JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

TECHNOLOGICAL INNOVATIONS FOR NOISE REDUCTION IN TURBOFANS AND AIRFRAMES

[1]Rakesh Kumar Shah, [2]Dr. P. Karunakaran, [3]Sumit Pandit,[4] Nitesh Prasad Mandal, [5]Pradeep Kandel

[1,3,4,5] Final Year Students, Department of Aeronautical Engineering, [2]Professor, Department of Aeronautical Engineering
[1,2,3,4,5]Excel Engineering College (Anna University), Namakkal, Tamilnadu, India

Abstract: In this day and age, the pivotal hindrance for the advancement and growth of air transportation leftover is aircraft noise and still remains to be critical environmental issues that requires modern and improved solutions. Reducing aircraft noise is and will continue to be a key driver for the aviation industry. This paper depicts a review of current aircraft noises and technologies to reduce noise. To deal with these issues, aircraft manufacturers, airliners and government agencies are engaged in research on technical and theoretical approaches for noise reduction concepts that should be applied to new aircraft in order to meet today's demand, since noise pollution has become a matter of concern at present. In this paper, we briefly overview the noise reduction technologies that have great potential to be applied or implemented on turbofan engines and airframes. This paper focuses on selection of enabling technologies and their implications on noise reduction techniques, gives a perspective on future trends and new directions in aeroacoustics required to address the challenges.

Index Terms - **Aircraft noises, noise pollution, noise reduction, aeroacoustics etc.**

I. INTRODUCTION

Aircraft noise refers to cacophony produced by aircraft or its components whether on the ground while parked, taxing or during takeoff from jet exhaust and propellers as well as during the landing. Noise from aircraft during take-off and landing is a serious issue in the vicinity of airports. Various Organizations (ICAO, FAA etc.) have set harsh rules and regulations for maintaining noise standards encircling airports. These standards are expected to become even more strict in most parts all over the globe in the near foreseeable future. With the huge growth and advancement in aviation industry, it is expected to have an approximate increment in air traffic volume of 2.6 of its current status over next 25 years, thus there will be an increasing need and demand for noise attenuated aircraft that can produce very low-level noise. The major sources of noise in ancient aircraft were jet engines this is because they used to produce wide ranging noise during increasing output power for takeoff and landing.

However, the recent advancement of low noise technologies of jet engines has aided to achieve substantial noise reduction compared to the early jet engines. Recent aircraft with low-noise jet engines have markedly lowered overall airport noise levels. To reduce aircraft noise levels further, special attention must be devoted to aerodynamic noise by airframes (airframe noise), which begins to exceed engine noise as the pilot closes the engine throttle during approach procedures since this airframe noise is caused by the interaction of the unsteady and typically turbulent airflow with the aircraft structures. The sound radiated from the side edge of a partial-span flap is one of the major contributors to airframe noise during aircraft approach and landing. Therefore, the elimination of aircraft noises is the long-term goals of the aircraft manufacturers, industries, universities and government agencies.

II. LITERATURE SURVEY

2.1 Noise Sources of Turbofans

The most prominent and admired powerplant system incorporated in commercial aircraft is turbofan engines due to their high thrust and satisfactory fuel efficiency. In order to reduce noise from the dominant noise source of turbojet (i.e., fan and high-speed hot and cold jet) various control approaches have been developed and implemented. Some of the noise control approaches embrace active control, passive control (compromising acoustic boundary control) and geometric shape optimization.

The research and technological advancement made on the active control, passive control, and geometric shape optimization are reviewed and discussed, focusing to provide useful guidance on next-generation low-noise turbofan engines.

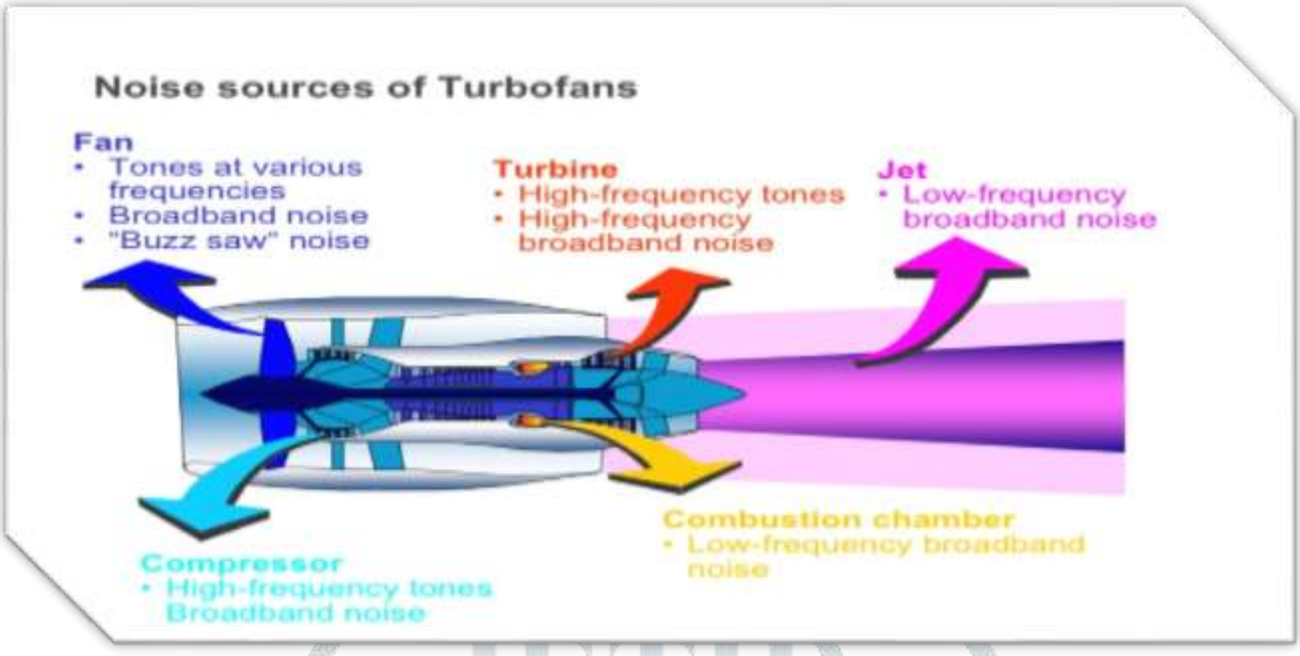


Fig1: Noise Sources of Turbofans

After in-depth study about airframe noise, it has been revealed that a large fraction of airframe noise comes mainly from high lift devices (Flaps and Slats) and Landing gear. Our ongoing challenge is to develop and verify the best optimized designs for high-lift devices and landing gear for passenger aircraft application based on our design methodology established till date.

2.1. Sources of Airframe Noise

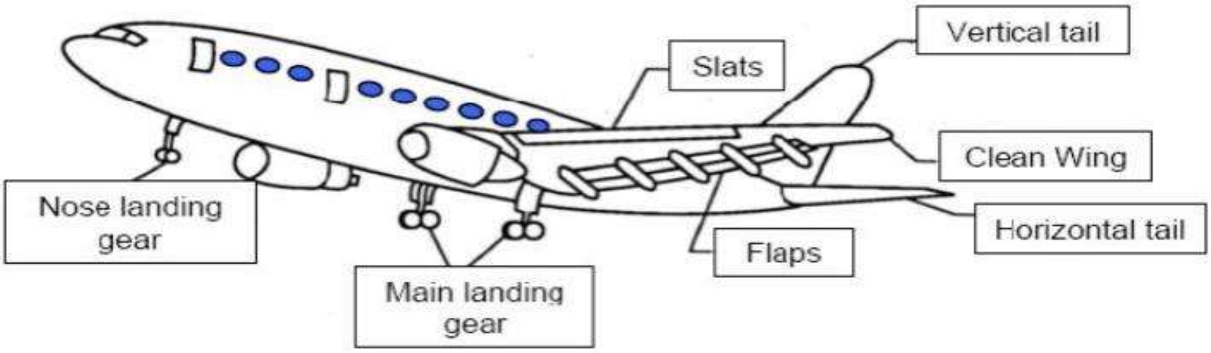


Fig2: Sources of Airframe Noise

Flaps are devices used to generate sufficient lift during slow flight (takeoff and landing). They extend from the trailing edge of the main wing. When flaps are deployed, strong vortexes are known to develop at the flap edge. Their turbulent flow causes aerodynamic noise at the flap edge.

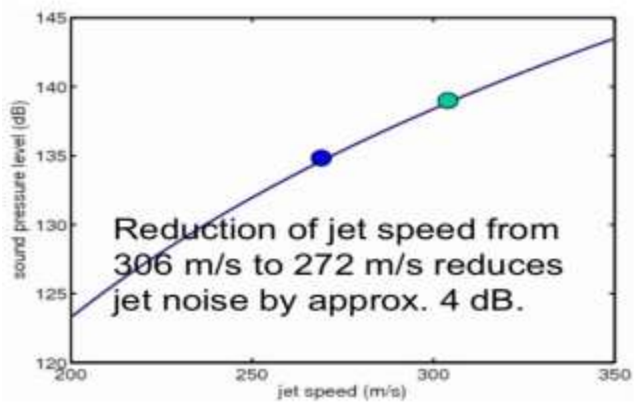
A slat is a similar device deployed from the leading edge. Although they generate higher lift without stalling, highly disturbed turbulent flow around them generates aerodynamic noise. Slat noise is generated from swirling shear flow inside the slat cove (the concave part of slat). The turbulent shear flow produces noise as it passes through the gap between the slat and the leading edge of the main wing. Although noise can be reduced substantially by eliminating the shear flow with a modified smooth profile of a slat, storing of the slat presents a mechanical problem that is difficult to solve. Consequently, many aircraft manufacturer companies are studying concepts to serrate the lower part of the slat (cusp) to break down the large-scale vortices in the shear layer which generate much of the noise.

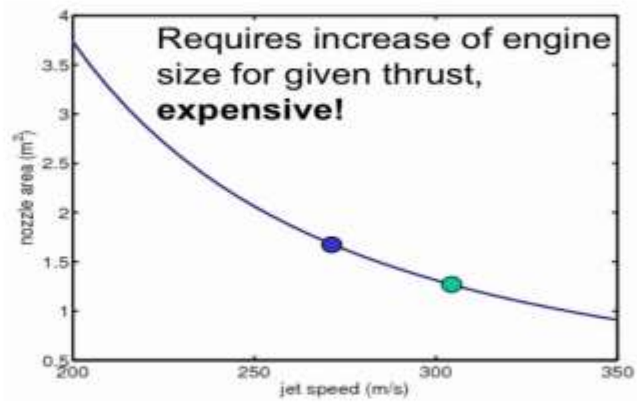
Similarly in case of the landing gear, noise is generated by highly vortical flow generated around very complicated geometries such as wheels, brakes, shock-absorbing structures, and hydraulic piping. Although covering such structures with a streamlined fairing can reduce noise effectively, it causes problems in cooling brake system.

III. CURRENT INNOVATION IN TURBOFAN ENGINE

There are mainly two noise sources in today's commercial turbofan engines: fan(compressor)noise and jet noise (also called as exhaust noise). But among these two, jet noise is the dominant one this is because it compromises of turbulent mixing noise and in the case of imperfectly expanded jets, shock noise. So, in order to solve the jet noise issues, many innovations and improvements have been made in turbofan engines such as:

1) Increase of By-pass ratio (mass flow in bypass over mass flow in core)
2) To be technically more precise: reduction of fan-pressure ratio, resulting in
   - ✓ Smaller jet speeds (see lower left)
   - ✓ Higher mass flows to maintain thrust (see lower right)





3)Relocation of fan guide vanes to position downstream of rotor.
4)Incorporation of forced mixer which increases thrust and reduces noise (Current Examples: Rolls Royce BR710, BR715 (Boeing 717).

Fig3: Rolls Royce BR700 Engine with Forced Mixer.

5)Increased number of stator vane count.
6)Increased distance between rotor and stator.
As a result of all these innovations and improvements in early turbofan engines, drastic changes have been seen in the current turbofans. Some of the models are shown below:

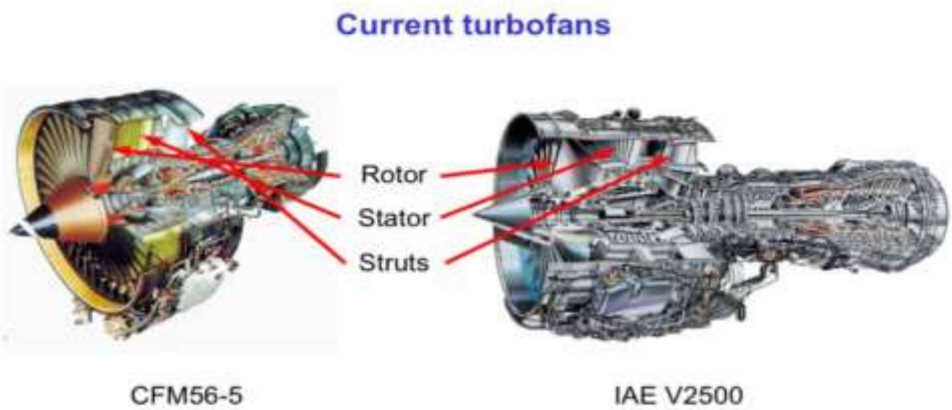


Fig4: Current turbofans

6)Reduction of tip Mach number of fan blades

Past	Mach number= 1.45	Airbus A340-500/600 (Trent 500)
Present	Mach number=1.28	Airbus A380 (Trent 900, GP7200)
Future	Mach number=1.15	Boeing 787 (Trent 1000)

7)Serrated nozzles (Chevrons) improves mixing between hot core-flow (inner nozzle) and cold bypass flow (outer nozzle) and aids for reduction of cabin noise on cruise.
8)Improvement of Acoustic liners (passive acoustic liners reduces sound emission of internal sound sources by up to 18 dB).
Similarly, for the reduction of airframe noise various innovations are also incorporated such as replacement of slats by drooped leading edges on part of wing (also results in better climb performance), eliminating of cavity tones since cavity tones are the loudest sound sources during the approach of some aircraft.

IV. PROPOSED DESIGN PHILOSOPHY

After a thorough study and detailed examination about aircraft noise and its main sources (turbofan engines and airframe as discussed in this paper) we came to a conclusion that various components need to be designed and improved in order to reduce noise produced from turbofan engines and airframes.

- The first one is deploying a fan flow deflector which is specially designed with the purpose to keep the exhaust coaxial but deflect the secondary (fan) flow through vanes or similar devices in the secondary flow path. It is mainly incorporated for reducing convective Mach number of turbulent eddies that generate intense downward and sideward sound radiation. The deflectors thicken the low-speed flow underneath the core jet, resulting in lower noise emission towards the ground.
- Similarly, another technology that can make significant contribution for noise reduction is Active noise control. It's working principle is just to produce a sound field that is exactly the mirror image of the offending sound. Hence, active noise cancels out the disturbance with the net result of significantly reduced sound.
- Combining Chevrons and Microjet together so as to use simultaneously. The combination of these methods is more beneficial than each method alone this is because of its unique feature of applying micro jets to the shear layer at the tip of chevrons.
- In the main landing gear, a porous cover to decelerate the airflow around the noise source between the wheels and its supporting frames can be designed and installed. Similarly, deflectors for the landing gear bay can also be applied along with landing gear mesh fairings.
- Porous devices along with flap edge noise reduction fins can be applied at the edge of flaps and tip of an aircraft flap so as to reduce flap side edge noise and airframe noise.
- Measures such as width reduction of slat gap can be implemented to reduce slat noise, further increasing of By-pass ratio.
- Developing Ultra high Bypass ratio fan with Gearbox and counter rotating fan as shown in the figure below.

Fig: Counter Rotating open rotor engine

V.CONCLUSION

In this paper, we have discussed and analyzed the major principles involved in the jet noise and airframe noise production. We have also reviewed about various measures and innovations that have been done over the period for reducing airframe noise and exhaust noise. Some of the examples of the technology that has been presented here are chevrons, increasing by-pass ratio, incorporating greater number of stator vane count, increasing distance between rotor and stator etc. Thus, we believe that the work done in this paper will be particularly useful for the students, researchers to understand about reasons of aircraft noise production and also aid the researchers to incorporate modern innovative ideas for further reduction of aircraft noises.

VI.ACKNOWLEDGMENT

This paper become a reality with the kind support and help of many individuals, we would like to extend our sincere thanks to all of them. First and foremost, we want to offer this endeavor to our GOD Almighty for the wisdom he bestowed upon us, the strength, peace of mind and good health in order to finish this research. We would like to express our gratitude towards our family for the encouragement which helped us in completion of this paper. We are highly indebted to Excel Engineering College, Department of Aeronautical Engineering and Head of the Department along with the faculty members for their guidance and constant supervision as well as for providing necessary information regarding this research & also for their support in completing this endeavor.
We would like to express our special gratitude and thanks to our adviser, Dr.P. Karunakaran for imparting his knowledge and expertise in this study.
We would like to thank and appreciate our colleague Habib Dhuniya, Ajay Kumar Yadav and people who have willingly helped us out with their abilities.

VII.AUTHOR'S PROFILE

1)Mr. Rakesh Kumar Shah, currently pursuing Final year of Aeronautical Engineering at Excel Engineering College, Tamil Nadu, India. Has presented papers at many National level symposium and seminars, also published research paper on Wing morphing and Water scooping mechanism for Fire- fighting Aircraft. Research interest includes Aerodynamics, Propulsion, Aircraft Model designing (RCs and UAVs).
Contact: rakeshkumarshah70@gmail.com

2)Dr.P. Karunakaran, Professor in department of Aeronautical Engineering. Pursuing research in the field of Industrial Aerodynamics. Having more than 25 years of teaching experience in Aeronautical Engineering. Published more than 25 papers in conferences and journals. Also, into the research in wind tunnel analysis, materials science and manufacturing technology.
Contact: pkarunakaran.eec@excelcolleges.com

3)Mr. Sumit Pandit, currently pursuing final year of Aeronautical Engineering at Excel Engineering College, Tamilnadu, India. Has presented many papers in national level seminars and workshops. Core research interest includes aircraft designing and propulsion systems, designing software (Solid works, Catia).
Contact: sumeetpal107@gmail.com

4)Mr. Nitesh Prasad Mandal, currently pursuing final year of Aeronautical Engineering at Excel Engineering College, Tamilnadu, India. Has presented many papers in national level seminars and workshops. Research interest includes Propulsion, Aerodynamics, Structural Integration of the Aircraft and Aircraft modelling (RCs and UAVs). Also, into the research of Jet Engine optimizations.
Contact: npmandal68@gmail.com

5)Mr. Pradeep Kandel, currently pursuing Final year of Aeronautical Engineering at Excel Engineering College, Tamilnadu, India. Has presented many papers in national level seminars and workshops and, also published research paper on Water scooping mechanism for Fire- fighting Aircraft. Research interest includes Structural Integration of the Aircraft and Aircraft designing (RCs and UAVs). Also, into the research of nozzles, turbines and compressors.

Contact: pkandel056@gmail.com

VII. References

1. Papamoschou, D. 2006. Fan flow deflection in simulated turbofan exhaust, AIAA Journal 44(12): 3088–3097. http://dx.doi.org/10.2514/1.22552

2. Papamoschou, D.; Debiasi, M. 1999. Noise measurements in supersonic jets treated with the Mach wave elimination method, AIAA 37(2): 154–160. http://dx.doi.org/10.2514/2.702
3. R.E. Gillian: Aircraft Noise Prediction Program User’s Manual, NASA Langley Re-search Center, 1982
4. C. Burley, L. Lopez: ANOPP2: Progress Update, NASA Spring Acoustics Technical Working Group, presentation, April 21-22 2011, Cleveland, OH.
5. L. Bertsch: Noise Prediction within Conceptual Aircraft Design, DLR Forschungs-bericht, ISRN DLR-FB–2013-20, 2013.

6. ICAO (2004) Environment protection. Vol.1: aircraft noise—specifications for aircraft noise certification, noise monitoring, and noise exposure units for land use planning.

   Available on http://www.icao.int
7. NASA Press Release https://www.nasa.gov/press-release/nasa-technologies-significantly-reduce-aircraft-noise

8. Kannepalli C, Kenzakowski DC, Dash SM (2003) Evaluation of Some Recent Jet Noise Reduction Concepts. Paper No. AIAA-2003-3313, 9th AIAA/CEAS Aeroacoustics Conference & Exhibit, Hilton Head, SC

9. Aircraft Fan Noise Reduction Technology Using Leaned Stator Blades Available on: https://doi.org/10.1016/j.proeng.2015.06.047

10. ResearchGate

    Available on: https://www.researchgate.net/publication/274587628_Aircraft_Noise_The_major_sources_modelling_capabilities_and_reduction_possibilities

11. Turbo jet engine nozzle design optimization to reduce noise – IOPscience Available on: https://iopscience.iop.org

12. Jet Noise Reduction of Turbofan Engine by Notched Nozzle Available on: http://www.sea-acustica.es
13. JAXA website Available on: https://www.aero.jaxa.jp/eng/research/frontier/feather/

14. Prasad, C.; Morris, P. A study of noise reduction mechanisms of jets with fluid inserts. J. Sound Vib. 2020, 476, 115331.
.
15. Birch, N.; Webster, J. Gas Turbine Engine Exhaust Nozzle Having a Noise Attenuation Device Driven by Shape Memory Material Actuators. US. Patent 6813877B2, 11 September 2004. Available online: https://patents.google.com/patent/US6813877