IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 19, Issue 2 Ser. I (Mar. – Apr. 2022), PP 35-38
www.iosrjournals.org

Design And Acoustic Analysis Of N8 Chevron Nozzle With Varied Tip Angle(β)

Irfan Nazir Wani [1], S Chaitanya [2], Deepak Singh Sisodiya [3],
Dr. Ankur Kulshreshtha [4].

[1][2][3](M.TECH SCHOLAR NIMS School of Aerospace and Mechanical Engineering, NIMS Institute of Engineering and Technology NIMS UNIVERSITY Jaipur India)
[4](ASSISTANT PROFFESSOR NIMS School of Aerospace and Mechanical Engineering, NIMS Institute of Engineering and Technology NIMS UNIVERSITY Jaipur India)

***Abstract**: When the nozzle of a jet engine increases the velocity of a fluid, a lot of noise is produced. This noise is called jet noise and is unfavourable to the population and airports nearby. To subdue this problem, chevron nozzles are installed in jet engines. They help to reduce the pressure fluctuations and thus the jet noise. In this project study, N8 chevron nozzle, which is similar to chevrons installed at the trailing edge of nozzle of Bombardier CRJ900, is studied. Various models have been studied based on the geometric parameters of the chevrons to obtain effective design parameters of chevron nozzle. Selected designs of N8 chevron nozzle was modelled in CATIA and were analysed in ANSYS-Fluent software. In this project, acoustic power levels of those models are calculated at take-off and compared for obtaining an efficient model.*

***Results**: N8β108 model shows the highest noise suppression experiences low acoustic power of just 100.45dB at a velocity of 590m/s.*

***Key Words**: Chevron nozzle; CFD analysis; Aircraft engine; Acoustic power.*

Date of Submission: 01-03-2022 Date of Acceptance: 12-03-2022

I. Introduction

Chevrons are a zigzag or raw tooth shape at the tip of the enclosure, with tips that are bent slightly into the flow, and are being enforced on new age jet engines. The triangular cut outs created on the edge of the nozzle induce stream-wise vortices into the shear layer resulting in inflated mixture and reduced jet plume length, hence the chevrons enhance mixture by the proper quantity and therefore the total jet noise reduces. The number of chevrons to be equipped on a nozzle will be decided according to the design parameters and the efficiency and performance of the chevrons on the given engines. The noise that's detected from an aircraft throughout varied stages in its flight ranging from take-off to landing could be a combination of the sounds made from its engines in addition as those made by the aircraft body as an entire. However, in general, all noise stems from pressure fluctuations in an unsteady flow. In an unsteady flow, pressure fluctuations occur so as to balance out the fluctuations in momentum. Since all real fluids are compressible, these pressure variations are communicated to the surrounding fluid and propagate outward from the flow. These pressure waves within the encompassing fluid compose what's recognized as sound.[1]When a fluid flows as a jet into a stagnant or relatively slower moving background fluid, the shear formed between the moving and stationary fluids results in a fluid-mechanical instability that causes the interface to disintegrate into vortices. These vortices then travel downstream at a velocity that is of an intermediate magnitude of those of the high and low speed flows. The characteristics of the noise produced by the jet depends on whether this velocity is subsonic or supersonic in comparison to the external flow [2]The project mainly concentrates on finding out the best chevron nozzle design, evaluating the acoustic performance of different profiles of chevron nozzle for attaining maximum suppression of noise at the exit of the nozzle of the turbofan engine of the aircraft. The flow parameters such as pressure, acoustic power, velocity are evaluated to find the most efficient model of N8 chevron configuration.

II. Chevron Configuration

Simple triangular chevrons are used for present configuration study. Geometry of a chevron nozzle is defined by parameters such as number of chevrons (N), length of chevron (L), tip angle (β) and penetration angle (α).The below figure represents the simple schematic of the chevron geometry with its shape defining parameters.

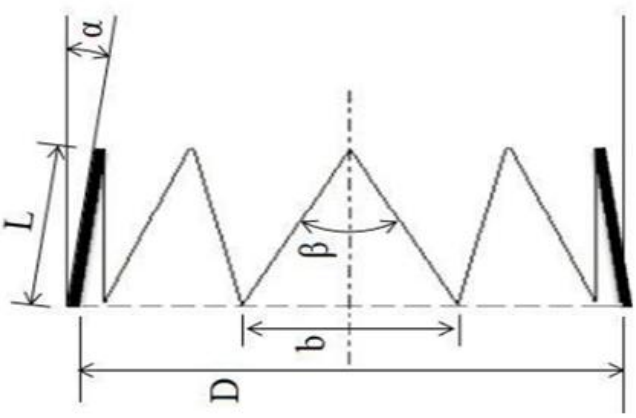

Fig 1 Schematic view of geometric parameters of chevrons

Base of the individual chevron (b) can be calculated as,

$$b = \frac{\pi D}{N} \quad (1)$$

The relation between the tip angle (β), base of chevron (b) and length of chevron can be calculated using trigonometric functions from fig 3.2(a)

$$\tan\left(\frac{\beta}{2}\right) = \frac{b}{2L} \quad (2)$$

By combining and rearranging equations (1) and (2), it gives

$$\frac{L}{D} \times \tan\left(\frac{\beta}{2}\right) \times N = \frac{\pi}{2} \quad (3)$$

Length of the nozzle which is dependent on the exhaust diameter of the nozzle that's given a

$$L' = 4.25 \times D \quad (4)$$

Height of the chevron is given as

$$h = \frac{b}{2} \quad (5)$$

From these formulas we can say that the length of the chevron is depends on the No. of chevrons and tip angle for showing chevron configuration we can write simply as "Nxβy". Equation (3) shows that the length to diameter ratio is purely dependent on the number of chevrons and the tip angle. This relation suggests these basic parameters defining the geometry of chevron are interdependent and changing individual parameter without changing the other is not possible. Hence, chevron configurations are chosen very carefully such that effect of individual parameter can be deduced from that.[3]

N	β (in degrees)	L (in mm)	D (in mm)	L/D	% of L wrt to D
8	60	17.278	50.8	0.34012	34
8	76.3	12.7	50.8	0.25	25
8	88.8	10.2	50.8	0.2	20
8	101.6	8.14	50.8	0.1602	16
8	108	7.25	50.8	0.14272	14.2

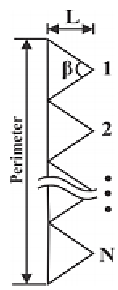

Table 1. Chevron configurations with geometric parameters

The project mostly focuses on varying the tip angle (β) while un-altering the chevron count. Its been clear that there will be only one value of length to diameter ratio to a combination of chevron count and tip angle even if the other geometrical parameters are varied. Numerous calculations have been done to check out the best possible variants of N8 chevron nozzle. Tip angle has been varied from 20° to 110°and have cornered 5 models/variants with respect to length to diameter ratio of the variants. Geometrical parameters of those selected models have been studied by altering the diameter of each variant.

III. CAD Models

The basic outline of the models was taken from a baseline nozzle. The baseline nozzle was also modeled in CATIA as a reference to the selected models.

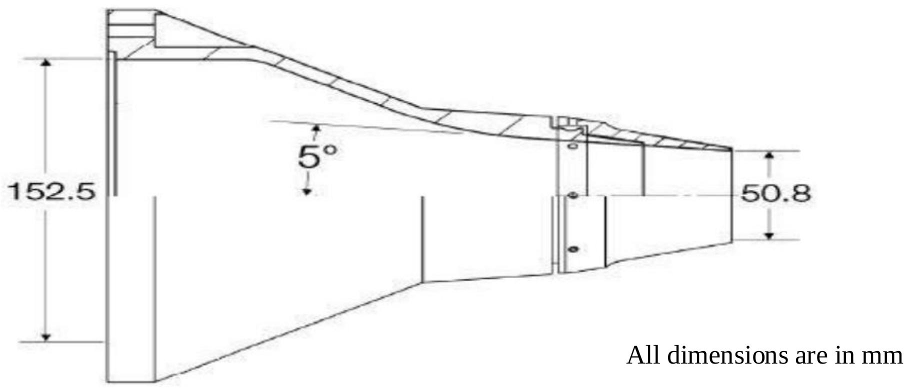

Fig 2 Outline of Baseline Nozzle for mounting

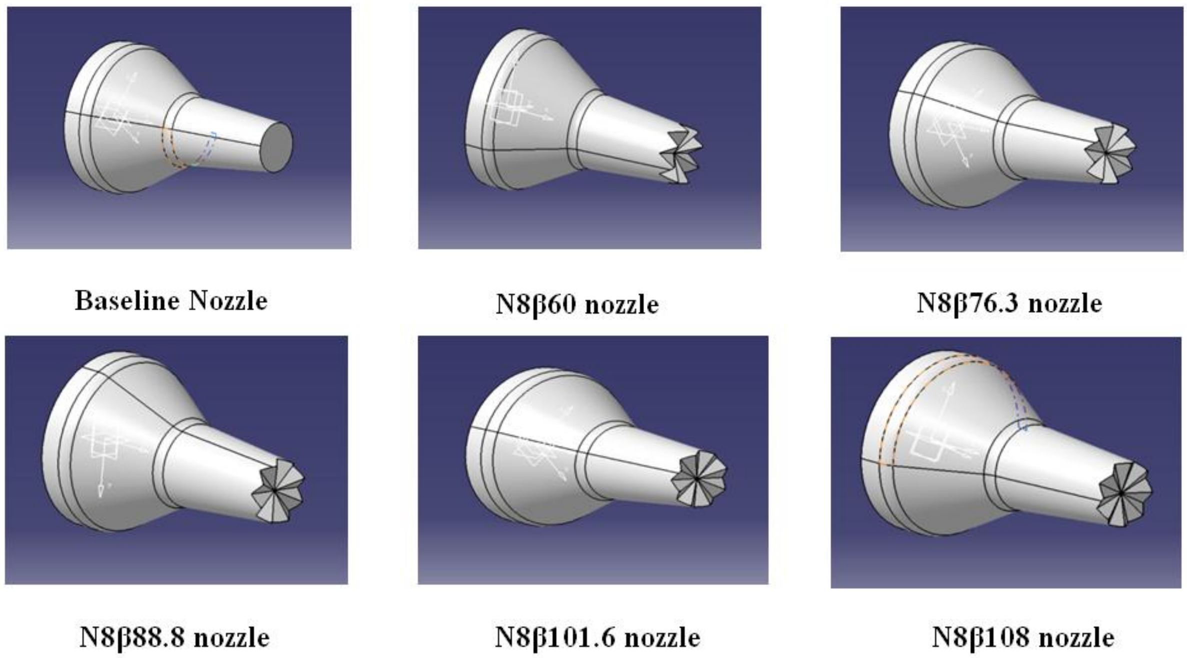

Fig 3 CAD Models of N8 Chevron variants

The design of a nozzle with chevrons is simple when the geometrical parameters are known. It only involves basic calculations and simple formulas and varying each parameter would result in unique values. Also, the 3D modeling of chevrons is also simple because it does not have intricate parts and does not involve complex tools of any CAD software. But the actual design of chevrons used in aircraft engines is totally different and involves more than the considered parameters in the study. Hence this design is used for basic analysis and is deplorable for pragmatic conditions.

IV. CFD Analysis

Every model in this project has been uniformly solid-meshed without an enclosure with maximum face size of 0.005m. Before generating a 3D volume mesh, quality of the faces has been checked to get an indication of the overall mesh quality. The skewness was checked to be in a range of 0.4 to 0.9, deducing the mesh quality to be average.

In this study, acoustic power level is the main parameter considered. Hence the analysis was mainly concentrated on acoustic power level. Nonetheless, the static pressure fluctuations and the velocity profiles were also examined for different models at stagnation temperature of 300K. Theoretical calculations for flow parameters through the nozzle has been performed by taking reference from CF34-8C5 engine used in Bombardier CRJ900, which is equipped with a N8 chevron nozzle. The model was considered to be pressure-based and the inlet and out pressures were taken as 170023.34Pa and 28441.92Pa respectively. The inlet velocity was calculated to be 45.27m/s.

V. Results and Discussion

Contours of acoustic power level and static pressure, velocity vector of all 6 models, has been keenly visualized. They have been checked with the calculated parameters and found out to be almost accurate. A graph has also been plotted comparing the acoustic power levels of different nozzles.

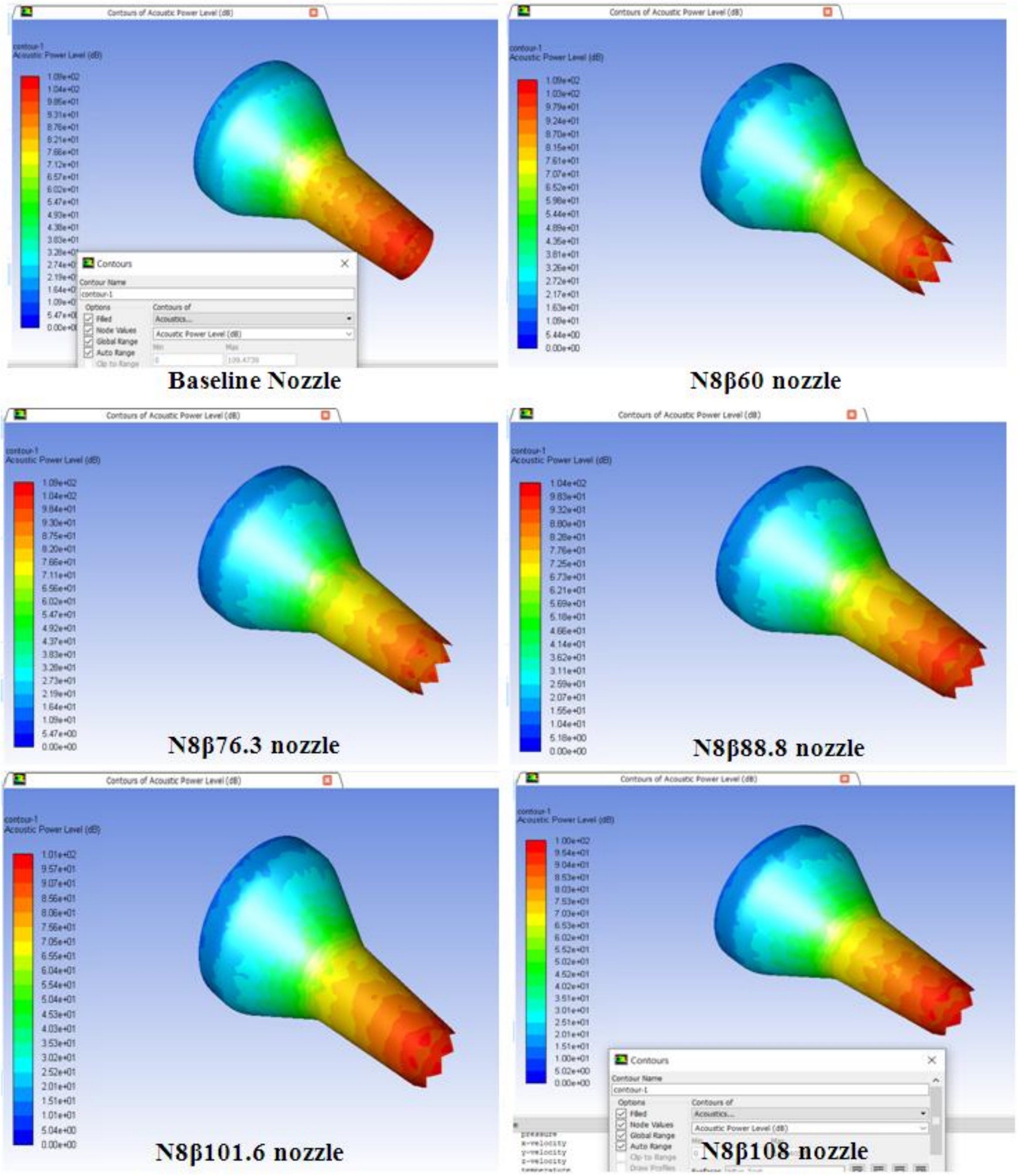

Fig 4Acoustic Power level of N8 Chevron variants

The results of the models in the above models ended up in an acute discernment. There have been four keen notable outcomes from the observations done-

- It's obvious to note that when the tip angle is increasing the noise suppression is increasing or the acoustic power level is decreasing which is what is desired from the project.
- The range of pressures is same for all nozzles with chevrons but different from the baseline nozzle.
- The magnitude of velocities, from the velocity profile, kept on decreasing but the least value was recorded in the baseline nozzle which is 550m/s.
- The most important part of the observation is that the area of the highest bandwidth increased with the tip angle.

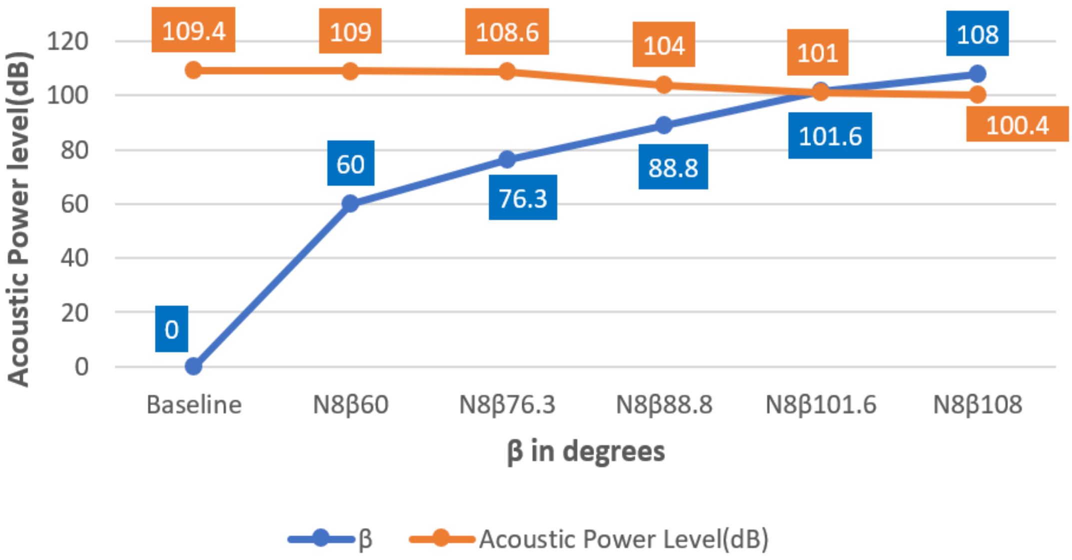

Fig 5 Plot of Acoustic power levels of different chevron configurations

VI. Concluding Remarks

From the acoustic analysis of a chevron nozzle it is understood that noise suppression is acquired with the implementation of chevrons. The variations in the N8 chevron nozzle also showed the variations in different parameters, and the effective model is considered. Although the N8β108 model shows the highest noise suppression, experiences low acoustic power of just 100.45dB, it is to be noted that this sound power is observed at more surface area than the other models which results in higher pressure drag. In consequence, considering all possible factors, it is concluded that the efficient model in N8 configuration would be either N8β88.8 or N8β101.6 and is recommended to be used in the aircraft engine as it provides effective performance. Hence the implementation of N8 chevron nozzle in the CF34-8cs engines of Bombardier CRJ900 is pertinent.

References

[1]. https://en.wikipedia.org/wiki/James_Lighthill
[2]. https://mitpress.mit.edu/books/aircraft-engines-and-gas-turbines
[3]. Malay Suvagiya, S. D. Sharma Malay Suvagiya, S. D. Sharma "On the effect of geometric parameters of chevron nozzle on generation of streamwise vortices in high subsonic jets" 20th Annual CFD Symposium, 2018
[4]. J.E. Bridges and C. Brown, "Parametric Testing of Chevrons on Single Flow Hot Jets" 10th AIAA/CEAS Aero-acou. Conf., 2004.
[5]. Tamer Raef, Aly Elzahaby, Mohhamed K Khalil "Enhancement of propulsion performance through jet noise reduction technologies: AReview" Conference Paper · May 2014
[6]. I.MohamedAkbarali, Dr.S.Periyasamy "Design and analysis of nozzle for reducing noise pollution" IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)X, Volume 17, Issue 1 Ser. IV, Jan - Feb 2020
[7]. J.E. Bridges, M. Wernet, and C. Brown, "Control of Jet Noise Through Mixing Enhancement", NASA Report 2003
[8]. Usha Bharathi, B. Balamanikandan, J. Blessing Sam Paul, V. Naveen Sundar, J. Vikash "Effect of Chevron on Transonic Nozzle" IJERT Vol. 4 Issue 04, April-2015
[9]. Rajashree, Antony D, Palanisamy, Prakash, Ranjithkumar "Design and Analysis of a Nozzle to Enhance Noise Suppression"IJERT Vol.3 Issue03
[10]. P. Kaleeswaran, P. Shanmughasundaram "Experimental and Statistical analysis on the noise reduction using chevron nozzle in supersonic free jet"

Irfan Nazir Wani, et. al. "Design And Acoustic Analysis Of N8 Chevron Nozzle With Varied Tip Angle(β)". *IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)*, 19(2), 2022, pp. 35-38.