Noise Reduction in Jet Engine using Chevron Nozzle

Sadanandan R[1], Dheeraj R[2], Aswin B[3], Akshay Kumar k[4], Arjun Radhakrishnan[5]

[1]Asst.Professor, Dept. of Mechanical Engineering, Ammini College of Engineering, Palakkad-678613
[2,3,4,5]B.Tech Scholars, Dept. of Mechanical Engineering, Ammini College of Engineering, Palakkad-678613

---***---

Abstract - *Aircraft noise is an issue of enormous environmental, financial and technological impact. There are two main sources of noise seen in commercial aircraft engines: compressor noise and jet noise. This is due to the high turbulence structure created in the jet shear. These turbulence structures are generally caused by the flow instability due to pressure fluctuation created in nozzle. The effort is to study the way of noise reduction in exhaust nozzle. Chevron nozzle is one successful method for reducing jet noise by enhancing mixing of fan, core and ambient streams faster than conventional nozzles with minimal impact on performance. In this project work, It is proposed to analyze different types of nozzle for performance evaluation and see to provide better outcome than chevron nozzle. Different nozzle design are modelled using CATIA V5R20 software and analysed in ANSYS CFD for acoustic performance evaluation.*

***Key Words*: Chevron, Turbulence, Meshing, SPL, Structure, Lobes**

1. INTRODUCTION

Aircraft noise is an issue of enormous environmental, financial, and technological impact. There are two main sources of noise in today's commercial aircraft engines: fan/compressor noise and jet noise. Jet noise comprises of turbulent mixing noise and, in the case of imperfectly expanded jets, shock noise. Turbulent mixing noise is very difficult to control and turbulent mixing is caused by eddy formation due to the mixing of air streams at different temperature and speed. Usually outside air and high speed gasses from the engine results in eddies.

Chevrons are zigzag or raw tooth shapes at the end of the nacelle, with tips that are bent very slightly into the flow, and are being implemented on modern jet engines. The technology has a potential for reduction of turbulent mixing noise that is the dominant component of jet noise for most aircraft. The triangular cut outs made along the trailing edge of the nozzle induce stream-wise vortices into the shear layer leading to increased mixing and reduced jet plume length, Hence the chevrons enhance mixing by the right amount and the total jet noise reduces. If the mixing is too much, the chevrons make the noise go up. If the mixing is too little, no noise reduction benefits are realized. The nozzle allows the core and bypass flows to miss in a way that reduces low frequency mixing noise from highly turbulent flows.

2. METHODOLOGY

2.1. MODELLING

In order to study the noise generated and thereby the reduction in various nozzles, the base shape of the nozzle is designed first. The chevron nozzle model is considered as the benchmark for the modification made in further modeling. The model is then imported to ANSYS for analysis of the models. The details of the geometry is given in table below.

2.2 CFD ANALYSIS

Sl. No	NOZZLE	CHEVRON COUNT	CHEVRON LENGTH (mm)	BENT ANGLE	EXIT DIAMETER (mm)
1	Baseline	0	-	-	16
2	Chevron 6-0		7.25	0	16
3	Chev6- sine	6	7.25	0	16
4	Chev6-asym	6	7.25 and 10.88	0	16

The geometric model, created with the help of CATIA V5R20 software was exported to the ANSYS CFX by convert the model file into IGS format for carrying out the CFD analysis. The CFD analysis was carried out by specifying the input data. Simulations have been performed for jets, with stagnation temperature = 286.44K and pressure = 178200Pa.

The sound pressure level (SPL) of nozzle is calculated by using the formula

$$LP = 20 \log [(p/pref)]$$

3. GEOMETRIC MODELLING

3.1 CATIA V5R20

The CATIA Version 5 part design application makes it possible to design precise 3D mechanical parts with an intuitive and flexible user interface, from sketching in an assembly context to iterative detailed design. CATIA Version 5 part design application will enable you to accommodate design requirements for parts of various complexities, from simple to advance.

3.2 BASELINE NOZZLE MODEL

Fig-1: Three dimensional view of baseline nozzle model

3.3 CHEVRON NOZZLE MODEL

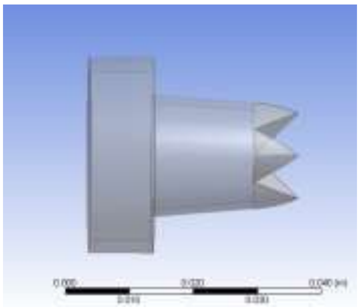

Fig-2: Three dimensional view of chevron nozzle model

3.4 ASYMMETRIC CHEVRON NOZZLE MODEL

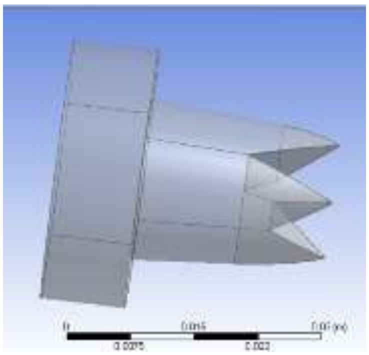

Fig-3: Three dimensional view of asymmetric chevron nozzle model.

3.5 M LOBE CHEVRON NOZZLE MODEL

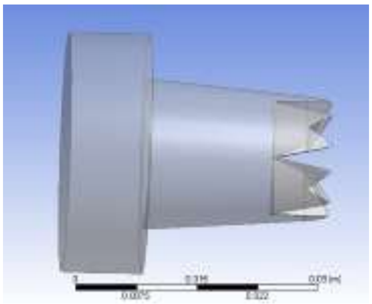

Fig-4: Three dimensional view of M Lobe chevron nozzle model

3.6 M LOBE CHEVRON WITH C CURVE MODEL

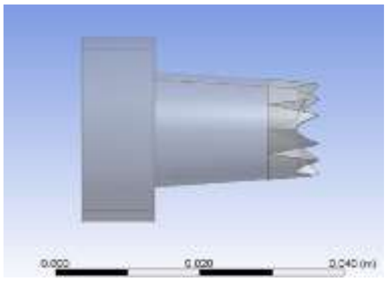

Fig-5: Three dimensional view of M lobe chevron with c curve model

3.7 M LOBE CHEVRON WITH SINUSOIDAL NOZZLE MODEL

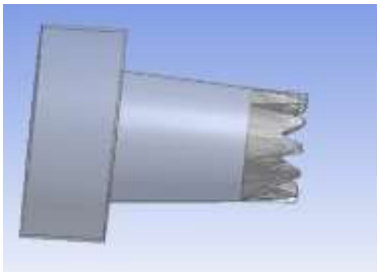

Fig-6: Three dimensional view of m lobe chevron with sinusoidal nozzle model

4. ANALYSIS AND MESHING

ANSYS (ANALYSING SYSTEM) is a general purpose finite element modeling and analyzing software package for numerically solving a wide variety of mechanical problems. These problems include: static/dynamic structural analysis (both linear and nonlinear), heat transfer and fluid problems, as well as acoustic and electromagnetic problems.

4.1 ANSYS-CFX

ANSYS-CFX is a commercial Computational fluid dynamics (CFD) program, used to simulate flow in a variety of applications. The ANSYS – CFX product allows engineers to test systems in a virtual environment. ANSYS CFX used to simulate the flow through the chevron nozzle for the given input, output and boundary conditions.

4.2 MESHING

ANSYS Meshing is a general-purpose, intelligent, automated high-performance product. It produces the most appropriate mesh for accurate, efficient Multiphysics solutions. A mesh well suited for a specific analysis can be generated with a single mouse click for all parts in a model. Full controls over the options used to generate the mesh are available for the expert user who wants to fine-tune it. The power of parallel processing is automatically used to reduce the time you have to wait for mesh generation.

5. RESULTS AND DISCUSSION

In ANSYS CFX software, results are obtained in the workbench platform. As convergence is an iterative process, successive iterations were performed by the CFX solver to obtain the pressure distribution, velocity distribution. The problem of CFD based jet noise prediction methods is thus one of great interest for real-world applications This is especially important for fast evaluation of designs intended to reduce the noise level from the jet. For such purposes, it is sufficient to predict the trends in the sound pressure level. Acoustic characteristics were studied for the main flow parameters namely pressure, velocity to find the most efficient shape of chevron.

5.1 RESULTS

5.1.1 BASELINE NOZZLE MODEL

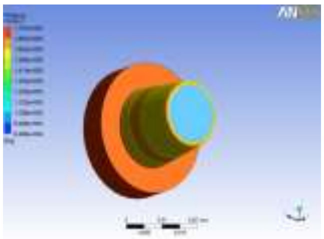
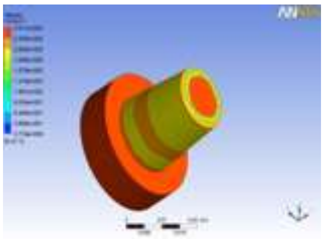

Fig-7 pressure distribution of baseline nozzle model
Fig-8 velocity distribution of baseline nozzle model

5.1.2 Chevron nozzle model

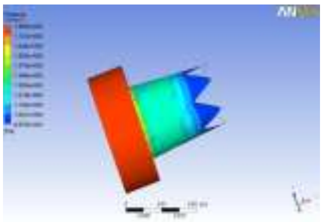
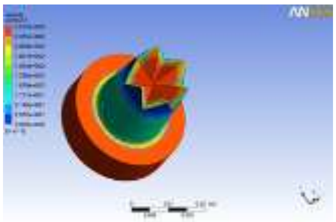

Fig-9 pressure distribution of chevron nozzle model
Fig-10 velocity distribution of chevron nozzle model

5.1.3 Chevron asymmetric nozzle model

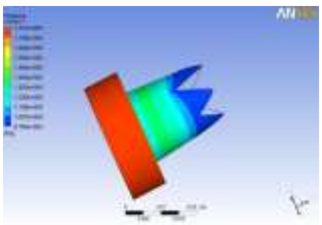
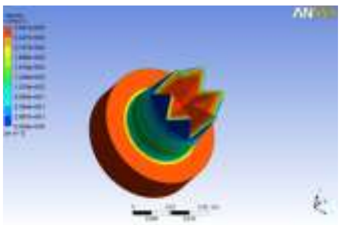

Fig-11 pressure distribution of chevron asymmetric nozzle model
Fig-12 velocity distribution of chevron asymmetric nozzle model

5.1.4 M lobe chevron nozzle model

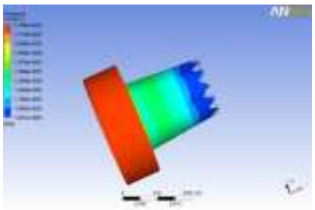
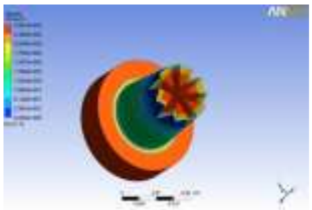

Fig-13 pressure distribution of M lobe chevron nozzle model Fig-14 velocity distribution of M lobe chevron nozzle model

5.1.5 M lobe chevron nozzle with c curve

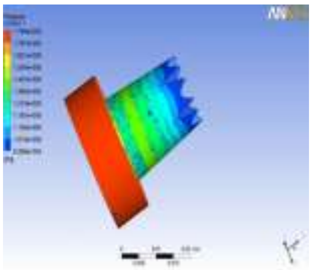
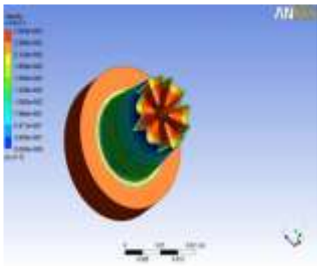

Fig-15 pressure distribution of M lobe chevron nozzle with c curve
Fig-16 velocity distribution of M lobe chevron nozzle with c curve

5.1.6 M lobe chevron nozzle with sinusoidal curve

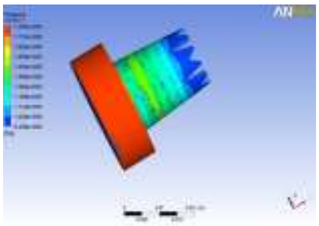
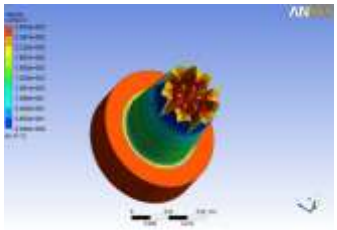

Fig-17 pressure distribution of M lobe chevron nozzle with sinusoidal curve
Fig-18 velocity distribution of M lobe chevron nozzle with sinusoidal curve

5.2 RESULTS

TABLE-1 Pressure, velocity and noise values

NOZZLE TYPE	PRESSURE (pa)	VELOCITY (m/s)	SPL (dB)
BASELINE	1.226*10^5	261.1	95.75
CHEVRON	1.135*10^5	257.2	195.08
ASYMMETRIC CHEVRON	1.139*10^5	269.7	95.11
M LOBE CHEVRON	1.08*10^5	256.1	94.65
M LOBE CHEVRON WITH C CURVE	1.03*10^5	265.3	94.24
M LOBE CHEVRON WITH SINUSOIDAL CURVE	1.02*10^5	265.5	194.15

6. CONCLUSION

Different chevron nozzle design analyzed in ANSYS CFD for evaluating acoustic performance. Acoustic characteristics were studied for the main flow parameter namely pressure, velocity to find the most efficient shape of chevron. Based on the analysis the five shapes of chevrons, the following inferences are derived: M lobed chevron nozzle with sinusoidal generates 1.6 decibels less than the baseline nozzle and 0.93 decibel less than that of chevron symmetric nozzle. The values obtained for the nozzle design analyzed have no impact on the perfomance of the nozzle.

REFERENCES

1. Bartlett, Donald (2016) "THE EFFECTS OF USING NOISE REDUCTION TURBOFAN ENGINE NOZZLE DESIGNS ON A TURBOJET ENGINE," Journal of Applied Sciences and Arts: Vol. 1 : Iss. 2 , Article 2.

2. Saurabh Shriwas, Sachin Shah,Prashant Singh, Kalpit P. Kaurase,(2015)," Reduction of Jet Noise in the Aircraft Nozzle", INTERNATIONAL JOURNAL OF RESEARCH IN AERONAUTICAL AND MECHANICAL ENGINEERING .

3. Clayton J. Bargsten , Malcolm T. Gibson NASA Headquarters, Washington, DC National Aeronautics and Space Administration NASA Headquarters Washington DC20546-0001,(2011)

"NASA Innovation in Aeronautics:

Select Technologies That Have Shaped Modern Aviation The Chevron Nozzle: A Novel Approach to Reducing Jet Noise"

4. P S Tide and K Srinivasan(2008), ''Novel chevron nozzle concepts for jet noise reduction '' DOI:10.1243 / 09544100JAERO347

5. L. Leylekian, M. Lebrun P , Lempereur," An Overview of Aircraft Noise Reduction Technologies" , DOI : 10.12762/2014.AL07-01, Journal Aerospace Lab, issue 7-2014