Amirkabir Journal of Mechanical Engineering

Amirkabir J. Mech. Eng., 54(7) (2022) 309-312
DOI: 10.22060/mej.2022.20701.7296

Acoustic Simulation of Hot and Cold Flow mixing by a Lobed Mixer in a High Bypass Ratio Turbofan Engine

S. Fazeli[1], R. Khoshkhoo[1]*, A. Khoeni Poorfar[2]

[1] Department of Mechanical Engineering, Malek Ashtar University of Technology, Tehran, Iran
[2] Maintenance Engineering Department, Mapna Turbine Engineering and Manufacturing Company (TOGA), Alborz, Iran

ABSTRACT: Noise reduction laws for turbofan engines require effective configurations to reduce jet engine noise. Lobed mixers are known to be effective for noise reduction in high bypass ratio turbofan engines. In this study, a mixture of hot and cold flow is simulated in a lobed mixer for a high bypass ratio turbofan engine. Navier-Stokes equations are considered three-dimensional, compressible, steady, and turbulent. To solve the turbulent flow, the turbulent model has been used; besides, to investigate the acoustic power, the Broadband noise source model was applied. In this research, first, the simulation method was validated and the results were compared with the experimental data of previous studies. Then, the impact of the lobed mixer was investigated on mixing hot and cold flow and noise reduction in a high-bypass ratio turbofan engine. The results of this study show that the maximum acoustic power was obtained at about 72 dB at a distance of 14 meters from the nozzle, decreasing by moving away from the engine nozzle; also, the maximum amount of acoustic power in the central body at nozzle exit has decreased from about 90 dB to 72 dB. The maximum acoustic power was observed at about 95 dB on the mixer surface next to the central body flow. Finally, we can conclude that a mixture of flow reduces the acoustic power and improves its uniformity at the nozzle exit while increasing the acoustic power near the central body.

Review History:

Received: Oct. 23, 2021
Revised: May, 30, 2022
Accepted: May, 31, 2022
Available Online: Jun. 21, 2022

Keywords:

Lobed Mixer
Turbofan Engine with High Bypass Ratio
Numerical Simulation
Acoustic

1- Introduction

A mixer is a device used in gas turbine engines to internally mix the hot core with the cold fan bypass. In commercial applications of mixing process can make a thrust increment. A two-dimensional schematic of a turbofan engine and its mixer and fan flow and core flow is shown in Fig. 1. [1].

The rate of mixing of the core and bypass exhaust flow in aircraft turbofan engines influences the extent of aerodynamically generated jet noise, thrust augmentation, specific fuel consumption, and the infrared radiation visibility of the engine [2].

In 2013, Gong [3] investigated a four-lobed mixer and one baseline confluent mixer in a computational study of the aerodynamic and aeroacoustic effect of an actual turbofan jet engine with the Lattice Boltzmann Method (LBM). The results showed that the boundary conditions and artificial forcing functions imposed at the inlet produced realistic turbulent kinetic energy levels downstream of the nozzle exit.

According to previous research on noise reduction, no research has been conducted on high bypass ratio turbofan mixers and lobed mixers, and the results of numerical simulation of flow mixing and acoustic flow in the nozzle exit have not been investigated. In this study, the geometries have a different number of mixer lobes. In this research, first, the numerical simulation method and acoustic results for a confluent mixer were numerically validated and then the flow mixing in the desired lobed mixer was simulated and

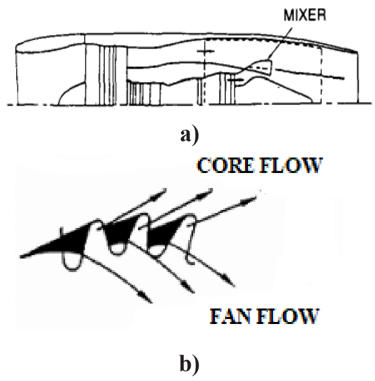
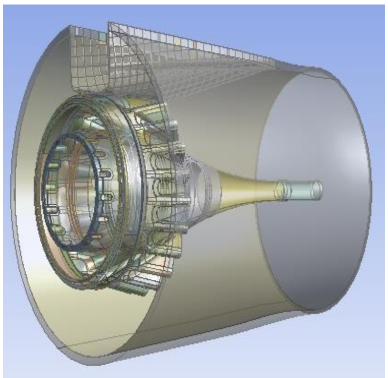
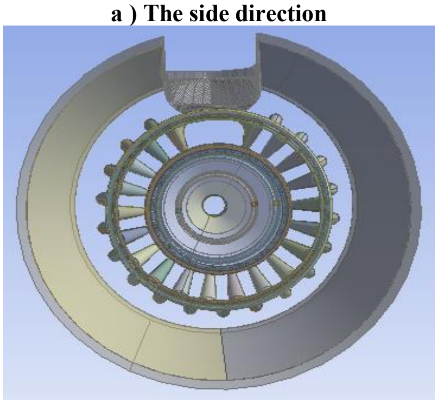


Fig. 1. a) Two-dimensional schematic of a turbofan engine and its mixer b) Axial flow motion in the side view of the mixer [1]

*Corresponding author's email: r.khoshkhoo@mut.ac.ir



a) The side direction



b) The front direction

Fig. 2. The desired geometry

Table 1. The initial condition of the desired mixer

	Unit	Fan exit	Core exit
Static temperature	K	319.9	814.87
Mass flow ratio	kg/s	403	69.309

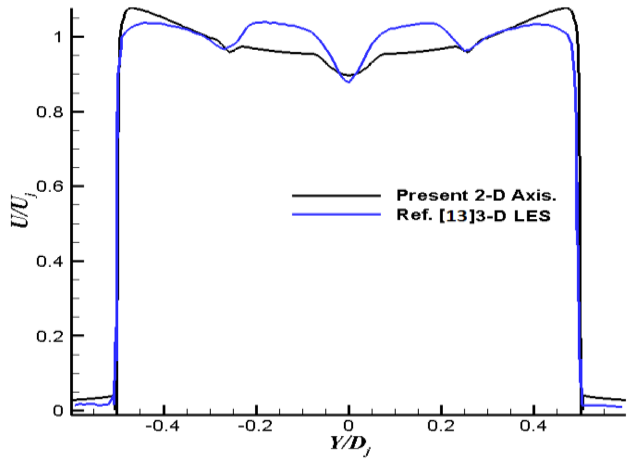


Fig. 3. Comparison of velocity profiles at the nozzle exit.

investigated.

2- Mixer Geometry and Initial Conditions

The mixer has 22 lobes and consists of three parts, the central body, the lobes, and the duct. The schematic of the mixer geometry is shown in Fig. 2. To perform the simulation, the geometry of the mixer was considered axial symmetric.

The input conditions of flow from the bypass ratio and the central body are shown in Table 1. The static pressure of the environment adjusts the engine's atmospheric pressure.

3- Validation

In this section, Gong results [3] have been used for validation. So, the geometric information of the confluent mixer was extracted from the reference [3] and then two-dimensional symmetrically simulated. The comparison between velocity profiles at nozzle exit with data Ref. [13] is showed in Fig. 3.

4- Results and Discussion

In this section, the acoustic results of the lobed mixer are analyzed. Fig. 4 shows the acoustic power in the central plate of the mixer. The amount of acoustic power in the bypass area is less than the amount of the central body and the amount of acoustic power with passing from the mixer decreases.

In Fig. 5, the diagram of the acoustic power distribution can be seen on the nozzle exit plate. It is visible that, the maximum acoustic power in the central body has been reduced from 90 dB to 72 dB.

5- Conclusions

In this research, the acoustic research of mixing hot core with the cold fan bypass by a mixer has been investigated. Ansys Fluent software was used for simulation. Also, Navier-Stokes equations are considered compressible, steady, three-dimensional, and turbulence. The k-ω SST turbulence model is used to solve the turbulent flow. First, the simulation results with the experimental data of others were validated, and then research was performed on the desired turbofan engine mixer. In this study, the effect of the mixer lobes on noise reduction has been investigated. The results show that by moving away from the engine nozzle, the amount of acoustic power decreases, also the amount of acoustic power in the bypass area is higher than the core, by mixing the two flows with the mixer, the amount of acoustic power decreases after the mixer and then with the passing of the flow from the nozzle, the amount of acoustic power near the core increases, which then with increasing distance radially or axially, the amount

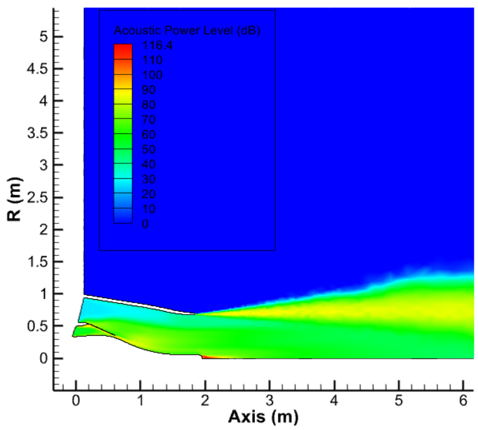


Fig. 4. Acoustic power in the middle plane

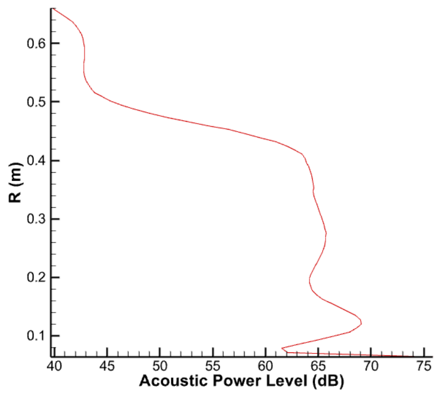


Fig. 5. Acoustic power distribution at the nozzle exit

of acoustic power decreases. The maximum acoustic power was observed on the surface of the mixer in the area close to the flow of the central body and about 95 dB. Finally, the combination of the two flows by the mixer reduces the acoustic power and its uniformity at the nozzle exit. Maximum acoustic power was obtained at a distance of 14 meters from the nozzle exit and at about 72 dB. The acoustic power was achieved at about 116 dB In front of the central body. Finally, the maximum acoustic power on the surface of the mixer was observed nearby the central body about 95 dB.

References

[1] T. Barber, G. Muller, S. Ramsay, E. Murman, Three-dimensional inviscid flow analysis of turbofan forced mixers, 23rd Aerospace Sciences Meeting, (1985).

[2] J. Brinkerhoff, H. Oria, M. Yaras, Experimental and computational study of mixing mechanisms in an axisymmetric lobed mixer. Journal of propulsion and power, 29(5) (2013) 1017-1030.

[3] H. Gong, Numerical Study of Jet Noise Generated by Turbofan Engine Nozzles Equipped with Internal Forced Lobed Mixers using the Lattice Boltzmann Method, MSc. Thesis, Department of Mechanical Engineering, McGill University, (2013).

HOW TO CITE THIS ARTICLE

S. Fazeli, R. Khoshkhoo, A. Khoeni Poorfar, Acoustic Simulation of Hot and Cold Flow mixing by a Lobed Mixer in a High Bypass Ratio Turbofan Engine , Amirkabir J. Mech Eng., 54(7) (2022) 309-312.

DOI: 10.22060/mej.2022.20701.7296