American Journal of Science, Engineering and Technology
2020; 5(1): 33-41
http://www.sciencepublishinggroup.com/j/ajset
doi: 10.11648/j.ajset.20200501.14
ISSN: 2578-8345 (Print); ISSN: 2578-8353 (Online)

Review Article

Investigation All Types of Aircraft Noises: Review Paper

Mojtaba Sadeghian[1, *], Mofid Gorji-Bandpy[2]

[1]School of Mechanical Engineering, Babol Noshirvani University of Technology, Babol, Iran

[2]Faculty of Mechanical Engineering, Noshirvani University of Technology, Babol, Iran

Email address:

m.sadeghian@nit.ac.ir (M. Sadeghian), gorji@nit.ac.ir (M. Gorji-Bandpy)

[*]Corresponding author

To cite this article:

Mojtaba Sadeghian, Mofid Gorji-Bandpy. Investigation All Types of Aircraft Noises: Review Paper. *American Journal of Science, Engineering and Technology*. Vol. 5, No. 1, 2020, pp. 33-41. doi: 10.11648/j.ajset.20200501.14

Received: January 8, 2020; **Accepted**: March 2, 2020; **Published**: March 10, 2020

Abstract: This article presents a review of current aircraft noises. Noise is a fascinating area of research combining statistics, applied mathematics, and engineering. Aircraft noises are an impact of enormous financial, environmental, and technological issue. Aircraft noise remains the key inhibitor of the growth of air transportation and remains an acute environmental problem that requires advanced solutions. To advance our understanding of the sound source mechanisms, it should be noted that predominant noise sources of aircraft engines are from the exhaust (referred to as the jet) and fan (including the stator). The noise generated in these two areas during takeoff and landing has a strong influence on the communities around the airports. One of the most important sources of aircraft noises in modern jet aircraft is the turbulence that occurs in the shear layers around the engine's exhaust. But this is not just an academic issue also jet noise is highly relevant to the aviation industry and on a wider scale, has been related to economic, social, and subsequently political. To deal with this problem, aircraft manufacturers and public establishments are engaged in research on technical and theoretical approaches for noise reduction concepts that should be applied to new aircraft. This review paper discusses a selection of enabling technologies and their implications on acoustics and noise and gives a perspective on future trends and new directions in aeroacoustics required to address the challenges.

Keywords: Aircraft Noise, Landing Gear Noise, Technology Trends, Aero Acoustics, Airframe Noise, Fan Noise, Jet Noise

1. Introduction

Aircraft noise is a major concern for those living near large airport. With the increase in air traffic, it also affects the growing number of people living near busy airports. When an aircraft gets to fly it produces friction and turbulence that causes sound waves. In general, as the faster flight of the aircraft becomes more turbulent and friction will occurs. As long as the flaps and landing gear of aircraft are used, more noise is created because more drag is being generated. The quantity of noise which is generated can be different according to the way the plane is flying. Turbine and Compressor noise results from the interaction of pressure fields and turbulence for rotating blades and fixed vanes. However, low landing-approach thrusts cause a drop in exhaust jet noise and an increase in low pressure compressor and turbine noise due to greater internal power handling. The introduction of a single stage low pressure compressor significantly reduces the compressor noise because the overall turbulence and interaction levels are diminished. Another source of noise is the combustion chamber which is located inside the engine. However, due to being buried in the engine core, it does not have dominated influence.

The significant noise sources originate in the compressor or fan, the exhaust jet and the turbine. Noise generation of these components increases with higher relative velocity of airflow. The volume of Exhaust jet noise varies by a larger factor than those of the compressor and turbine.

The exhaust jet noise has the significant part of the noise in comparison with compressor or turbine, so reducing it has a profound effect than a similar reduction in above mentioned.

The noise generated by the airframe is a factor of several parameters affecting the noise level of aircraft; the main source of noise is in the engine.

Jet exhaust noise is generated when a mixture of produced gases with a turbulent cases are being released that also being affected by the shearing action due to the relative velocity between the exhaust jet and the atmosphere. One of the most important sources of aircraft noise in modern jet aircraft is the turbulence that occurs in the shear layers surrounding the engine‘s exhaust. For the separate flow exhaust designs common on large commercial aircraft there are two such shear layers generating noise, the inner and outer shear layers. The inner shear layer is the layer between the primary, or core flow, and the secondary, or fan flow. The outer shear layer lies between the secondary flow and the free stream.

The turbulence which is generated near the exhaust exit is the reason of high frequency noise (small eddies) and more at the lower exhaust, turbulence makes low frequency noise (large eddies). Also, a shock wave is created as the exhaust velocity exceed the velocity of sound The noise of the compressor and the turbine is due to the interaction of pressure and turbulence fields for rotary blades and fixed vanes. In the jet engine, the exhaust jet noise is of a high level that the turbine and compressor noise is negligible in most operating conditions. However, low landing gears reduce exhaust jet noise and low pressure compressor and turbine noise will be increased for the cause of internal power.

Aircraft manufacturers and aircraft engines face the technical challenge of making aircraft simultaneously quieter, more efficient and more powerful.

The primary aim of the present paper is to provide a review on the main noises of aircrafts.

2. Types of Noises

2.1. Airframe Noise

In the early 1970s Research into airframe noise reduction and prediction was started. This investigation was done by Crighton [1]. Crighton defined airframe noise as the non-propulsive noise of an aircraft in flight and includes the noise of a glider. The empirical data recorded on aircraft noise assisted in the formulation of an experimental airframe noise prediction method published by Fink [2]. Airframe noise is defined as the noise generated as a result of the airframe moving through the air. The main components of airframe that lead to airframe noise generation are high lift devices and landing gears. in 1970s Some initial airframe noise studies were carried out [3], and reference [4] provides a good summary of this airframe noise research work. During the 1980s, a lack of funding for research on airframe noise caused the technology to remain at the 1970s level. In the 1990s, research about an airframe noise has been kept on again in the USA where analytical and experimental works were conducted effort between NASA and the aircraft industry. Noise testing was performed on scaled aircraft models and adequate noise localization techniques were developed [5, 6]. An airframe noise occurs when air passes over the plane’s body and it wings. This cusses friction and turbulence, and make noise. Even gliders make a noise when in flight and they have no engines at all. Planes land with their flaps down and their landing gear deployed. This creates more friction, and produces more noise, than when the flaps are up and the landing gear is stowed. The aerodynamic noise which is created by all the non-propulsive components of an aircraft is classified as airframe noise. For advanced high-bypass engine powered commercial aircraft, the airframe noise has the major role in the overall amount of flight noise levels during landing approach stages, when the high-lift devices and the landing-gear are ready to be used. Five main mechanisms are known to significantly contribute airframe noise: (i) the landing-gear multi-scale vortex dynamics and the consequent multi-frequency unsteady force applied to the gear components, (ii) the flow unsteadiness in the recirculation bubble behind the slat leading-edge, (iii) the vortex shedding from slat/main-body trailing-edges and the possible gap tone excitation through nonlinear coupling in the slat/flap coves, (iv) the roll-up vortex at the flap side edge, (v) the wing trailing-edge scattering of boundary-layer turbulent kinetic energy into acoustic energy. Since the Seventies most of these mechanisms have been addressed both empirically and theoretically. Aerodynamic noise which is created from airframe components identified as a most important contributor to commercial aircraft noise emissions. The intense regulatory context governing civil aviation has caused of research in optimize of noise generated by airframe and other aircraft components in large amount. Adaptive techniques and Flow control are two possible solutions for noise reduction, when other methods are not effective. Such unconventional techniques include boundary layer excitation, exploitation of cavity resonance effects and flow distortion in airframe components. It was triggered by this US initiative and the intended extension of a very large aircraft; in 1995 Airbus industry was volunteer for sponsoring two airframe noise related research projects. These include the full scale noise testing of the landing gears and scaled aircraft model high lift devices in wind tunnel [7, 8]. Dobrzynski W, et. al, in 1998 worked in results of initial and basic experiments conducted on a model scale high-lift wing-section in DLR’s AWB provided detailed information on source noise characteristics, led to a better understanding of the dominating mechanisms on slats or flaps and revealed perspectives for noise reduction [9]. Werner Dobrzynski, et al in 2001, Since airframe noise has become a significant contributor to the overall radiated noise from commercial aircraft during landing approach, a research project was initiated to investigate the noise of wing HLD, known to represent one major source of airframe noise. Noise source studies where performed on both a 1/7.5 scaled complete model and an A320 full scale wing section, employing far field microphones and source localization techniques, to quantify airframe noise levels and identify the major aero acoustic sources. Potential source areas were instrumented with unsteady pressure sensors to study local source characteristics in detail [10].

In 1999 Leung Choi Cho and Pierre Lempereurn announced a brief description of research project which took them for three years, ‘reduction of airframe and installation noise (RAIN) [11].

Figure 1. *Sources of noise on a typical wing.*

2.2. Trailing-edge Noise

The main source of airframe noise is achieved by wing trailing-edge noise. A solid surface immersed in a turbulent flow has a dual effect on the radiated acoustic field. On one hand, it affects the structure of the flow field and consequently of the aeroacoustic sources. On the other hand, it constitutes an acoustic impedance discontinuity which affects the scattering of the acoustic waves. The noise from a trailing edge is a singular problem for which a wrong separation of these two effects can lead to wrong theoretical conclusion.

A trailing edge in a fluctuating flow felid generates an unsteady vertical wake. This phenomenon can be considered as an unsteady boundary-layer separation due to fluid viscosity. An inviscid model of the vortex shedding process involves in prescribing an edge condition. Since the vortex shedding smears the singular behavior of the flow at trailing edge.

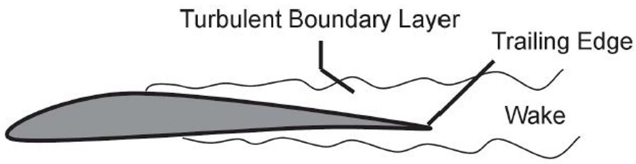

Figure 2. *Trailing-edge noise.*

2.3. Flap Noise

It's too long that flap side edge flows have been recognized as important factor in airframe noise. Vertical flow around the side edge of a deployed flap is one of the most effective sources of airframe noise at landing and takeoff conditions. Additionally, vortex breakdown at high flap angles is observed as an additional noise source mechanism.

The noise source mechanisms are the cause of the vortex structure of the cross flows in the flap side edge region [12–16]. This concept has caused the concepts for noise mitigation like flap side edge fences, seeking to reform the properties of the vortex structure in a desirable approach to reduce the noise from these currents. While there are difficulties in the use of this concept in real aircraft, such as the cost and added weight, its effectiveness in reducing noise –associated with flap has been shown to be very clear [17, 19]. These successful demonstrations include both simplified flaps and realistic aircraft configurations. Typically, side edge fences can reduce noise by up to 4 dB in the middle to high frequency domain in which flaps are known to be major noise sources.

It has been proved in wind tunnel experiments that the fences only alter the local flows in that the overall lift characteristics of the flaps and the high lift systems is not influenced by the fences in any significant way [18]. The vortex structure in the cross flow will be appeared in the surface pressures in the form of distinct spectral humps [20]. In 2003 Yueping Guo shows that reduction of flap-related noise by shifting the source spectra downward in frequency can be achieved. Analytical prediction for the frequency change has been given and has been shown to agree with data quite satisfactorily. It should be noted that with the weakness of the source current, fences might also reduce noise [21].

Figure 3. *Flap of the wing.*

2.4. Landing Gear Noise

The noise from the airframe, of which landing gear noise is an important part, is equal to the noise of engine. There are several methods have been used to predict landing gear noise, but none have been applied to predict the change in noise due to a change in design of landing gear. For many types of aircraft which are used nowadays, the main landing gear is located under the wing and usually aligned with the inboard tip of the deflected flap. As such, the turbulent wake of the main gear typically affects on the flap side edge at the inboard tip. Previous studies of aeroacoustic (flight tests and model scale experiments) have shown that the aircraft landing gear and high-lift devices such as slats and flaps to be the most prominent sources airframe noise [22-26].

The landing gear represents an important challenge Due to the non-uniform under the wing [27] and complex landing gear geometries with small-scale details that affect the high frequency noise [28]. Interactions between the landing gear wake and the system also involved in the complex noise signature [29]. Interactions is difficult to predict because the magnitude and turbulence intensity of the landing gear wake is difficult to measure [30] or calculate [31] due to the wake's dependence on landing gear geometry, wind-tunnel and measurement technique, grid resolution, Reynolds number effects, and turbulence model. It is important to note that each component of landing gear, such as the oleo, is not represented by a single acoustic source.

Figure 4. *Landing gear.*

2.5. Fan Noise

Reduction of fan noise radiation to the far field can be followed by five general concepts: (i) reducing the interaction mechanisms between an optimal design of the rotor blades and the stator vanes, or to reduces the velocity deficit in the rotor wakes with the flow control techniques, (ii) reduce the aerodynamic response to an impinging gust by tuning of the stator cascade parameters in order to, (iii) to drive only few propagating (cut-on) duct modes by tuning of the rotor blades and stator vanes numbers, (iv) use of passive/active duct wall treatments in order to reduce noise during transmitting from the duct, (v) manipulation of sound diffraction mechanism in exhaust nozzle and at the inlet lip through advanced nacelle devices. Since the first two noise mitigation concepts requires analytical models that highlight the mutual influence of all the design parameters.

In turbofan aero-engines, noise is created by the interaction between flow non-uniformities and stator vanes and rotating bladed. In modern high-bypass-ratio turbofans, the noise generated by the fan system has the main role than the one generated by the turbine stages and the compressor. Since there is connection between the duct acoustic modes and aero acoustic excitation mechanisms.

Through the duct under the condition, at supersonic blade tip, the rotor-locked shock wave system makes propagative several pure tones at rotational shaft harmonics frequency, the so called “buzz-saw” noise.

Fan noise is a powerful performance of the fan pressure ratio and rotational tip speed. The reliable approach to reduce fan noise is to mitigate the pressure ratio and tip speed, but this will increase the engine diameter to recover thrust. Optimization examinations demonstrate that the best fan speed for takeoff is where the rotational tip speed is just below Mach = 1 to eradicate shock induced noise. After achieving this engine design; the fan pressure ratio becomes the controlling factor for broadband noise. Reducing pressure ratio and fan tip speed, reduce the number of noise sources, which makes noise reduction design features more effective [32]. European Brite-Euram project called RESOUND (Reduction of Engine Source Noise through Understanding and Novel Design) was launched in 1998. A task of this project was dedicated to laboratory experiments relative to passive/ active design [33].

Currently active noise control approach (ANC) that has been studied by many authors [34–40]. The use of the well-known concept of noise reduction in fan noise involves of attempting to cancel the interaction modes by generating the identical out-of-phase spinning modes. Typical ANC studies are generally based on two possibilities: (1) as active sources use of flush-mounted loudspeakers; (2) the active source is an airfoil equipped with actuators (active airfoil). Using a sophisticated experimental set-up shows the capability of these ANC techniques to the noise reduction. Unfortunately, because of weight, applications to turbofans are not straightforward, complexity of such devices and aerodynamic penalties.

Figure 5. *Ryanair Boeing 737-800 EI-FRB.*

2.6. Duct Flow

The fan noise can be reduced effectively by the use of the equipment of an optimally designed acoustic liner in the engine nozzle. To this end, some design challenges must be addressed, including the choice of acoustic liner material and layer structure. To reduce noise within the turbofan bypass duct, the use of acoustic liners is already common, and it is usual practice to consider the effect of liner configuration as a noise reduction measure. The basic idea of the shape optimization is to minimize the far-field acoustic radiation by controlling the geometry of an engine duct. The embedded propulsion system allows smaller engine diameter and thus increased non-dimensional (length/diameter) duct length. The longer inlet and exit ducts causes engine noise reduction by allowing additional acoustic liners, compared to ordinary nacelles, to absorb the engine noise. Another promising technique for fan noise reduction is to increase the acoustic treatment area on the tip of the rotor. Existing engines only use acoustic liners in fan ducts and the inlet, and sometimes in the inter-stage region. To provide maximum insertion losses around a desired target frequency, they usually use honeycomb materials with porous or felt metal face sheets. NASA has explored that metal foams can be used to provide optimum bulk liner properties which also provide engine requirements over a range of temperatures for either the fan ducts or the core [41]. The concept of active absorption was first put forward by Olson and May [42] who mentioned an electronic sound absorber providing pressure release on the back face of a resistive sheet. In the 1980s, Guicking and Lorenz [43] confirmed this concept by experimental. Several researches have sought to implement hybrid absorption technology, leading to patent applications [44]. Thenail [45] and Furstoss [46] developed an active treatment consisting of a layer of glass wool layer backed by an air cavity closed through an active surface. Beyene and Burdisso [47] obtained active boundary conditions by using impedance adaptation in a porous rear face layer. More recently; Cobo et al [48] illustrated the feasibility of designing thinner hybrid passive/active absorbers using micro perforated panels instead of the conventional porous materials.

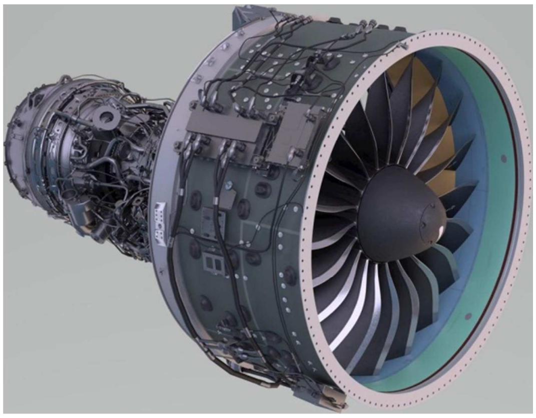

Figure 6. *Duct flow in Turbofan engine.*

2.7. Jet Noise

Mixing of the high-velocity exhaust stream with the still air causes Jet noise, which causes friction. When these two Streams at different velocities are mixed, significant amount of turbulence is created [49], with the intensity of the turbulence, and hence the noise increases as eighth power of the velocity difference [50, 51]. Modern bypass engines, which introduce a layer of moderately fast-moving cold air between the hot exhaust and the ambient air, are quieter than early jet engines, which didn't use this technology.

Engine noise is created by the sound from the moving parts of the engine and by the air coming out of the engine at high speed and interacting with still air, creating friction. Most of the engine noise comes from the exhaust or jet behind the engine as it mixes with the air around it. Modern bypass engines introduce a layer of moderately fast-moving cold air between the hot exhaust and the still air. This makes them quitter than the engines on earlier jets, which didn't use the bypass technology. The degree to which people experience aircraft noise on the ground has a lot of do with atmospheric condition. Temperature wind speed and direction, humidity, rain, cloud cover all have a part to play. The reverberation of sound waves caused by the weather can make noises seem louder. Sometime the aircraft flying at the altitudes that would not normally produce noise may be heard in certain atmospheric condition. The noise that coming from airplane is caused by two things: from air going over its body (or 'airframe') and from its engines. Over the years there was considerable decrease in Jet noise, mainly because of an increase in (BPR) in turbofan engines, which reduces the velocity gradient therefore, the shear stresses within the shear layer of exhausted jets. In modern high-BPR engines, an increase in the nacelle diameter has caused the aircraft to operate by reducing exhaust flow velocities without affecting the thrust. The engine exhaust velocity has to decrease in order to reduce the engine noise during takeoff. The exhaust nozzle is designed to have variable area in order to ensure fan operability at the low power, with cruise bypass ratio of 12 and take-off bypass ratio of 18. The low engine rotational speed during approach enabled by the variable nozzle mitigates the rearward fan noise and the airframe drag requirements. The fan design, however, must now accommodate the wide range of flows related to the performance of low pressure ratio fans at different flight conditions. A change in fan design methodology was required to enable the fan to cope with the various conditions imposed by the variable area nozzle.

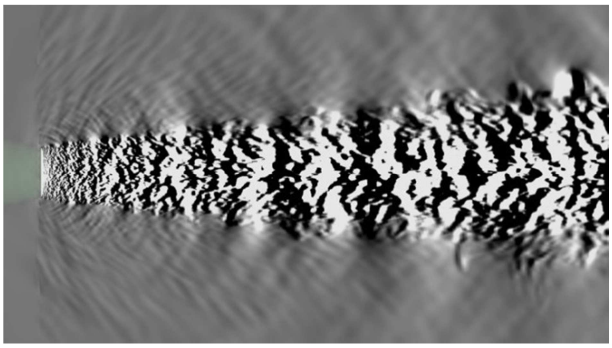

Figure 7. *Nozzle Jet flow.*

2.8. Propeller Noise

A propeller can generally be described as an open (enshrouded), bladed, and rotating device. Although there are many differences in details among various designs and applications, such as blade shape, number of blades, and airfoil section, the process of noise-producing is generally the same for all. The main components of propeller noise are steady-loading noise (due to the steady forces on the blades), thickness noise (due to the volume displacement of the blades unsteady-loading noise (due to the circumferentially non uniform loading), broadband noise and quadruple (nonlinear) noise. Although the relative importance of these sources depends on operating conditions and design, defining them will fully describe the acoustic signature of a propeller.

Propeller noise can be classified into three categories: harmonic noise, broadband noise, and narrow-band random noise. Harmonic noise is the periodic component, that is, its time signature can be represented by a pulse which repeats at a constant rate. If an ideal propeller with B blades is working at constant rotational speed N, than the resulting noise appears as a signal with fundamental frequency BN.

Figure 8. *Hartzell propeller.*

Broad band noise is naturally random and contains components at all frequencies. Broadband source of noise is the interaction of inflow turbulence with the blade leading edges. Since the inflow is turbulent, the resulting noise is random. The importance of this noise source depends on the magnitude of the inflow turbulence.

Thickness noise arises from the transverse periodic displacement of the air by the volume of a passing blade element. The amplitude of this noise component is proportional to the blade volume, with frequency characteristics dependent on the shape of the blade cross section (airfoil shape) and rotational speed.

Loading noise is a combination of torque and thrust (or lift and drag) components result from the pressure field that surrounds each blade as a consequence of its motion.

2.9. Mixing Noise

When a supersonic jet nozzle operates at adapted ambient condition, no shock cell is created in the plume. In this case, the only noise generation mechanism is associated with the small – scale turbulence mixing noise and Mach wave radiation. The mixture of these two mechanisms is commonly referred to as supersonic turbulent mixing noise [52]. Two commonly observed features of this noise generation mechanism are: The first is the high directionally, with downstream predominant radiation between the angle of 25 and 45 from the jet flow direction. The second characteristics is a broadband power spectral density spanning over about two frequency orders, with a very smooth peak separating a variation law as the square of the frequency on the left, from a variation law as the inverse of the frequency on the right. The noise from jet contains both turbulent mixing noise and broadband-shock associated noise. The interaction between the vertical disturbances in the jet stream and the shock fronts generates additional noise, referred to as shock associated noise.

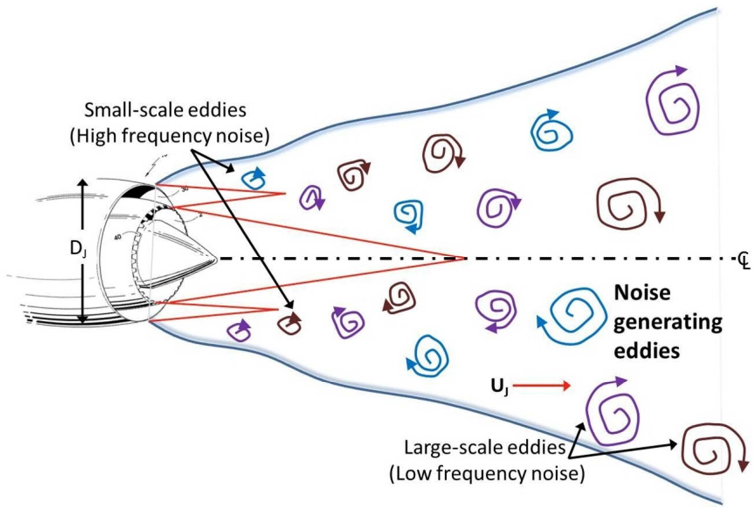

Figure 9. *Jet noise mixing region.*

3. Technology Trends

3.1. Micro-tab Device

In 2010, Brian C. Kuo et al conducted an investigation about a two-dimensional numerical study, in the case of acoustic influence of micro-tab device on airframe noise mitigation. While the noise generated by leading-edge slat and trailing-edge flap rise as long as deflection angles are increasing, it is possible to reduce such high-lift noise by using reduced settings without sacrificing the aerodynamic performance during procedure, micro-tab device connected to the pressure side of the flap surface is intended as a means to this end. The resolution of the computation was selected so that the details of flow were captured in the critical noise generation area [53].

3.2. Flow-Induced Unsteady Blade Forces

Mathias Steger et al found that additional sound field is the causes of the interaction between the rotor blades and these jets. The number of nozzles is as the same as the number of vanes in the stator due to create the same azimuthal modes as the stator. A slight decrease in overall sound power was made in a first optimization attempt, by shifting the azimuthal jet location relative to the stator vane. Most likely an optimization with respect to the axial position, nozzle diameter, and mass-flow rate of the jet will bring a significant reduction in the initial noise field from the rotor-stator interaction [54].

Under certain conditions, this secondary sound field may offset the main sound field as was shown empirically for a low-speed fan by Schulz et al [55] and numerically by Ashcroft and Schulz [56]. This method is now applied numerically to the fan of an aero engine with the objective to show that ANC is possible and to find the optimum position for the required flow rate and nozzles.

3.3. Swept and Leaned

Rotor-stator interaction is one of the mechanisms in noise generation in an aero engine; this includes periodic impingement of the rotor wake on the stator. As future designs are heading towards higher bypass ratio the interaction process is also expected to become more significant. Swept stators reduce fan noise by increasing the phase changes from hub-to-tip of the unsteady aerodynamics producing the sound and by increasing the effective distance from the fan to the stator vanes [57]. In general, the modern aircraft engines are designed using combination of the structural noise reduction technologies and passive methods which are assumed to install and absorbed the noise treatment in engine ducts [58-59]. Among the first group of noise reduction approaches in complying of the cutoff condition, choosing the optimal axial clearance between rotor and stator as on the one hand the increasing of axial clearance leads to noise mitigation and on the other hand to negative increasing of the engine weight. Recently scientific papers have been reported in which the configuration of fan design with the swept and leaned stator vanes were considered in terms of noise mitigation as compared to the conventional radial vanes [60]. Fan stator leaned and swept vanes are provided in order to weaken the mechanism of interaction between the stator vanes and the rotor wake.

One of the first published articles [61] related to this subject shows that the stator vane angle equal to 45.2 in the rotation reduces noise by 9 db. Envia [62] describes general physical phenomena of noise mitigation in fans with swept-and-leaned stator vanes. Compared to radial stator vanes, the swept stator vanes provide an increased axial gap at the tip that is useful for noise mitigation. Additionally, the vane leaning leads to a great number of rotors wake-stator vanes span wise intersections. As a result, there is an additional decrease in the amplitude of sound wave.

3.4. Noise Reduction Technologies for Future

What will be the challenges beyond 2020? In the last sections, various technologies presented, or to be applied, to conventional engine architectures, i.e., so-called “tube and wings” equipped with turbofans. However, the challenge to reduce fuel consumption is so great that new architectures are required. As mentioned before, Ultra High Bypass Ratio engines (UHBR) are being studied, but with difficult integration issues, because the fan diameter is even greater than it is currently used. With this option, noise reductions essentially require pushing for the same technologies more than the above technologies. In this case, the main machine noise, such as turbine noise, combustion noise or even compressor noise would need to be considered.

In addition to UHBR, another strategy could also be to keep on increasing BPR using the Open Rotor architecture (OR). The most critical issue is Noise, along with safety: while mostly tonal noise in the propeller plane radiated by single propellers. Actually, the radiated frequencies combine all of the possible linear combinations between the two blade passing frequencies and this spectrum is propagated in all directions. Currently there is ongoing research about facing this drawback and in order to lower this excessive noise several tricks are being investigated. From a programmatic perspective, Clean Sky research program is the main framework for such integrated research, by the end of the decade which will allow the engine manufacturer to produce a demonstrator.

4. Conclusion

This article has reviewed the current state of noises which are produced in aircrafts. This review paper has focused on various sources of aircraft noise. Examples of these sources have been presented, such as airframe noise which contains trailing edge noise and flap noise, and other parts of engine like fan noise or jet noise and mixing noise, Landing gear noise and propeller noise are issues of enormous environmental, financial and technological impact. It is extremely difficult to reduce theirs while not impacting anything else negatively, due to the constraints imposed by the engine and aircraft system requirements.

Effects of swept and leaned, blade forces and Micro-tab device also were investigated. While many scientific and technological elements have not been addressed, while these coefficients have evolved overtime, as more measurements of sources of noise are released, methods must be researched for discerning their physics based mechanisms. Clearly, there is a need for further theoretical and experimental research if we are to achieve future noise goals economically.

We believe that this work may be useful for a quick access to information in the field of aircraft noise sources.

Nomenclature

ANC = Active Noise Control
ASAC = Actuator semi active control
DLR = Deutsches Luft- Raumfahrt
AWB = Aeroacoustics Wind Tunnel Brauschweig
HLD = High Lift Device

RAIN = Airframe And Installation Noise
HBR = High Bypass Ratio
UHBR = Ultra High Bypass Ratio
DDTF = Direct Drive TurboFan
CRTF = Counter-Rotating TurboFan
GTF = Geared TurboFan
RESOUND = Reduction of Engine Source Noise through Understanding and Novel Design

References

[1] D. G. Crighton Chapter on Airframe Noise in Aero acoustics of Flight vehicles: theory and Practice: Noise Sources. NASA Reference Publication 90-3052 (H. H. Hubbard, editor) 1991.

[2] M. R. Fink FAA-RD-77-29, Airframe noise prediction, 1977.

[3] Heller H, Dobrzynski W, Sound radiation from aircraft wheel-well/landing gear configurations, Journal of Aircraft, vol. 14, no. 8, pp. 768-774, August 1977.

[4] Hubbard H, Aero acoustics of flight vehicles: theory and practice, volume 1: noise sources, in: Crighton: D. (Ed.), Airframe noise, pp. 391-447, NASA RP- 1258. 1991.

[5] Hayes H, W. Horne, Paul Soderman, Airframe noise characteristics of a 4.7% DC 10 model, AIAA-97-1594.

[6] Blackner A. M, Davis C. M, Airframe noise source identification using elliptical mirror measurement techniques, Proceedings of Inter-Noise 95, pp. 203-206, Newport Beach, CA, USA, 70 - 12 July 1995.

[7] Dobrzynski Wet al, Full scale noise testing on Airbus landing gears in German Dutch wind tunnel, AIAA-97-1597.

[8] Piet J et al, airframe noise source localization using a microphone array, AIAA-97.1643.

[9] Dobrzynski W et. al, Airframe Noise Studies on Wings with Deployed High Lift Devices, IAA/CEAS-98-2337. 1998.

[10] Werner Dobrzynski, Burkhard Gehlhar, Heino Buchholz, Model and full scale high-lift wing wind tunnel experiments dedicated to airframe noise reduction, Aerospace. Sci. Technol. 5 27–33. 2001.

[11] Leung Choi Cho, Pierre Lempereurn, aircraft airframe noise and installation effects research studies, Air and Space Europe. vol. 1, No 3. 1999.

[12] J. C. Hardin, Noise radiation from the side edges of flaps, American Institute of Aeronautics and Astronautics Journal 18 (5) 549–552. 1980.

[13] S. A. McInerny, W. C. Meecham, P. T. Soderman, An experimental investigation of wing tip turbulence with applications to aero sound, AIAA Paper 86-1918. 1986.

[14] D. G. Crighton, Airframe noise, aeroacoustics of Flight Vehicles: Theory and Practice, NASA RP-1258, Vol. 1, pp. 391–447. 1991.

[15] Y. P. Guo, Prediction of flap edge noise, AIAA Paper 99-1804, 1999.

[16] T. F. Brooks, W. M. Humphreys, Flap-edge aeroacoustic measurements and predictions, Journal of Sound and Vibration 261 31–74.2003.

[17] J. C. Ross, B. L. Storms, H. Kumagai, Aircraft flyover noise reduction using lower-surface flap-tip fences, NASA CDTM-21006. 1995.

[18] B. L. Storms, T. T. Takahashi, W. C. Horne, J. C. Ross, R. P. Dougherty, J. R. Underbrink, Flap-tip treatments for the reduction of lift-generated noise, NASA CDTM-21006. 1996.

[19] Y. P. Guo, M. C. Joshi, Noise characteristics of aircraft high lifts systems, American Institute of Aeronautics and Astronautics Journal 41 (7) 1247–1256. 2003.

[20] Y. P. Guo, P. Bent, K. Yamamoto, M. C. Joshi, Surface pressure fluctuations on aircraft high lift system and their correlation with far field noise, Journal of Fluid Mechanics 415 175–202. 2000.

[21] Yueping Guo, on noise reduction by flap side edge fences, Journal of Sound and Vibration 277 369–390. 2004.

[22] Michel, U., Barsikow, B., Helbig, J., Hellmig, M., and Schüttpelz, M., "Flyover Noise Measurements on Landing Aircraft with a Microphone Array," AIAA Paper 98-2336, May 1998.

[23] Piet, J.-F., Elias, G., and Lebigot, P., "Localization of Acoustic Sources from a Landing Aircraft with a Microphone Array," AIAA Paper 99-1811, May 1999.

[24] Michel, U. and Qiao, W., "Directivity of Landing-Gear Noise Based on Flyover Measurements," AIAA-99-1956, May 1999.

[25] Pott-Pollenske, M., Dobrzynski, W., Buchholz, H., Gehlhar, B., and Walle, F., "Validation of a Semiempirical Airframe Noise Prediction Method through Dedicated A319 Flyover Noise Measurements," AIAA Paper 2002-2470, May 2002.

[26] Stoker, R., Guo, Y., Streett, C., and Burnside, N., "Airframe Noise Source Locations of a 777 Aircraft in Flight and Comparisons with Past Model Tests," AIAA Paper 2003-3232, May 2003.

[27] Guo, Y, A Study on Local Flow Variations for Landing Gear Noise Research," May 5{7 2008, AIAA Paper No. 2008-2915, 14th AIAA/CEAS Aerodynamics Conference (29th AIAA Aeroacoustics Conference).

[28] Stoker, R. W. Landing Gear Noise Test Report," NASA Contractor Informal Report NAS1-97040, Boeing, 1999.

[29] Kipersztok, O. and Senguptat, G., Flight Test of the 747-JT9D for Airframe Noise," AIAA Journal of Aircraft, Vol. 19, No. 12, December 1982, pp. 1061.

[30] Stoker, R. W. and Sen, R., An Experimental Investigation of Airframe Noise Using a Model-Scale Boeing 777, AIAA Paper No. A01-16784, 39th AIAA Aerospace Sciences Meeting & Exhibit" January 2001.

[31] Lockard, D. P, Khorrami, M. R., and Li, F, High Resolution Calculation of Landing Gear noise, AIAA Paper No. 2004-2887, 10th AIAA/CEAS Aeroacoustics Conference " May 10, 13 2004.

[32] R. J. Jeracki, "Comprehensive Report on Fan Performance From Duct Rake Instrumentation on 1.294 Pressure Ratio, 806 ft/sec Tip Speed Turbofan Simulator Models," NASA TM-2006-213863 (2006).

[33] C. Polacsek, Reduction of fan rotor–stator interacting modes using a novel design: an experimental study, Proceedings of the Sixth International Congress on Sound and Vibration (ISCV), Copenhagen, 1999.

[34] R. E. Kraft, K. B. Kontos, Theoretical implications of active noise control for turbofan engines, 15th aero acoustics Conference, Long Beach, CA, October 1993.

[35] R. H. Thomas, R. A. Burdisso, R. A. Fuller, C. R. O'Brien, Active control of fan noise from a turbofan engine, American Institute of Aeronautics and Astronautics Journal 32 (1) 23–30. 1994.

[36] T. Ishii, H. Kobayashi, H. Oinuma, Wave-form technique for reduction of tones radiated from a ducted fan, AIAA No. 97-1664-CP,, pp. 619–625. 1997.

[37] S. Sawyer, S. Fleeter, Active control of discrete-frequency noise generated by rotor–stator interactions, AIAA No. 97-1663-CP, pp. 609–617. 1997.

[38] D. L. Sutliff, Z. Hu, F. G. Pla, L. J. Heidelberg, Active noise control of low speed fan rotor–stator modes, Third AIAA/CEAS Aero acoustic Conference, Atlanta, GA, 1997.

[39] W. Just, I. U. Borchers, H. Antoine, E. Bouty, J. Zillmann, R. Maier, Control of fan noise by active stators, Seventh AIAA/CEAS, Maastricht. 2001.

[40] A. R. D. Curtis, Active Control of Fan Noise by Vane Actuators, BBN Technologies, Cambridge, MA, NASA/CR-1999-209156. 1999.

[41] Dennis L. Huff, Noise Reduction Technologies for Turbofan Engines, 35th International Congress and Exposition on Noise Control Engineering (INTER–NOISE 2006) sponsored by the International Institute of Noise Control Engineering Honolulu, HI, December 3–6. 2006.

[42] H. F. Olson, E. G. May, Electronic sound absorber, Journal of the Acoustical Society of America 25 1130–1136. 1953.

[43] D. Guicking, E. Lorenz, An active sound absorber with porous plate, Journal of Vibration and Acoustics 106 389–392. 1984.

[44] F. P. Mechel, Hybrider Schallda mplfer, Patent No DE4027511.

[45] D. Thenail, Control active impedance optimization des performances, PhD Thesis, Ecole Centrale de Lyon, Ecully, France, 1995.

[46] M. Furstoss, D. Thenail, M. A. Galland, Surface impedance control for sound absorption: direct and hybrid passive/active strategies, Journal of Sound and Vibration 203 (2) 219–236. 1997.

[47] S. Beyene, A. Burdisso, A new passive/active noise absorption system, Journal of the Acoustical Society of America 101 (3) 1512–1515. 1997.

[48] P. Cobo, J. Pfretzschner, M. Cuesta, D. K. Anthony, Hybrid passive–active absorption using microperforated panels, Journal of the Acoustical Society of America 116 (4) 2118–2125. 2004.

[49] Suddaby, P. A study of the velocity fluctuations in the noise producing region of jet. MSCThesis, Cranfield University, 1964.

[50] Lighthill, M. J. On sound generated aerodynamically. I. General theory. In Proceedings of the Royal Society of London, Series A211, pp. 564–587. 1952.

[51] Lighthill, M. J. On sound generated aerodynamically. II. Turbulence as a source of sound. In Proceedings of the Royal Society of London, Series A222, pp. 1–32.1952.

[52] H. H. Hubbard, Aeroacoustic of fligh veheles: Theory and practice, volume 1: noise sources, Nasa Langly Research center 1992.

[53] Brian C. Kuo, Nesrin Sarigul-Klijn, Conceptual study of micro-tab device in airframe noise reduction (I) 2D computation, Aerospace Science and Technology 14 307–315.2010.

[54] Mathias Steger, Ulf Michel, Graham Ashcroft, and Frank Thiele, Turbofan Tone Noise Reduction by Flow-Induced Unsteady Blade Forces, Active Flow Control II, NNFM 108, pp. 157–170. 2010.

[55] Schulz, J, Neise, W., Moser, M.: Active control of the blade passage frequency noise level of an axial fan with aero acoustic sound sources. Noise Control Engineering Journal 54, 33–40 2006.

[56] Ashcroft, G., Schulz, J. Numerical modeling of wake-jet interaction with application to active noise control in turbo machinery. AIAA Paper 2004-2853 2004.

[57] Fathollah Ommi and Mohammadreza Azimi, main fan noise mitigation technologies in turbofan engines, Taylor and francis, ISSN 1648-7788 / eISSN 1822-4180, Volume 18 (3): 141-146. 2014.

[58] Khaletskiy, Y. D, Effectiveness of Combined Aircraft Engine Noise uppresions. Acoustical Physics, vol. 58, № 4, pp. 510-515. 2012.

[59] Osipov, A. A., Reent, K. S., Mathematical modelling of sound propagation in flow duct with impedance walls. Acoustical Physics, vol. 58, № 4, pp. 467-480. 2012.

[60] Envia, E., Fan noise reduction: an overview. International J. of Aero acoustics. vol. 1, no 1, pp. 43-64. 2002.

[61] Rao, G. V. R., Use of Leaning Vanes for Fan Noise Reduction. 10th Aerospace Sciences Meeting. San Diego, USA. AIAA paper. no. 72-126, pp. 1-16. 1972.

[62] Envia, E., Nallasamy, M., Design selection and analysis of a swept and leaned stator concept. Journal of Sound and Vibration. vol. 228, no 4, pp. 793-836. 1999.