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CFD ANALYSIS OF RB211 AND CFM56 CHEVRON NOZZLES

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Abstract

With the increase in advancements in the aerospace industry, the introduction of the concept of the chevron to reduce noise and turbulence has been effective to a certain extent. In the present context, a baseline axisymmetric separate-flow nozzle with standard dimensions is taken into consideration. Then the chevron nozzle represents the conventional chevron nozzle in use today. Noise emission and its intensity have been a major concern for the past few decades. This paper mainly deals with the velocity magnitude and acoustic power level of the four types of nozzles which includes the combination of two nozzles accounting the baseline model and its modification with a set of chevrons. Based on the two results the unprejudiced one is ideal for the airplane.

Keywords: Chevrons, Nozzles, Noise, Turbulence

I. Introduction

In the early 1930s, the first jet engine was designed by a German designer Hans von Ohain. Frank Whittle of Great Britain registered it for the patenting and tested it in the year 1941. Since then the problem of turbulence and irregular acoustics around the airplane was found common. The efforts to reduce the effects on the plane and optimize it to the safer standards was a tedious effort. But it wasn't another 40 years until flying became an inexpensive and common form of traveling [I]. In the era of such problems, the introduction of chevrons to the nozzles of the jet engines has taken a great turn in the optimization of the effects. The current paper discloses the variations and the purpose of the design of the two types of nozzles with chevrons. The variation of design between the Rolls Royce RB211 and the CFM International CFM56 also leads to a change in the results of the outlet. This paper concerns about the velocity change and the acoustic analysis between the two types of design. The manufacturers of aircraft were constantly inspired by stringent airport noise reduction

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legislation. Much of the sound detected from the aircraft's engines usually at takeoff or landing. Jet noise is created by the jet engine shear layers: core flow, fan flow, and free flow. Some study was carried out on jet engine dust to speed up mixing of the shear layers without increasing performance significantly. The goal of the nozzle is to increase the kinetic energy of the flowing medium at the expense of its pressure and internal energy [III]. Over most of the years, some progress has been made regarding noise as the need to keep the aircraft quieter has grown. With the up-gradation of sound regulations from time to time, agreed noise levels have been continuously updated from previous years. Consequently, today's new planes are about 80 percent quieter than 60 years ago in operation.



Fig. 1: RB211, Rolls Royce Engine's Nozzle



Fig. 2: CFM56, CFM International Engine's Nozzle

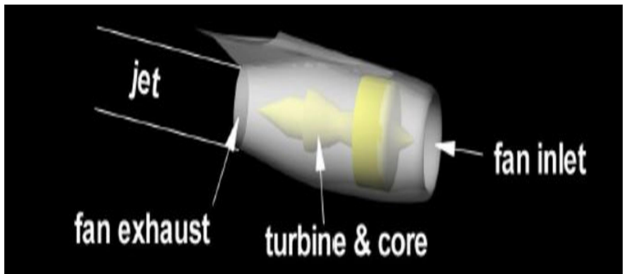


Fig. 3: Major noise sources from the engine [III]

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II. Design Methodology

The design process for this project is outlined in this paragraph. The geometries of all the nozzles studied were set out first. The standard nozzle is then analyzed using CFD and the findings are correlated with the available data from the literature review. After this, the chevron nozzles are numerically evaluated, and the data obtained compared to the reference nozzle. It is crucial that the jargon for the nozzles isclarified before proceeding to the next part. The nozzles mentioned here are likewise alluded to as the technique used during the SFNT process for their nomenclature [IV]. This research is referred to as the reference nozzle ' 3BB' The' 3' is the first of five boxes listed as simple settings during the SFNT process. The' 3' in 3BB. The first' B' indicates that there are no changes to the core nozzle and that no mixers have been introduced to guarantee that the core nozzle is the standard configuration. The second' B' is established differently but is the fan nozzle. The letters 'C' and 'F' would be used to signify that the chevrons on core and fan respectively [III].

For the following simulation the dimensions of the nozzles were chosen and modeled in CATIA V5 R20:

- Rolls Royce Engine Nozzle RB211: Exit Diameter 1200 mm with plug angle as 16° and inlet diameter as 900mm with plug angle as 14°, it is of 1500 mm long. It has 12 chevrons on the nozzle.

- CFM International CFM56: Exit diameter as 1200 mm with plug angle 90° and inlet diameter as 740 mm with plug angle as 5°, it is of 1500 mm long. It has 12 chevrons on the nozzle.

III. Geometry of Nozzles

A. RB211 Base Line Nozzle (3BB)

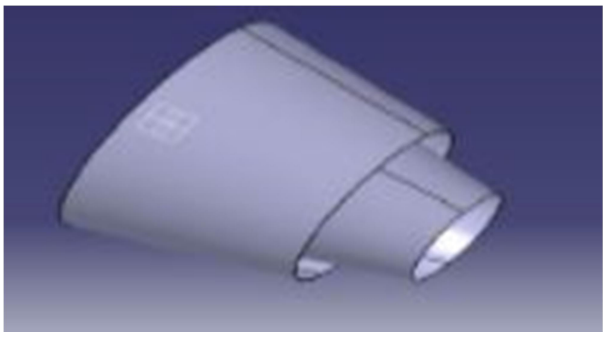


Fig. 4: RB211 Base Line Nozzle

Figure 4. displays the reference nozzle or the actual nozzle, for earlier turbofan engines this nozzle was used. It has a short transmission passage to occur. It simultaneously produces higher speeds and thrust and produces a higher level of acoustic power due to high turbulence at the exit.

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B. RB211 Nozzle with Chevrons on Core and Fan (3C12F12)

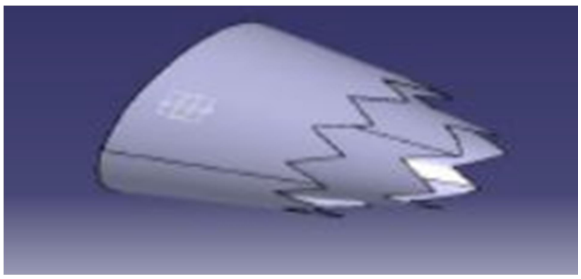


Fig. 5: RB211 Nozzle with chevrons

The chevron nozzle with a three-way design on the fan and middle is shown in Figure 5. A form of the chevron is often used with the turbofan engine in commercial aircraft. The acoustic strength with high thrust loss is reduced.

C. CFM 56 Base Line Nozzle (3BB)

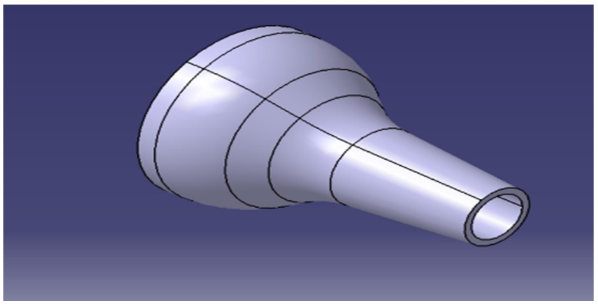


Fig. 6: CFM56 Base Line Nozzle

Figure 6 illustrates the CFM International reference nozzle, CFM56. In prior turbo fan generators, this nozzle was used. It has a longer transmission nozzle path. The high speed and thrust are generated concurrently and generate comparatively less acoustic energy than the 3BBR version by low distortion at the outlet.

D. CFM 56 Nozzle with Chevrons on Core (3C12)

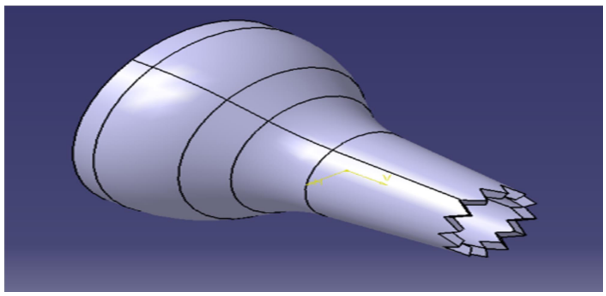


Fig. 7: CFM56 Nozzle with chevrons

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The nozzle with the triangular model is shown in Figure 7. Such kinds of chevron pins are commonly used with turbofans in commercial aircraft. The sound energy level is reduced by high thrust reduction.

1. Pre-Processing Setup

A. Meshing

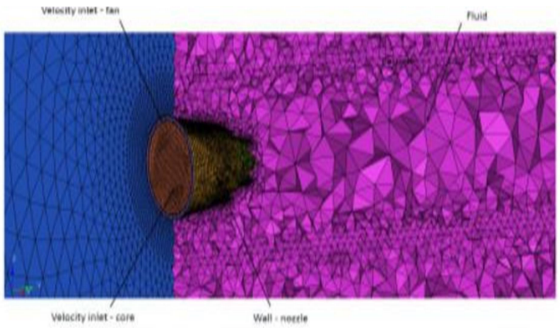


Fig. 8: Common Meshing for all the four Nozzles

The meshing for both these nozzles is chosen common to find out the results in an accurate way. The outer surface meshes with a 2D element Tria-Mesh, the inner surface meshes with 3D Element Quad-Mesh and a Penta Element mesh at the outerboundary layer of the nozzle. The common mesh is showed with the different types of elements and the different boundary conditions applied on the nozzle in figure X and Y respectively.

B. Boundary Conditions

The following boundary conditions were used for the simulation in ANSYS FLUENT

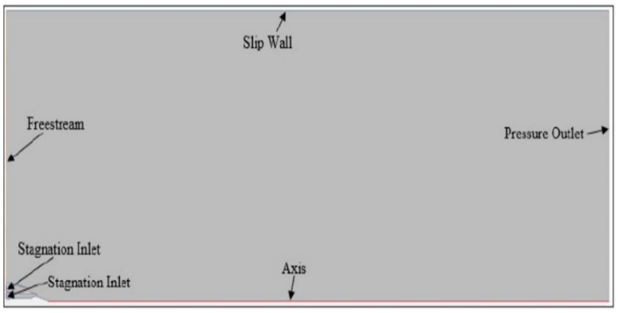


Fig. 9: Boundary Conditions [6]

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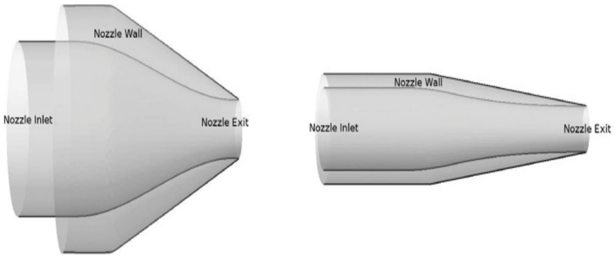


Fig. 10: The difference in the flow field in the nozzles considered

Table I: Boundary Conditions for CFD analysis

Parameter	Rolls Royce Engine RB211		CFM International CFM56
	Core Nozzle	Fan Nozzle	Core Nozzle
Total Pressure (atm)	1.65	1.80	1.65
Velocity (m/s)	270.85	363	272
Total Temperature (K)	833.3	333.3	843.3
Freestream Static Pressure (atm)	0.975		
Freestream Total Pressure (atm)	1.012		
Freestream Total Temperature (K)	300		
Freestream Mach Number	0.28		

II. Results

The expected visual results are assessed by acoustic power over the entire domain and velocity over the four types of nozzles. The analysis with different kinds of base models and chevrons in CFD software was carried out. And the results are taken as graphs and pictures and the comparison results are taken from the diagram below and the results are taken into consideration.

A. Velocity Magnitude

To begin with, the velocity magnitudes of the nozzles we have chosen the baseline nozzle of the RB211 without chevrons is chosen and the following result is obtained.

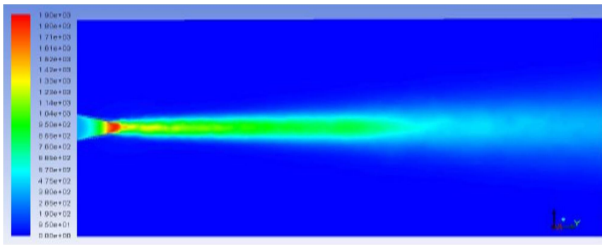


Fig. 11: Velocity contour of RB211 Base Line Nozzle

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The magnitude of a baseline nozzle in which the velocity level is high to some extent which is illustrated in figure 11, compared to the other four kinds of nozzle this is placed fourth in the velocity magnitude list. This has the maximum thrust loss even though there are core and fan present.

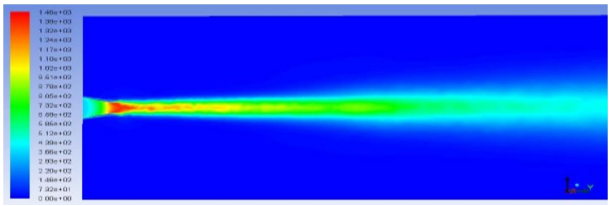


Fig. 12: Velocity contour of RB211 Chevron Nozzle

With the use of chevrons, the velocity magnitude of the RB211 has gone to a greater extent standing first in the velocity magnitude comparison as the core and fan have a dual power-producing capacity. It has the least thrust loss which is almost negligible.

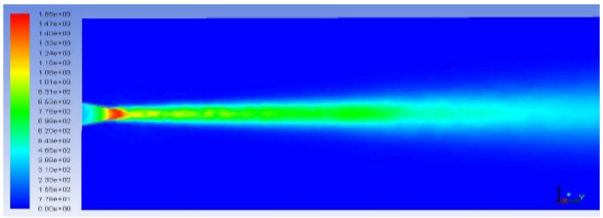


Fig. 13: Velocity contour of CFM56 Base Line Nozzle

The long-shaped nozzle of the CFM56 has increased its velocity range when compared with the RB211 baseline model. This result stands third in the list. The thrust loss is normal as it is the one commonly used.

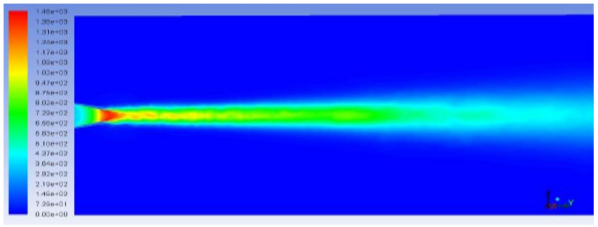


Fig. 14: Velocity contour of CFM56 Chevron Nozzle

The chevron up-gradation of the long shaped CFM56 nozzle has a long-range of the velocity magnitude but the uncertainty after some time duration is to be considered. The thrust loss is negligible, but it is more when compared to the chevron model of the RB211.

From the above results, we cannot conclude the effect of chevrons on the nozzles. In fact, the only conclusion that can be considered is that the chevron model of the

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RB211 is highly recommended for the aircraft with passengers as the thrust loss is minimal.

B. Acoustics Level

The sound intensity or acoustic power is the degree of absorption, eflectance, amplification, and accumulation of sound energy per system. The watt (W) is the SI sound power unit. The main characteristic of the aircraft is to maintain the least noise-producing capability so that the passengers feel comfortable in the airplane.

To start with the baseline nozzle of the Rolls Royce RB211 without chevrons is considered and the order is followed as the velocity magnitude.

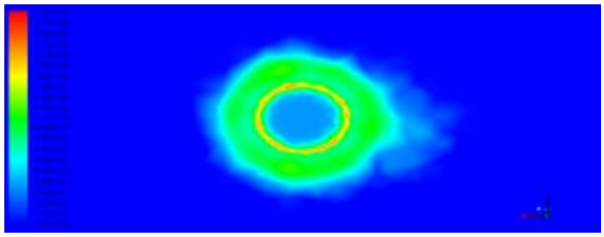


Fig. 15: Acoustics contour of RB211 Base Line Nozzle

The acoustic contour of the baseline nozzle is shown in Figure 15. The sound level shows a magnitude of 240 dB at the end of the nozzle of the RB211 baseline model. The level of noise is made without chevrons in the nozzle which is the highest among the nozzles we have considered.

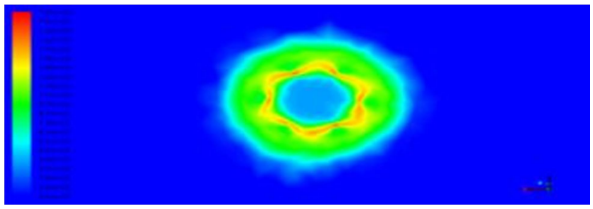
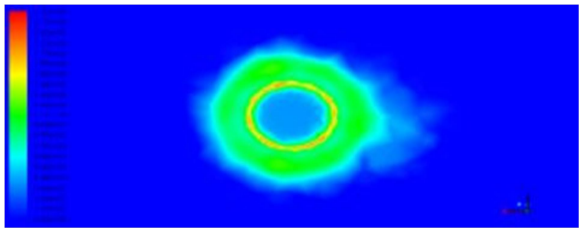


Fig. 16: Acoustics contour of RB211 Nozzle with chevrons

The acoustic contours of a chevron with a triangular design on fan and core are shown in Figure 16. below. At the end of the nozzle, it shows 190 dB of acoustic capacity. The noise level of the nozzle is decreased to about 50 dB as the frequency of the standard nozzle.



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Fig. 17. Acoustics contour of CFM56 Baseline Nozzle

The acoustic contour of the base nozzle is shown in Figure 17. At the top of the nozzle, the acoustic intensity is 232 dB. The sound level created by the nozzle is reduced to approximately 8 dB relative to the noise provided by the RB211 baseline.

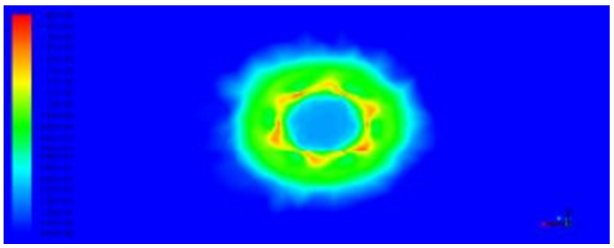


Fig. 18: Acoustics contour of CFM56 Chevron Nozzle

Figure 18 shows the acoustic contours of a chevron with a triangular core design of the CFM56 with chevrons on the core side. Underneath. It has an acoustic capacity of 205 dB at the end of the nozzle. As the frequency for the chevron nozzle RB211 with chevron, the noise level of the nozzle is lowered to about 27dB.

Acoustic strength throughout the whole field and velocity are the predicted visual effects among the four different types of combinations considered. The research was carried out for a nozzle with different types of chevron in the CFD application. The findings are taken as diagrams and photos, and the data are taken from the table seen below in the comparison chart and the conclusions.

Table II: Velocity values at the end of the exit of the nozzle

Type of Nozzle	At distance of 1500 mm the velocity (m/s)
RB211 Baseline Nozzle	1.23e3
RB211 Nozzle with Chevrons	1.61e3
CFM56 Baseline Nozzle	1.29e3
CFM56 Nozzle with Chevrons	1.52e3

It is clearly observed that the velocity magnitude selected at some certain points along the length of the nozzle in the four types of nozzles portrays that the graph follows a parabolic path with an increase in its velocity. The chevron nozzles of both RB211 and CFM56 have an upper hand in the good combustion of the air-fuel mixture and make the mixture to continuefor a greater distance without deviation in velocity. But, to differentiate between the RB211 and CFM56 chevron nozzle this parameter cannot be considered for declaring a conclusion.

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Table III: Acoustic Power Level at the exit of the nozzle

Type of Nozzle	Maximum acoustic power level (dB)
RB211 Baseline Nozzle	240
RB211 Nozzle with Chevrons	190
CFM56 Baseline Nozzle	232
CFM56 Nozzle with Chevrons	205

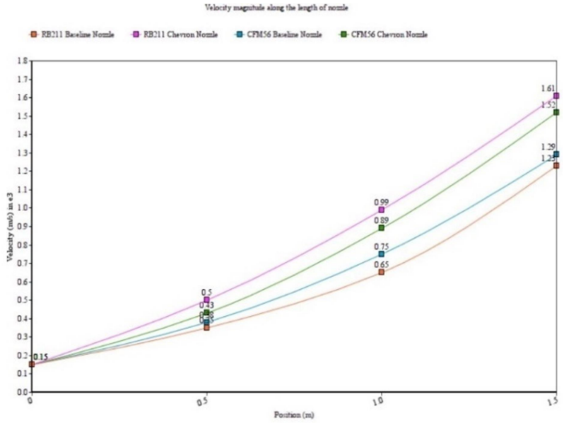


Fig. 18: Velocity magnitude along the length of the nozzle

The further analysis of this paper includes acoustics power (dB) in comparison with the four types of nozzles. The interesting fact of the introduction of chevrons to the nozzles is to reduce the intensity of sound produced. The same fundamental is applied with the proper basics of Fluid Dynamics.

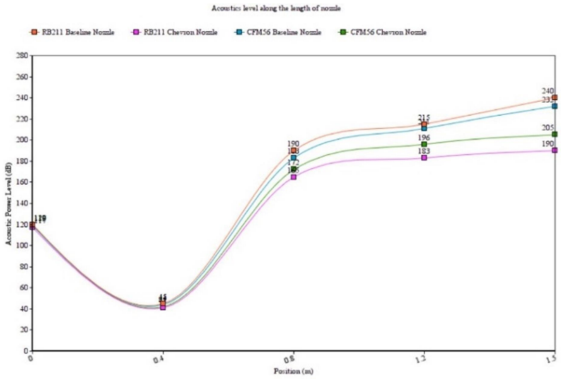


Fig. 19: Acoustic Power Level along the length of the nozzle

It is clearly observed that the nozzles with chevrons produce less intensity than the ones without the chevrons. To begin with, the RB211 with chevrons produces less sound intensity when compared with the others. The modification of the design in the

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nozzle has produced this effect. The double chevrons placed on the core and the fan have reduced the intensity which has an upper hand when compared with the chevron nozzle of the CFM56. The real-time flow analysis inthe RB211 chevron nozzle is shown below considering the superiority in the parameters among the others.

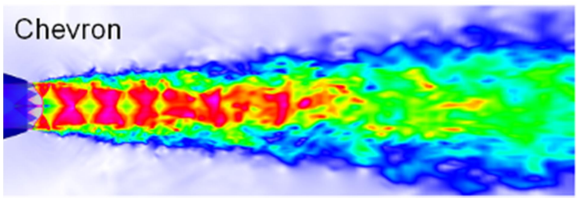


Fig. 20: Real-time flow capture of the RB211 nozzle

Conclusion

This paper deals with the use of two different types of nozzles of the Rolls Royce RB211 and the CFM International CFM56 jet engines. The velocity and acoustic factors of the nozzles are considered in this work. It is concluded that the modification of the RB211 baseline nozzle with chevrons on the core and fan of this nozzle is considered superior and the most affordable in terms of the sophisticated technological advancements.

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