

Aeroacoustic Analysis and Geometric Tuning Of Nozzle Tabs for Advanced Jet Noise Control In Aviation Propulsion Systems

Arun Kumar S¹, Hithesh Kumar V², Sivashankaran V³, Dr. A. R. Saravanan⁴

^{1, 2, 3}UG – Department of Aeronautical Engineering, Kalaignarkarunanidhi Institute of Technology, Coimbatore, Tamil Nadu, India.

⁴Associate Professor – Department of Aeronautical Engineering, Kalaignarkarunanidhi Institute of Technology, Coimbatore, Tamil Nadu, India.

Email ID: kit.26.22bae004@gmail.com¹, kit.26.22bae021@gmail.com², kit.26.22bae049@gmail.com³, arsaran1977@gmail.com⁴

Abstract

Jet noise generated from high-speed exhaust flows is a major concern in modern aviation due to environmental and regulatory constraints. This study focuses on aeroacoustic analysis and geometric optimization of nozzle tab configurations to reduce jet noise while maintaining aerodynamic performance. A baseline convergent nozzle and modified tabbed configurations with ± 5 mm penetration was designed and analyzed using Computational Fluid Dynamics (CFD) in ANSYS CFX. The study evaluates flow characteristics such as velocity distribution, pressure variation, temperature decay, and Mach number contours to understand mixing enhancement and noise reduction mechanisms. Results indicate that geometric tuning significantly affects shear-layer development, potential core length, and turbulence intensity. Increased mixing due to optimized tab geometry leads to faster jet decay and reduced shock-cell structures, which are responsible for broadband shock-associated noise. The findings demonstrate that passive control through nozzle tab modification is an effective method for improving aeroacoustic performance with minimal thrust penalty.

Keywords: Aeroacoustics; Jet noise; Nozzle tabs; CFD; Mixing enhancement

1. Introduction

Jet noise is one of the dominant contributors to aircraft noise, especially during take-off and landing. It is mainly generated due to turbulent mixing and shock-cell interactions in high-speed exhaust flows[1]. With increasing demand for high-performance propulsion systems, controlling jet noise without compromising efficiency has become a major research challenge. Passive flow control techniques such as tabs and chevrons are widely used to enhance mixing between jet exhaust and ambient air. These devices generate streamwise vortices that accelerate jet decay and reduce the potential core length, thereby reducing noise levels. This study focuses on analyzing the effect of nozzle tab geometry on jet mixing and aeroacoustic performance using CFD simulations[2]. The objective is to identify an optimized configuration that reduces noise while maintaining thrust efficiency[3].

1.1. Objective Of The Study

To analyze jet flow characteristics using CFD To study the effect of tab penetration on mixing. To evaluate aeroacoustic performance using flow parameters. To optimize geometry for noise reduction[4].

2. Method

This study follows a structured computational approach beginning with problem definition and literature review to identify research gaps. The geometry is designed and discretized through mesh generation, followed by CFD simulation setup with appropriate boundary conditions and turbulence models. Numerical simulations are executed to obtain flow field data, which is then used for aeroacoustic prediction. Finally, results are post-processed, analyzed, and comparatively evaluated to draw conclusions and provide recommendations Table 1.

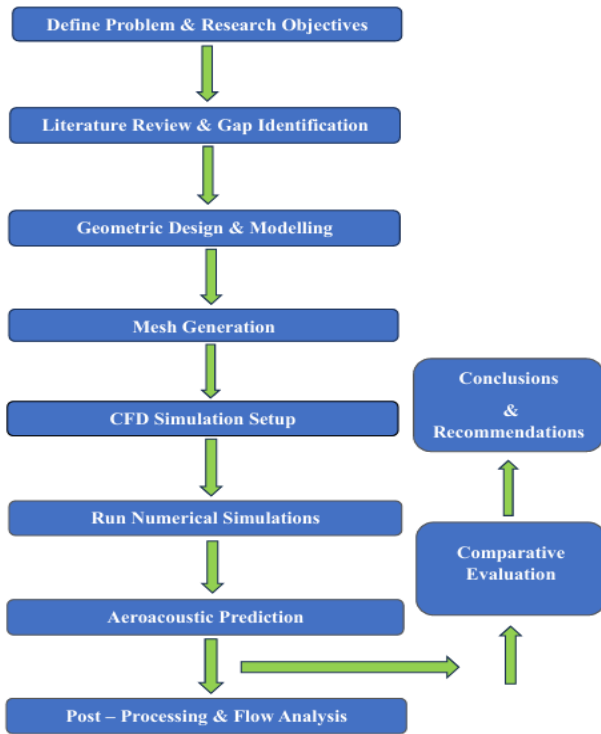


Figure 1 Jet Noise Control

2.1 Geometric Design

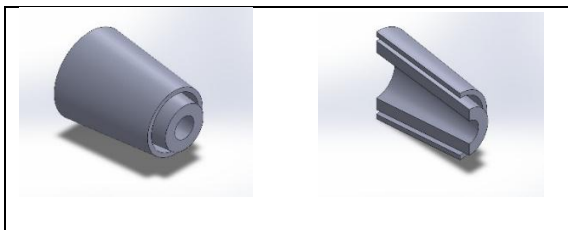


Figure 2 Jet Noise Control

To evaluate aeroacoustic performance using flow parameters. To optimize geometry for noise reduction Figure 1.

A convergent nozzle was designed with:

- Inlet diameter: 20 mm
- Outlet diameter: 10 mm
- Lip thickness: 5 mm

Two tab configurations were analyzed:

- -5 mm penetration
- +5 mm penetration

2.2 Mesh Generation

A high-resolution computational mesh was generated with a mesh size of 0.5 mm and an average mesh

density of 0.6 mm to ensure numerical accuracy. Local refinement was applied near critical regions, including the nozzle lip, shear layer, and jet core, to accurately capture steep gradients and flow features[5].

2.3 CFD Simulation Setup.

Simulations were conducted using ANSYS CFX, solving the compressible Navier–Stokes equations with $k-\epsilon$ and $k-\omega$ SST turbulence models. Boundary conditions included specified total pressure and temperature at the inlet, ambient pressure at the outlet, and no-slip conditions at the walls to ensure realistic flow behavior Figure 2.

2.4 Flow Conditions

- Mach numbers: 0.6 and 0.8
- Subsonic jet flow conditions

3. Results And Discussion

Table 1 Result

CONTOUR TYPE	SPECIFIC VARIABLE	UNIT	OBSERVED MAXIMUM RANGE VALUE	OBSERVED MINIMUM RANGE VALUE	SIGNIFICAN IN JET NOIS ANALYSIS [General]
Pressure Contour	Total Pressure (Po)	Pascals (Pa)	4.237×10^5 Pa	4.27×10^4 Pa	Indicates Stagnation Pressure Distribution; us to Identify Sho Cell Strength
Pressure Contour	Static Pressure (P)	Pascals (Pa)	3.960×10^5 Pa	2.314×10^4 Pa	Visualizes Sho Waves, Pressur Gradients and Relative Pressu
Temperature Contour	Static Temperature (T)	Kelvin (K)	2.887×10^2 K	1.282×10^2 K	Shows Local Thermal Conditions; Temperature drops Indicate Flow Expansio
Temperature Contour	Total Temperature (To)	Kelvin (K)	2.922×10^2 K	1.679×10^2 K	Represents Stagnation Temperature; Faster Decay Indicates Stron Mixing of Jet with Ambient Fluid
Density Contour	Density (ρ)	Kg/m ³	4.803 Kg/m ³	6.277×10^{-1} Kg/m ³	Shows Compressibilit Effects; Densit Gradients Correspond to Shock Waves
Mach Number Contour	Mach Number (M)	Dimensionless	2.496×10^2 m/s	1.000×10^{-15}	Identifies Sho Structure, Maci disc, Jet Core Length and Expansion Characteristics

3.2 Discussion

The results clearly show that geometric modification of nozzle tabs significantly improves jet mixing. Increased tab penetration enhances streamwise vortex formation, leading to:

Faster jet core decay, Increased turbulence, Reduced shock-cell structures, Improved entrainment Higher Mach number flows (0.8) showed better mixing

compared to lower Mach number (0.6). The contour analysis reveals a maximum velocity of approximately 566 m/s, with tabbed configurations exhibiting faster decay and a reduced potential core length, indicating enhanced mixing. Pressure contours (4.23×10^5 Pa to 4.27×10^4 Pa) and temperature distributions show significant energy dissipation and improved thermal mixing, especially with increased separation. Strong density gradients highlight compressibility effects, while Mach number variations (0 to ~ 2.49) indicate that shock structures are weakened in the modified designs, further confirming improved flow characteristics.

The results align with previous studies indicating that passive flow control is effective for aeroacoustic noise reduction.

Conclusion

This study demonstrates that geometric tuning of nozzle tabs plays a crucial role in controlling jet flow characteristics and reducing aeroacoustic noise.

Key findings:

Tabbed nozzles reduce potential core length. Mixing efficiency improves with increased penetration. Shock-cell structures weaken significantly. Higher Mach number enhances mixing. Overall, passive flow control using optimized nozzle tab geometry provides an effective solution for jet noise reduction with minimal performance loss.

Acknowledgements

The authors would like to thank KIT – Kalaignarkarunanidhi Institute of Technology for providing facilities and support for this project. Special thanks to the project supervisor for guidance and technical support.

References

- [1]. Bridges, J., & Brown, C. (2004). Parametric testing of chevrons on single flow hot jets. NASA TM.
- [2]. Zaman, K. B. M. Q. (2010). Evolution from Tabs to Chevron Technology.
- [3]. Mani, S. et al. (2015). Jet Acoustic Characterization and Geometry Optimization.
- [4]. Callender, B., Gutmark, E., & Martens, S. (2005). Chevron nozzle acoustic investigation.
- [5]. Calkins, F. T. et al. (2006). Variable geometry chevrons for jet noise reduction.