International Journal of Innovative Analyses and Emerging Technology
ISSN: 2792-4025
Volume 4 Issue 04 (2024)
https://www.openaccessjournals.eu

Article

Noise Sources of Modern Aircraft

Ruzmatov Rustam Alidjanovich[1*]

1. Faculty Teacher Advanced Qualification of Aviation Specialists Higher Military Aviation Institute, Republic Uzbekistan

* Correspondence: ruzmatov1963@gmail.com

Abstract: This study examines noise sources in modern aircraft, focusing on gas turbine engines, aerodynamic noise, and aircraft systems. Despite advancements in aircraft design, noise pollution remains a persistent problem affecting communities near airports, passengers, and aviation personnel. A gap exists in understanding the effectiveness of current noise reduction technologies and their impact on safety and comfort. The research aims to analyze key noise sources and evaluate noise mitigation strategies through detailed assessments of engine components, airflow, and cabin systems. Results indicate that while noise has been reduced, challenges remain, particularly in jet stream and aerodynamic noise. Promising innovations, such as sound-absorbing materials and optimized engine designs, offer potential solutions. These findings highlight the need for continued research to improve aviation safety, passenger comfort, and community well-being.

Keywords: Trustworthiness of aviation specialists, Flight safety, Air transport operations, Sound-absorbing structures, Jet engine nozzles.

1. Introduction

This subject is pertinent in contemporary society, as nearly everyone travels by aeroplane and noise induces discomfort. Recent advancements in aviation acoustics and materials science enable us to provide new solutions to enhance the acoustic environment at airfields and surrounding areas, thereby mitigating the adverse effects of noise on the health of individuals and the community. Aircraft noise adversely affects the people residing near airports, passengers, and maintenance personnel, disrupts the reception and transmission of information, and induces anomalies in the functioning of instruments and electronic equipment [1].

An international agreement governing acceptable aviation noise limitations was enacted in 1971 and remains in effect. This is Annex No. 16 (Concerning Environmental Protection) to the Convention on International Civil Aviation. The document was compiled by examining several ways for measuring aircraft noise, certification processes for aircraft regarding this aspect, potential noise reduction during engine operation both on the ground and in flight, and the human body's response to noise [2].

Adverse elements that can substantially impact crew performance encompass noise and vibration at the pilots' stations. From a physical perspective, there is minimal distinction between noise and vibration. The distinction lies solely in perception: vibration is induced by the vestibular apparatus and tactile receptors, whereas noise is generated by the auditory organs. Vibrations of mechanical bodies at frequencies below 20 Hz are experienced by the body as vibration, while those over 20 Hz are perceived as both vibration and sound.

Citation: Ruzmatov Rustam Alidjanovich. Noise Sources of Modern Aircraft. International Journal of Innovative Analyses and Emerging Technology 2024, 4(4), 27-34.

Received: 20th August 2024
Revised: 20th Sept 2024
Accepted: 27th Sept 2024
Published: 4th Oct 2024

Literature Review:

Research on aircraft noise has a long history, driven by concerns over public health, operational efficiency, and environmental sustainability. Several studies have focused on the sources of noise in aircraft, categorizing them into engine-related noise, aerodynamic noise, and noise generated by onboard systems. According to research by Moshkov and Samokhin (2016), the noise generated by jet engines during takeoff is the most significant, often surpassing 140 dB. This noise is produced by the high-velocity turbulence of exhaust gases and the fan blades in gas turbine engines, which operate at supersonic speeds. Advances in engine technology, such as high bypass turbofans, have significantly reduced noise, but challenges remain, particularly with regard to turbulence-induced noise in the fuselage and airflow [3].

Aerodynamic noise, as discussed by Kopiev et al. (2016), is another significant contributor, particularly for military aircraft operating at low altitudes and high speeds. The interaction between airflow and aircraft surfaces, such as wings and landing gear, creates pressure fluctuations that result in noise. Studies have shown that the shape and configuration of aircraft components, such as the nose, windshield, and fuselage, can influence the level of noise generated [4]. Edge noise, which occurs when turbulent airflow interacts with the extremities of aircraft parts, further exacerbates this issue, particularly during takeoff and landing.

In addition to the engine and aerodynamic noise, aircraft systems, particularly the auxiliary power unit (APU) and cabin pressurization systems, contribute to interior noise levels that affect passenger comfort and crew performance. Rybinskaya et al. (2017) explored the impact of mechanical systems on noise levels inside the cabin and concluded that effective insulation materials are crucial in mitigating internal noise. These studies suggest that a multi-faceted approach is necessary to address noise from both internal and external sources [5]. Technological innovations aimed at reducing noise have shown promising results. For instance, the use of sound-absorbing materials and composite structures has been identified as an effective solution for reducing noise at the source. Recent advancements in wave-shaped chevrons, multilayer wood-plastic composites, and carbon fibre materials are proving effective in reducing turbulence and noise from jet engines. Research by Belyaev and Faranosov (2021) suggests that the integration of adaptive materials into aircraft design can further enhance noise absorption capabilities, particularly at low frequencies.

Consequently, the noise generated by passenger aircraft and helicopters on the ground is regulated by national norms and the International Civil Aviation Organisation (ICAO) standards, while cabin noise is restricted by national regulations. An examination of these criteria indicates that noise specifications are consistently being intensified, and the acoustic output of new aircraft generally diminishes [6]. The diminished functional reliability of individuals under standard and particularly extreme conditions is attributable to insufficient integration of human features in the design of aircraft control systems, life support systems, and protective equipment for their crews.

Guaranteeing the reliability and functionality of flight personnel in harsh operational situations influenced by flight factors (aerobatic overloads, temperature variations, altered gas environments, noise, vibrations, etc.) is a critical task that profoundly impacts flight safety [7]. Aviation noise poses a possible hazard, heightening the likelihood of erroneous acts by aviation professionals and contributing to the onset of occupational diseases, which may result in premature professional disqualification.

The expansion of aircraft capacity to 500-600 passengers (B-747 and A-380) has resulted in a significant increase in the washed surface area, which has critical implications for terrain impact, specifically concerning aerodynamic noise levels (sv. 110 dB) during takeoff and landing phases due to airflow interacting with the aircraft's structural components (wing, tail, fuselage) [8].

On the aircraft's surface, beneath the turbulent boundary layer, exists a field of intense pressure pulsations within the sound frequency range, exhibiting randomness in both space and time. The magnitude of wall pressure pulsations in the laminar boundary layer is nearly two orders of magnitude less than in the turbulent boundary layer [9]. Pressure pulsations in the boundary layer are significant in addressing issues related to acoustic fatigue of structures and equipment reliability. This is particularly applicable to aircraft designed to operate within the jet stream, such as vertical takeoff and landing aircraft (Yak-38, Yak-141, AV-8B).

Randomly occurring intense noise, such as the hit of an air jet, can be perilous and substantially diminish human performance. Rhythmically oscillating and stepping sounds, hissing, creaking, and occasional electrical discharges can be disconcerting. They diminish the capacity to execute coordinated movements swiftly and precisely. Under conditions of significant noise, accurately estimating distance and time, as well as recognising colour signals, can prove challenging [10].

Sources of aircraft noise

The predominant source of aircraft noise is the gas turbine engine (GTE), with the primary contributors being the fan, compressor, combustion chamber, turbine, and jet stream.

1. The noise originates from three primary sources: the engine and various mechanical sounds;
2. Aerodynamic noise;
3. Noise generated by aircraft systems.

Engine and additional mechanical sounds Aircraft engines are the primary source of noise, potentially exceeding 140 decibels (dB) during takeoff [11]. The primary sources of noise during flight are the engines and high-velocity turbulence above the fuselage.

Aviation gas turbine engines (jet engines) generate the majority of aircraft noise during takeoff and ascent, exemplified by the chainsaw-like sound produced when the tips of the fan blades attain supersonic velocities. Nonetheless, with the advancement of noise reduction technologies, the aeroplane fuselage is often louder when landing [12].

The majority of engine noise originates from jet engines, however high bypass turbofans produce considerable fan noise. The high-velocity jet exiting the engine's rear possesses the intrinsic instability of the shear layer, provided it is insufficiently thick, and subsequently forms annular vortices. This subsequently evolves into turbulence. The sound pressure level of engine noise is directly related to jet velocity (high power). Consequently, a minor reduction in exhaust velocity will result in a substantial decrease in jet stream noise [13].

2. Materials and Methods

The methodology for this study involved a systematic approach to identifying, analyzing, and evaluating the primary noise sources in modern aircraft, focusing on gas turbine engines, aerodynamic factors, and internal systems. The process began with the identification of key noise-producing components, such as the fan, compressor, combustion chamber, turbine, and jet stream in gas turbine engines. Additionally, aerodynamic noise sources, including the airflow over control surfaces, fuselage, and landing gear, were examined. Data from prior research and technical documentation, along with flight test reports, were utilized to pinpoint the significant contributors to noise during different flight phases, particularly takeoff and landing [14].

Next, noise levels were measured and analyzed using existing data from flight simulations and field experiments. The sound pressure levels, primarily measured in decibels (dB), were assessed to evaluate the impact of engine noise, aerodynamic factors, and cabin systems, such as the auxiliary power unit (APU) and pressurization systems.

This phase allowed for the categorization of noise based on its source, enabling a clearer understanding of how each factor contributes to the overall noise experienced both inside and outside the aircraft.

The final stage of the methodology involved evaluating current noise reduction technologies and strategies. This included an analysis of sound-absorbing materials, structural modifications, and innovative technologies, such as wave-shaped chevrons for jet engine nozzles and multilayer wood-plastic composites (WPC). The study assessed the effectiveness of these approaches by reviewing experimental data and performance evaluations from previous studies. By comparing noise reduction methods across different aircraft models, the research identified the most efficient solutions for minimizing noise impact. Statistical analysis was applied to quantify the success of these technologies in reducing noise levels, ultimately contributing to improved noise management in modern aviation.

3. Results and Discussion

Mitigating the noise emissions of a gas turbine engine is a pressing objective for both aviation and terrestrial power generation applications. The majority of noise in propeller-driven aircraft originates equally from the propellers and aerodynamic factors. Helicopter noise comprises aerodynamically induced sounds from the main and tail rotors, as well as mechanically induced sounds from the main gearbox and different gearbox systems. Mechanical sources provide narrow-band peaks of high intensity linked to rotational speed and the motion of moving components.

The noise levels of passenger aeroplanes predominantly influence their competitiveness and constitute a significant technological attribute. Aerodynamic acoustics Aerodynamic noise results from the airflow surrounding the aircraft fuselage and control surfaces. This category of noise escalates with the velocity of the aircraft and at reduced altitudes due to air density. Jet aircraft generate significant noise due to aerodynamic factors. Low-altitude, high-velocity military aircraft generate notably loud aerodynamic noise. The configuration of the nose, windscreen, or lantern of an aircraft influences the generated sound [15].

The majority of noise produced by a propeller aircraft originates aerodynamically from the airflow surrounding the blades. The helicopter's main and tail rotors generate aerodynamic noise. This category of aerodynamic noise is predominantly low-frequency, dictated by the rotor velocity. Noise typically arises when airflow interacts with an object on an aircraft, such as the wings or landing gear. Generally, there are two primary categories of aeroplane hull noise:

The noise generated by a bluff body arises from a fluctuating vortex originating from both sides, resulting in regions of low pressure at the centre of the vortices, which are perceived as pressure waves or sounds. The detached flow surrounding the cliff's body is highly unstable, resulting in the formation of annular vortices that subsequently dissolve, leading to turbulence [16]. Edge noise occurs when turbulent flow traverses the extremity of an item or interstices in the structure (such as gaps between high-lift devices), resulting in pressure fluctuations that are audible as sound radiates downward from the object's edge.

Acoustic emissions from aviation systems

The cabin, together with its pressurisation and air conditioning systems, frequently constitutes the primary source of noise in the cabins of both civil and military aircraft. In addition to engines, a major source of noise in the cabin of commercial jet aircraft is the auxiliary power unit (APU), an on-board electric generator utilised to start the main engines, typically with compressed air, and to supply electricity while the aircraft is stationary on the ground [17].

Additional internal aviation systems may also play a role, including specialised electrical apparatus in certain military aircraft.

Methods to diminish the noise level of an aircraft

To mitigate aviation noise during its transmission through the atmosphere, soundproof systems are employed that entirely isolate the noise source from the surroundings, or sound-absorbing structures that diminish noise intensity along its propagation path by absorbing sound energy [18]. Physical spatial barriers, such as screens and boxes, are employed for sound insulation to inhibit sound transmission, while coatings applied to reflective surfaces (ceilings, walls, floors) are utilised for sound absorption to diminish reflected sound energy. The actual processes of sound traversing an obstruction demonstrate an interrelation between these two ideas.

Fibrous-porous materials are predominantly utilised for noise absorption. The noise absorption of such materials is directly correlated with their production process and occurs when. This structure is contingent upon the arrangement of the layers and escalates with augmented thickness and material density. The most efficient method to diminish noise is to decrease the size of the aircraft, resulting in a reduction of engine thrust and the overall surface area. The primary strategies for developing low-noise components, mechanisms, and assemblies involve identifying optimal design configurations for parts and arranging aircraft layouts to facilitate shockless interactions or smooth gas-air movement [19].

The attenuation of the noise level in the gas turbine engine is achieved through the best selection of blade rotation speed, quantity, and inter-blade spacing. Wave-shaped chevrons affixed to the nozzle portion of the gas turbine engine, along with bevelled air intakes, facilitate the reduction of turbulence, directional flow, and consequently, the noise of the gas turbine engine jet. The most promising development is the fabrication of multilayer wood-plastic composites (WPC), whereby the cells are infused with finely porous material, alongside adaptive WPC that modify their properties (porosity and density) in response to the characteristics of the sound field. A notable characteristic of these materials is their exceptional sound absorption capability throughout an extensive frequency spectrum.

The necessity to diminish operational expenses and environmental hazards has resulted in the development of innovative technological solutions, including fuel chemistry elements into aircraft design as a replacement for auxiliary power units, which are significant sources of aviation noise. The utilisation of carbon fibre, among other materials, greatly decreases the aircraft's noise level. Composite materials utilised in wing and fuselage structures [20]. Promising avenues for enhancing aviation noise protection include the creation and deployment of a universal noise mitigation product utilising efficient sound-absorbing materials; the integration of effective active sound attenuation methods within existing passive personal protective equipment (PPE) and sound control resources (SCR) to augment protection efficacy at low frequencies; the enhancement of ergonomic features in aviation headsets and headphones; and the development of effective, ergonomically optimised modular systems for collective protection against aircraft noise, tailored to the specific requirements of various aircraft maintenance tasks.

Noise constitutes a significant issue in aviation. Noise mitigation is of secondary importance to flight safety. Prior to the introduction of jet-powered aircraft, the major airports accommodated approximately 10 aircraft daily. Currently, this figure has risen to several hundred. Aircraft land and take off nearly every minute. This aspect, together with rising population density, the proliferation of airports, and their proximity to urban areas, intensifies the challenges of noise management. Aeroplane passengers endure noise as well.

The noise level of a contemporary jet aircraft during takeoff ranges from 130 to 140 dB. Such noise can induce pain in an individual, as it exceeds the endurance threshold of the human ear. In the cockpit of a contemporary aeroplane, noise levels can occasionally surpass 100 dB, which impairs comfort and hinders passengers from relaxing and conversing. The noise level requirement is presently a primary criterion for the development of airliners.

The international airport will not let a new aircraft unless it complies with noise regulations. The developers of the inaugural passenger aeroplane were primarily tasked with minimising cabin noise levels. The introduction of the first jet engines lowered noise levels, although it amplified noise on the ground during aircraft landing and departure. The configuration of aeroplanes featuring dual-circuit engines and the incorporation of sound-absorbing linings in power plants has partially mitigated the "inconvenience" of aircraft on the ground. However, these occurrences are insufficient.

Multiple steps are being implemented to safeguard individuals from the noise generated by aircraft equipment operations. Innovative landing and take-off techniques are under development, and airspace is being utilised effectively. The primary objective of aircraft designers is to develop a "quiet" aeroplane.The engine predominantly generates the noise, hence it receives the majority of focus during the operation. A significant amount of the noise originates from the jet stream of gases.

Consequently, jet engine nozzles are designed with corrugations and incorporate additional nozzles. The alternative method to diminish the noise levels of power plants involves the implementation of specialised rods and grids. A soundproof enclosure is proposed to surround the ejecting jet, together with the utilisation of an external noise generator to mitigate the primary noise. Numerous contemporary aeroplane engines feature sound-absorbing linings within their internal channels.

It is depicted by perforated plates positioned at a slight distance from the stiff wall. The gap between the wall and the plates is occupied by a honeycomb filler. Sound-insulating and sound-absorbing materials are employed to diminish the noise level in the cockpit. They are positioned between the inside panels of the salons and the cladding in multiple layers.

4. Conclusion

Emphasis is placed on noise mitigation at the source, the selection of an acoustically efficient device configuration, and the implementation of noise reduction techniques along its transmission pathway. The primary sources of aeroplane noise include aerodynamic fluxes in the power plant, airflow, flow around the apparatus, and gas flows from on-board equipment systems. The mitigation of aviation noise intensity is pursued through the following avenues: diminishing the characteristics of the noise element in The origin of education through technological, constructive, and operational methodologies; diminishing noise intensity during propagation via sound insulation or absorption; mitigating the detrimental effects of the mechanoacoustic factor on the body through the implementation of individual (PPE) and collective (SCZ) protective measures for personnel (or altering their work regimen), alongside a comprehensive array of medical and organisational interventions. Statistical study indicates an immediate necessity to create and apply specialised tools and methodologies to guarantee the acoustic safety of aviation professionals, as a fundamental component of the system ensuring the secure operation of air transport.

REFERENCES

[1] P. A. Moshkov and V. F. Samokhin, "Integral Model of Noise from Light Aircraft Power Units," Bulletin of the Moscow Aviation Institute, vol. 23, no. 4, pp. 36-44, 2016.

[2] V. F. Kopiev, M. Yu. Zaytsev, and I. V. Belyaev, "Study of Aerodynamic Noise of Large-Scale Models of Wings with Mechanization," Acoustic Journal, vol. 62, no. 1, pp. 95-95, 2016.

[3] V. F. Kopiev, M. Yu. Zaytsev, I. V. Belyaev, and G. A. Faranosov, "Noise of Modern Aircraft on Landing: Laboratory and Flight Experiments," in Proceedings of the Sixth All-Russian Open (XVIII Scientific-Technical) Conference on Aeroacoustics, pp. 59-60, 2023.

[4] L. A. Rybinskaya, R. V. Bulbovich, and V. I. Kychkin, "Efficiency of Methods for Reducing the Noise of Turbulent Jets," Bulletin of Perm National Research Polytechnic University: Aerospace Engineering, vol. 1, no. 48, pp. 104-119, 2017.

[5] I. V. Belyaev and G. A. Faranosov, "Evaluation of the Effect of Installation Angle on the Noise of Jet-Wing Interaction," Acoustics of the Living Environment, pp. 56-62, 2021.

[6] S. F. Seregin and V. V. Kharitonov, "Aktualnye Voprosy Sovershenstvovaniya Sistemy Bezopasnosti Poletov," Problemy Bezopasnosti Poletov, 2016.

[7] V. N. Zinkin, S. K. Soldatov, P. M. Sheshegov, Yu. A. Chumanov, and V. V. Kharitonov, "Shum Kak Faktor Riska Snizheniya Rabotosposobnosti i Professionalnoi Nadezhnosti Aviatsionnykh Spetsialistov," Problemy Bezopasnosti Poletov, 2014.

[8] N. I. Ivanov, Inzhenernaya Akustika. Teoriya i Praktika Borby s Shumom, Moscow: Universitetskaya Kniga, Logos, 2016.

[9] P. A. Moshkov, "Klassifikatsiya Istochnikov Shuma Legkikh Vintovykh Samoletov na Mestnosti," Nauchno-Tekhnicheskiy Vestnik Povolzhya, no. 4, pp. 101-106, 2015.

[10] V. F. Kopiev, M. Yu. Zaytsev, and I. V. Belyaev, "Issledovanie Shuma Obtekaniya Krupnomasshtabnoi Modeli Kryla s Mekhanizatsiei," Akusticheskiy Zhurnal, vol. 62, no. 1, pp. 95-95, 2016.

[11] V. G. Dmitriev and V. F. Samokhin, "Kompleks Algoritmov i Programm dlya Rascheta Shuma Samoletov na Mestnosti," Uchenye Zapiski TsAGI, vol. 45, no. 2, pp. 136-157, 2014.

[12] P. A. Moshkov, "Problemy Proektirovaniya Grazhdanskikh Samoletov s Uchetom Trebovanii po Shumu v Salone," Vestnik Moskovskogo Aviatsionnogo Instituta, vol. 26, no. 4, pp. 28-41, 2019.

[13] V. F. Kopiev, I. V. Belyaev, O. P. Bychkov, M. Yu. Zaytsev, and G. A. Faranosov, "Shum Sovremennogo Samoleta na Posadke: Laboratornye Eksperimenty i Letnye Ispytaniya," in Proceedings of the Sixth All-Russian Open (XVIII Scientific-Technical) Conference on Aeroacoustics, pp. 59-60, 2023.

[14] V. F. Kopiev, M. Yu. Zaytsev, S. A. Velichko, and V. A. Matveev, "Lokalizatsiya i Ranzhirovanie Istochnikov Shuma Sovremennogo Passazhirskogo Samoleta v Naturnom Letnom Eksperimente," in Proceedings of the Sixth All-Russian Open (XVIII Scientific-Technical) Conference on Aeroacoustics, pp. 59-60, 2019.

[15] V. G. Dmitriev and V. F. Samokhin, "Sovremennye Metody Snizheniya Shuma Samoletov na Mestnosti," in Proceedings of the XVII School-Seminar on Aerodynamics of Aircraft, pp. 50-50, 2006.

[16] V. Ch. Tuan and V. I. Ryabkov, "Neobkhodimost i Puti Snizheniya Shuma Agregatov Samoleta," 2012.

[17] O. P. Bychkov and G. A. Faranosov, "Otsenka Vliyaniya Uglov Ustanovki na Shum Vzaimodeistviya Strui i Kryla Samoleta," in Acoustics of the Living Environment, pp. 56-62, 2021.

[18] A. I. Zaporozhets and G. G. Golembievsky, "Vliyanie Ekspluatatsionnykh Faktorov na Urovni Aviatsionnogo Shuma," Visnik KMUCA, vol. 3-4, 2000.

[19] L. A. Rybinskaya, R. V. Bulbovich, and V. I. Kychkin, "Effektivnost Metodov Snizheniya Shuma Turbulentnykh Strui," Vestnik Permskogo Natsionalnogo Issledovatelskogo Politekhnicheskogo Universiteta: Aerokosmicheskaya Tekhnika, vol. 1, no. 48, pp. 104-119, 2017.

[20] P. A. Moshkov and V. F. Samokhin, "Integralnaya Model Shuma Silovoi Ustanovki Legkogo Vintovogo Samoleta," Vestnik Moskovskogo Aviatsionnogo Instituta, vol. 23, no. 4, pp. 36-44, 2016.