


Figure 14: Chevron with Petal pattern on both Fan and Core

The figure 14 shows the acoustic contours of chevron nozzle with petal pattern on both fan and core. It shows the acoustic power level at the end of the nozzle is 197 dB. The noise level produced by the nozzle is reduced to about 25 dB than the noise produced by the baseline nozzle.

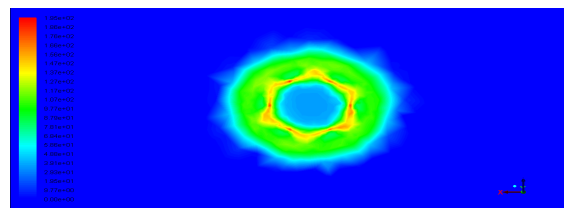


Figure 15: Chevron with petal pattern on fan and triangular pattern on core

The figure 15 shows the acoustic contours of chevron nozzle with petal pattern on fan and triangular pattern on core. It shows the acoustic power level at the end of the nozzle is 195 dB. The noise level produced by the nozzle is reduced to about 27 dB than the noise produced by the baseline nozzle.

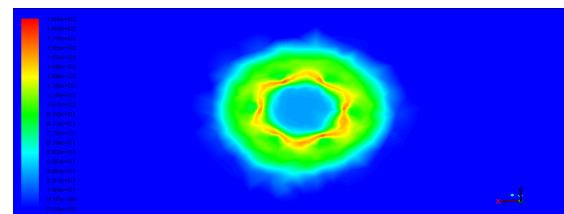


Figure 16: Chevron with triangular pattern on fan and petal pattern on core

The figure 16 shows the acoustic contours of chevron nozzle with triangular pattern on fan and petal pattern on core. It shows the acoustic power level at the end of the nozzle is 194 dB. The noise level produced by the nozzle is reduced to about 28 dB than the noise produced by the baseline nozzle.

IV. RESULTS AND DISCUSSION

The expected graphical results are set to Acoustic power level along the full domain and Velocity Magnitude along the length of nozzle of five different cases. The analysis was carried out for nozzle with various type of chevron in CFD software. And the results are taken in the form of graph and images and compare the results in the comparison graph and the conclusion were taken from the graph we shown below.

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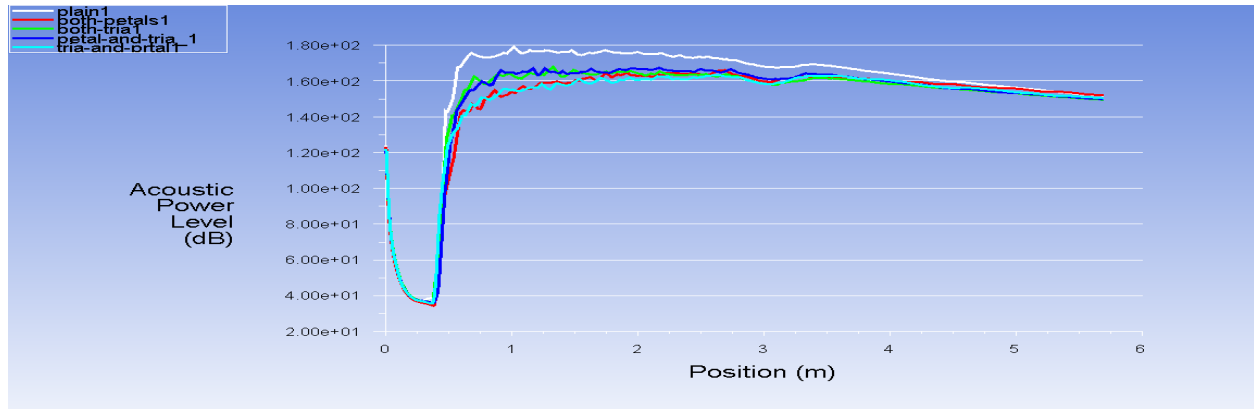


Figure 17: Acoustic power level along the full domain

The figure 17 is that shows the acoustic power level along the full domain for five different types of nozzle with chevron patterns. X-axis represents the position (m) and the y-axis represents the acoustic power level (dB). Each nozzle is indicated by different colours.

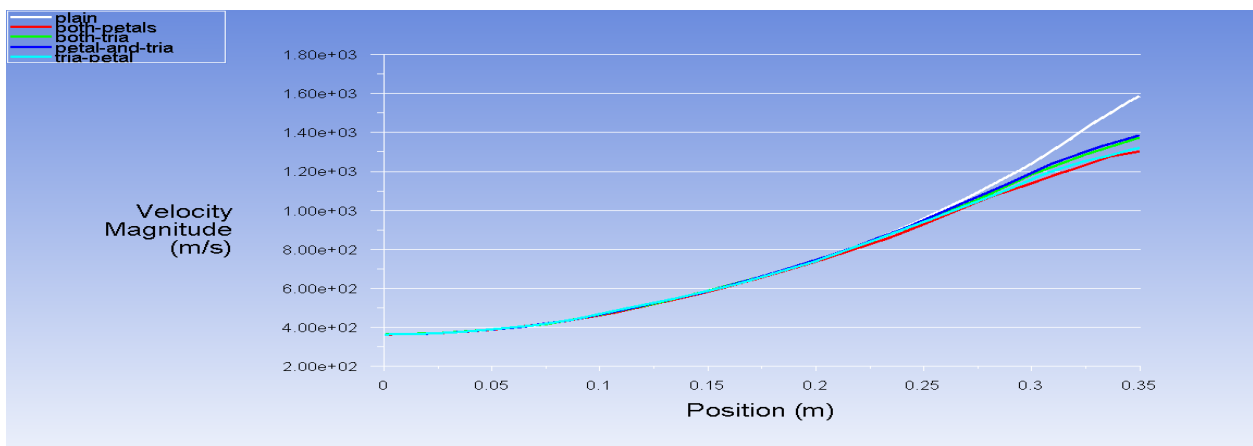


Figure 18: Velocity magnitude along the length of nozzle

The figure 18 is that shows the velocity magnitude along the length of nozzle for five different types of nozzle with chevrons. X-axis represents the position (m) and the y-axis represents the velocity magnitude (m/s). Each nozzle is indicated by different colours.

Table 2: Acoustic power level range

Nozzle	Maximum acoustic power level (dB)
Plain	222
Both petals	197
Both triangle	196
Petal and triangle	195
Triangle and petal	194

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The table 2 is that shows the acoustic power level range. From the above furnished results explains about various type of nozzle for a maximum Acoustic power level range.

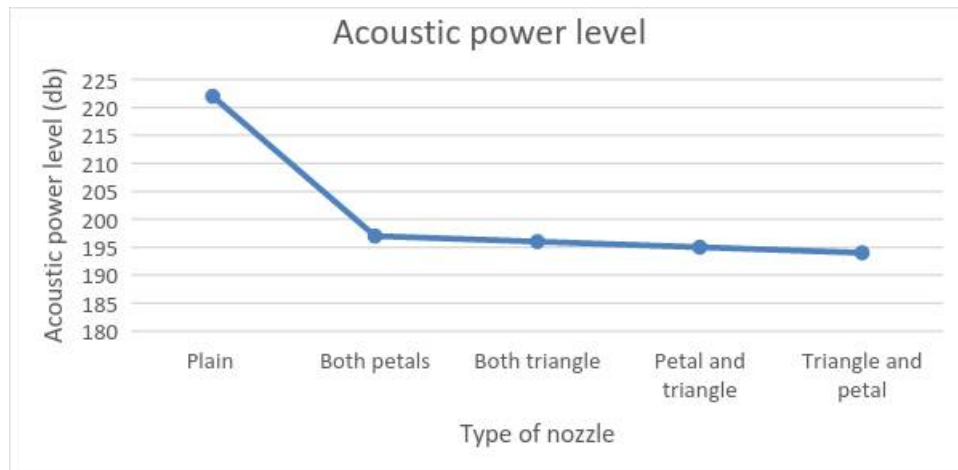


Figure 19: Type of nozzle Vs. Acoustic power level plot

The figure 19 is that shows the type of nozzle vs. acoustic power level plot for five different cases of nozzle with chevrons and plain nozzle.

Going further and analysing the acoustic power level we can find a difference of twenty six decibels between Baseline nozzle (222 dB) and nozzle with Triangular chevron pattern on both fan and core(196 dB), and the final result we obtained that the combining of different chevron patterns is that good results in reducing the acoustic power level is chevron with triangular pattern on fan and petal pattern on core.

V. CONCLUSION

In our project work, numerical analysis of chevron nozzle with various configurations for noise reduction is investigated. The numerical analysis of chevron nozzle is investigated to find the acoustic power level of various configurations of chevron nozzle and compared with baseline nozzle. Despite this, we can tell that the most efficient shape of chevron, from all points of view (noise reduction, turbulent intensity and air flow velocity) is nozzle with Petal pattern chevron on fan and Triangular chevron pattern on core(195 dB) reduces the sound pressure level by 27dB and produces high velocity compared to other chevron models.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the support of school of aeronautical science, Hindustan University, Chennai, Tamil Nadu and KIT- KalaighnarKarunanidhi Institute of Technology, Coimbatore, Tamil Nadu.

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ISSN(Online) : 2319-8753
ISSN (Print) : 2347-6710

International Journal of Innovative Research in Science, Engineering and Technology

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Vol. 5, Issue 5, May 2016

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