A proposal for an European aircraft noise calculation procedure

Thomas Myck[1], Berthold Vogelsang[2]

[1] Umweltbundesamt, 06813 Dessau-Roßlau, Deutschland, Email: thomas.myck@uba.de

[2] Niedersächsisches Ministerium für Umwelt und Klimaschutz, 30169 Hannover, Deutschland, Email: berthold.vogelsang@mu.niedersachsen.de

Introduction

In 2002 the European Environmental Noise Directive (END) was published. It requires the production of strategic noise maps and action plans for major noise sources by the member states. Due to the fact that common noise computation methods in Europe were not available at that time the Directive provides interim methods. For aircraft noise the END recommends an interim computation method based on ECAC Document 29 (2nd edition). Improvements with respect to the original Doc.29 were the introduction of a segmentation algorithm as well as the provision of a complete set of emission and flight performance data adopted from the German aircraft noise calculation method.

The European Commission was aware of the fact that these modifications did not make Doc.29 to a "Current Best Practice" noise model. Therefore the Commission was prepared to accept a revised Doc.29 as a harmonised European computation method for aircraft noise. So the ECAC / ANCAT subgroup initiated a Task-Group "AIRMOD" which had to update Doc.29. Result of the AIRMOD activities was the 3rd edition that was published end of Dec. 2005 [1]. This document was elaborated in close co-operation with the SAE Committee A21 - "Aircraft Noise" and observers from ICAO/CAEP. In Feb. 2007 ICAO adopted the revised Doc.29 as a draft for the replacement of ICAO Circular 205. So the European standard finally will turn into an international one.

Parallel to the AIRMOC activities a proposal for a harmonized methodology for calculating environmental noise including noise impact of aircraft noise was developed within the project IMAGINE [2]. This project was funded from the Communities 6th Framework Programme and was focused on the modelling of sound as it is generated by an aircraft and propagated towards a receiver close to the ground. For all relevant acoustical and flight operational input data IMAGINE refers to Doc.29 (3rd edition).

In 2007 a new Act for Protection against Aircraft Noise came into force in Germany [3]. This act requires the establishment of noise protection zones at numerous German airports – civil as well as military ones. A modern methodology for the calculation of these zones was developed. This model called "AzB" was developed to include not only the contributions of "air noise" but moreover those from "ground noise" (i.e. from taxiing operations as well as from the use of auxiliary power units (APUs)). This is a fundamental difference to most aircraft noise models currently used in practice. The AzB published in 2008 [4] incorporates the experiences made during the development of DIN 45684-1 and during the AIRMOD activities.

Since the interim computation method was not intended to be a candidate for a harmonised aircraft noise calculation model the comparison presented below is dealing mainly with Doc.29 (3rd edition) and AzB. IMAGINE is only touched as far as sound propagation modelling is discussed.

Comparison of new European Computation methods for aircraft noise

In general European calculation methods are expected to be compliant to a number of requirements, with respect to accuracy, flexibility and feasibility and in particular with respect to the scope of the Environmental Noise Directive. However there exists a fundamental difference in the scope of the AzB and Doc.29 (3rd edition) respectively: whereas the AzB is develop to deal with forecast situations Doc.29 (3rd edition) is concentrated on past situations as requested by the END (although for action planning it requires to simulate forecast situations too). Both methods are able to predict at least the noise indicators L_{den} and L_{night} as prescribed by the European Environmental Noise Directive.

Modern aircraft noise calculations methods are based on a flight-path segmentation by length or time. Engineering models ("Current Best Practice Models") like Doc.29 (3rd edition) and AzB use a point source model with segmentation by length. Reference models like DLRs SIMUL [5] use a multiple source model with segmentation by time ("moving source"). They are designed to estimate the sound level time histories for single flights from which any noise indicator can be derived.

The quality of a noise calculation in the vicinity of airports/airfields is limited by the following factors:

- o source noise data,
- o source noise model,
- o aircraft performance model,
- o noise model (source-receiver geometry) and
- o sound propagation model.

source noise data

The ICAO (Doc8643) specifies about 4000 Aircraft Types by a designator (ATD). For forecasts this number has to be reduced, usually by introduction of suitable aircraft categories. To get a manageable number of aircraft classes without a loss of accuracy the AzB is based on two principles: acoustic equivalency and noise significance (see Volume 1 of Doc.29 (3rd edition)). The resulting 36 aircraft classes cover jet-aircraft, propeller-driven aircraft and helicopters - civil as well as military ones. The class-specific data were validated by measurements from the airport monitoring systems that all major German airports are obliged to operate (except the data for APUs and ground movements of aircrafts which are derived from other sources). Standard deviation of emission data for a specific aircraft class should be less than 3 dB. Each class is well-defined by specific classification parameters, e.g. the aircraft class S 5.2: (A320, B737-300) by "Jet aircraft with a maximum permitted takeoff mass (MTOM) of between 50 t and 120 t, meeting the requirements of Annex 16 to the Convention on International Civil Aviation, Volume I, Chapter 3 or Chapter 4". Due to German law the aircraft classes have to be checked and revised periodically by the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety.

By contrast Doc.29 (3rd edition) uses a different approach: it is based on individual actual aircraft types and versions (i.e. airframe/engine combinations) and recommends to substitute an „unknown" aircraft type by one „that is available and that is acoustically equivalent, if necessary by an appropriately scaled number of them".

source noise model

Doc.29 (3rd edition) uses the Aircraft Noise and Performance (ANP) database that "contains aircraft and engine performance coefficients and NPD relationships for a substantial proportion of civil aircraft operating from airports in ECAC states". The NPD data consist of maximum and time integrated weighted sound pressure levels. Although spectral information is provided by some "spectral classes" it is not used for the sound propagation calculations.

Doc.29 (3rd edition) accounts for the directional characteristic of an aircraft in two ways: a simple semi-empirical dipole model describes the longitudinal directivity whereas a laterally directivity is modelled by an empirical function accounting for installation effects (i.e. wing- or fuselage mounting of engines).

In contradiction the AzB strongly consequently separates emission (sound power in octave-bands) and transmission. In place of using spherical harmonic functions for a description of the 3-dimensional directivity, the AzB uses a multipole expansion (3 coefficients) in octave bands that describes only a longitudinal directivity. A laterally rotational symmetry is assumed because the airport monitoring systems are not able to produce reliable data on lateral directivity.

aircraft performance model

The AzB uses a set of standard operational parameters for each aircraft class ("fixed point flight profiles") whereas Doc.29 (3rd edition) calculates the flight profile depending on aircraft mass, flight-track shape and operating procedure. The aerodynamic and performance parameters needed for the calculation of such "procedural profiles" are stored in the ANP, the underlying performance model is a simple flight-mechanical mass-point-model.

noise model:

The core of AzB is a segmentation procedure in three steps. The first two steps are pre-processing and generate flight-path sub-segments for which the specific emissions between adjacent ones differ in no case by more than 1 dB. During the calculation of the sound levels at a particular observer location the flight-path sub-segment has to be further subdivided until it satisfies the assumption of propagation from a point source representing the corresponding flight path segment.

Doc.29 (3rd edition) uses a segmentation procedure in two steps: the first one is nearly identical to the AzB whereas the second step is a slightly different approach distinguishing between T/O-roll-, airborne- and transitions-segments rather than accounting for specific emissions.

Both models describe the lateral spreading of real flight tracks by a central "backbone-track" with dispersed 'sub-tracks'. The AzB prescribes 15 sub-tracks whereas Doc.29 (3rd edition) recommends at least 7.

sound propagation model

The propagation of sound over longer distances is a characteristic of aircraft noise. Other kinds of environmental noise like road traffic, railway or industrial noise usually do not propagate over longer distances since the noise sources are weaker and located on the ground. There is no great difference between AzB and Doc.29 (3rd edition) with respect to sound propagation modelling. Both methods are based on the same straightforward empirical approach to describe air- and ground absorption (with a slightly different approach for the latter effect) and do not explicitly model meteorological effects like wind and temperature gradients.

Discussion and Outlook

In general a model including more features than another is not necessarily the better one. Or in a slightly modified quotation (Doc.29 (3rd edition), Vol. 1): „A practical noise calculation model must be simple, practical, unambiguous, and capable of accurate measurement (using conventional, standard instrumentation)". AzB and Doc.29 (3rd edition) can be seen both as "Current Best Practice" nevertheless showing the following differences:

Field of application of the AzB are civil airports as well as airfields, heliports, military airports whereas Doc.29 (3rd edition) is limited to civil airports. In addition the AzB includes ground noise sources.

Although the modelling of shielding effects of buildings is beyond the explicit scope of Doc.29 (3rd edition) and AzB the latter one is prepared to consider shielding these effects according to ISO 9613-2. However it must be noticed that these effects have an influence only in the nearest vicinity of aerodromes. They do not change the results of noise protection areas significantly.

On the one hand the AzB uses a more sophisticated directivity model capable of being extended; on the other hand Doc.29 (3rd edition) is not restricted to standardised flight profiles hence offering more flexibility with respect to investigations on flight procedures.

Both methods use similar propagation models. The recommended IMAGINE propagation model, which is easy to implement in the AzB, does not persuade in particular for noise mapping. It is intends to follow a different way namely a classification concept for propagation situations as a general method (VDI guideline 4101. The guideline formulates source independent propagation schemes for arbitrary applications.

A substantial conceptual difference is that Doc.29 (3rd edition) gives only recommendations whereas the AzB prescribes the calculation method and data formats unambiguously. This makes quality control much easier since a correct transformation of the model algorithms to software should provide well-defined results. The German Federal Environment Agency defined a set of exercises (e.g. a test airport) which have to be fulfilled for quality control of the AzB (i. e. programs can be certified). So different calculation programs for commercial as well as for scientific purposes are available. Furthermore a standardised interface for data interchange (QSI) is defined by DIN 45687.

The bottom line is that the AzB shows a couple of substantial advantages against the other above-mentioned calculation procedures. Therefore, it is a candidate for a future harmonized European computation method for aircraft noise.

References

[1] European Civil Aviation Conference: Methodology for Computing Noise Contours around Civil Airports. Volume 1: Applications Guide, Volume 2: Technical Guide. ECAC.CEAC Doc.29, 3rd Edition, December 2005. Download http://www.ecacceac.org.

[2] http://www.imagine-project.org

[3] Bekanntmachung der Neufassung des Gesetzes zum Schutz gegen Fluglärm (Act on Protection against Aircraft Noise) of 31.10.2007 (Federal Law Gazette (BGBl. I) p. 2550)

[4] Bekanntmachung der Anleitung zur Datenerfassung über den Flugbetrieb (AzD) und der Anleitung zur Berechnung von Lärmschutzbereichen (AzB) (Instructions on the Acquisition of Data on Flight Operations and the Calculation of Noise Protection Areas) from 19.11.2008, Bundesanzeiger

[5] Isermann, U.: Erweiterung des Rechenprogramms SIMUL. Forschungsverbund Leiser Verkehr, Bereich Leises Verkehrsflugzeug, Projekt 1600, Einzelaufgaben 1624-1627, Göttingen, Juni 2007.