Aircraft Noise Assessment, Prediction and Control

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This book is striking as an in-depth compilation of the vast knowledge gained by the two lead authors in their more than 30 years of teaching and research. Discussion of each topic starts with a qualitative description of the problem, but for those topics amenable to quantitative analysis, quickly moves to derivation and use of the applicable physics-based equations. Equations are developed not only for such expected topics as sub-sonic turbulent jet sound power, or air absorption as a function of frequency, humidity, temperature and pressure, but also for somewhat more unusual applications such as contour areas as a function of flight geometry or distribution of flight routes by aircraft type to minimize noise impact. Full understanding of the equations will require experience with differential and integral equations.

Specifics by chapter:

1 A Review of the Aircraft Noise Problem

This first chapter begins with a brief overview of the environmental impacts of airports, ICAO's balanced approach for noise management (reduction at the source, land-use planning, operational procedures and operational restrictions), and summarizes basic methods for reducing aircraft noise and some associated constraints. It identifies the primary sources of aircraft noise and provides informative plots of the contributions by frequency at the three noise certification points (FAA FAR Part 36) or "control points" (ICAO Annex 16). Section 1.3 provides extensive derivation of the equations describing jet noise based on Lighthill's work and for propeller, propfan, rotor, turbomachinery, and airframe noise based on the Ffowcs-Williams and Hawkings equation. The chapter summarizes various methods for quantifying the impacts of aircraft noise including limits of acceptable noise exposure, the "balanced" ICAO approach to control impacts, and regulatory limits on aircraft noise as manufactured.

2 The Main Sources of Aircraft Noise

This chapter addresses jet noise, fan and turbine noise, combustion chamber noise, and airframe noise and provides predicted spectral plots and overall sound pressure level directivity for each as well as contributions of each to the total noise. Propeller noise is discussed briefly and a typical spectrum provided.

3 Aircraft Noise Propagation

This chapter covers virtually all factors that affect sound propagation over the ground. Factors include spreading losses, atmospheric absorption, ground effect, effects of wind and temperature gradients and methods to predict the magnitudes of each including equations. Ground effects are examined at length as are meteorological effects, sound speed profiles as a function of height, the effects of turbulent atmosphere, and noise barriers, including the effects of trees.

4 Methods for Aircraft Noise Prediction

This is an extensive examination of the details of predicting aircraft operations noise in the vicinity of an airport. Two different prediction methods are derived. The first method is based on the spectra of individual aircraft noise sources, as identified in Chapter 2, and applies to specific modes of operation – approach or takeoff. A validation of this model is provided. The second applies to noise produced under a flight track by normal aircraft operations at an airport. This second is derived from basic force balance equation, including aircraft weight, engine power setting, and aerodynamic lift and drag. The associated noise spectrum is derived using the first method. Additionally, this second method includes the propagation effects of ground, and atmosphere and the shielding effects of wing and fuselage. Noise from ground operations is also addressed. Equations, and measured and predicted sound levels are provided. Lastly, the chapter discusses the use of the second model to predict noise exposures around an airport by including the specifics of flight paths and operations by different aircraft types.

5 The Influence of Operational Factors on Aircraft Noise

In the first brief section, ground operations are examined in terms of factors that alter pollutant emissions, noise and fuel burn. Section 5.2, "Under the flight path", discusses the effects that variables such as takeoff weight, bypass ratio, temperature, and non-standard atmosphere conditions can have on predicted levels. These effects on noise levels are determined by examining changes in the area of the 90 EPNdB contour and in EPNL as computed at ICAO Annex takeoff and landing certification points. The chapter also examines factors altering the 90 EPNdB contour area and certification point EPNL for takeoff and climbing operations and for descent and landing operations.

6 Methods of Aircraft Noise Reduction

The first section provides plots of changes in directivity and spectra for treatments of an Il'ushin-86 inlet and bypass ducts. It also discusses reductions in cabin noise resulting from exterior noise abatement treatments. The chapter establishes the fundamental differential equations of motion for an aircraft as a function of velocity, flight path angle and yawing angle, thrust, aerodynamic drag and lift, wing angle of attack, engine tilt angle, rolling angle, flaps angle, then demonstrates how to meet noise impact criterion for approach and takeoff using various aircraft and operations parameters. Mufflers for engine runups are discussed and equations for computing the effectiveness of acoustic screens for reducing ground operations noise are developed. Methods for minimizing noise impact through flight track assignment by aircraft type are developed.

7 Monitoring of Aircraft Noise

This chapter provides detailed descriptions of noise monitoring systems, their design, monitor site selection, monitoring data and comparison with predictions, noise measurement uncertainties, and uses for computing noise contours. Methods for identifying sources of noise events are discussed. Finally, the Ukraine experience of integrating aircraft design, flight scenario design and environmental cost-benefit is described, with examples shown for noise contour computations, air quality plots (NOx) and crash risk contours.

In general, the book is so full of detailed and complex information, that these brief summaries do not do full justice to the scope of the material. Because of this complexity, interested readers might do well to go to http://www.routledge.com/books/details/9780415240666/ and view pages 15 through 18. These begin the development of the basic acoustic equations and are indicative of the level of detail of the quantitative approach used throughout the book.

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