UDC 629.7.534.2 (045)

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ACCOUNTING FOR INFLUENCE OF THE OPERATIONAL FACTORS IN AIRCRAFT NOISE CALCULATIONS AROUND THE AIRPORTS

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Basic differences between Ukrainian method for aircraft noise calculation and current ECAC proposal are considered in the article: they include the influence of operational factors on noise radiation and propagation.

Розглянуто основні відмінності між українським методом розрахунку авіаційного шуму і поточним методом, що рекомендується Європейською конференцією цивільної авіації. Показано вплив експлуатаційних факторів на випромінювання і розповсюдження шуму.

Introduction

The workshop of the ANCAT Sub-Group on Aircraft Noise Modelling (AIRMOD) was held at the ECAC offices from 25 to 26 November 2004 [1] with the task to develop proposals for updating ECAC-CEAC Doc 29. A new proposed revised document is referred to now as 'Doc 29R'. It is planned to split it into three parts, Volume 1: Applications Guide, Volume 2: Technical Guide and Volume 3: Validation Guide.

The general objective of the workshop is to evaluate the practical implementation of the whole Doc 29R methodology by comparing noise contours for a range of airports calculated using: (1) the relevant national model; (2) the EC Interim Model; and (3) the ECAC Doc 29R model.

At first meeting the Ukrainian approach for the calculation of flight noise events and noise contour modelling around airports, which presented in [2]. This method is based on the ‘noise radius’ concept [3]. Flight profile data is computed using aerodynamic information obtained from flight and engineers’ performance manuals for FSU aircraft.

At second meeting the Ukrainian calculation approach [4] was compared with new revised ECAC method. It was concluded that ANP (Aircraft noise performance) database for IsoBella (Ukrainian software tool for noise assessment) currently is re-examined, and it is in full accordance with Doc 29R methodology.

The differences between the results were tried to be explained by influence of operational factors, some of them were emphasized at third meeting of the AIRMOD [5]. Here the details of these explanations are analyzed deeply.

Brief review of the calculation method

Current version of the Ukrainian calculation technique entirely complies with ICAO Cir. 205, ECAC Doc 29, and INM 6.0 Technical Guide. This calculation procedure includes the following main stages:

1) flight path (segmentation) designing along prescribed flight ground tracks;
2) noise indices calculation within a grid or discrete points;
3) noise contour definition for specific values of the noise indices inside the grid.

Concerning noise indices – maximum $L_{A\max}$ and equivalent L_{Aeq} are of the main interest because they provide a basis for noise zoning regulations. At the first stage the Ukrainian method is similar to the current ECAC technique:

– flight paths must be built along ground tracks around the runways of the airport under consideration like flight profiles;
– flight profiles are calculated (in segmentation technique) for previously defined flight stages, such as take-off roll, climb (descent) with acceleration (for example, during flap retraction phase) or at the constant speed etc.

Main difference in assessment of the take-off roll and safety distance (till height 10.7 m) between the current national method and ECAC technique consists in direct calculation of roll distance under Miele approach [6] and accelerated climb with gear retraction till height h =10,7 m and safety speed v_2 at this height. Other flight stages are calculated in the same manner as it is proposed in ICAO Cir. 205 [7] and ECAC Doc 29, while not using the averaged coefficients, but real lift and drag coefficients (using the real aircraft polara) and real thrust functional dependence on engine mode, flight altitude and speed.

Of course, such approach is possible to be provided that aircraft/engine parameters are known.

New international Aircraft Noise and Performance Database (ANP, which may be found on http://www.aircraftnoisemodel.org) allows to extend applicability of the national method owing to including the aircraft types that were missed in the national database used for current method.

Noise Level Calculation

Noise level calculation for discrete or mesh points of the grid are based on usage of NPD-relationships, typical for the aircraft/engine. Corrections to them must be provided with account of ground effect, directivity of noise radiation, sound shielding, installation effects etc. NPD-curves named in the national method as Noise Radiuses [2] are defined in the same manner for reference conditions, which are mostly required for noise zoning assessment (merely the same as in ICAO Cir. 205). In particular cases, different from the reference flight conditions, Noise Radiuses are to be recalculated.

So, for exposure indices the flight speed influence may be considered using known functional dependence [3] between Noise Radius R_N (i.e. distance for particular mode and index value) and flight speed v:

$R_N\, v = \text{const}.$

Different atmosphere operation factors, such as air temperature, noise radiation and air absorption may contribute essentially to NPD recalculation. Therefore the aircraft/engine reference spectra are used, just as in the new ECAC approach or INM current version. For noise radiation the recalculation is performed with account of dominant noise source for aircraft and the flight mode (stage) under consideration. There are three possible dominant sources considered under the current national technique: jet (usually, by-pass jet), fan (in forward and upward directions of noise propagation) and an airframe. Specific corrections for noise indices are included in the functional dependence on dominant source.

For different air absorption features the correction is performed just as in the new ECAC approach, but according to ISO 9613-1 [8] calculation scheme for coefficients and recalculated spectrum.

Directivity patterns are defined for various aviation engine types (fig. 1), and at that not only general pattern corresponding to ICAO Cir. 205 [7] model (applicable exclusively for jets) is used, but the specific directivity patterns of particular engine types, as well.

Installation effects are not considered by the current national methodology, but recent investigation concerning few types of the aircraft would produce possible corrections for engine installation, which are representative for flight turns and sideline control points at the noise calculation.

Ground effects are calculated under the routine procedure with account of surface covering effect and use of reference noise spectrum (LATER-generator in IsoBell software). SCREEN-generator is used for assessment of shielding effect (Maekawa model [9; 10]).

Noise contours are defined for pre-calculated levels in the mesh points of the grid using well-known Wasmer Consulting method (may be found in Internet http://www.wasmerconsulting.com) used in INM and NoiseMap software.

Influence of operational factors

In ICAO Cir. 205, ECAC Doc 29, and INM 6,0 before the interpolated/extrapolated noise level data is utilized for computations, an acoustic impedance adjustment, designated by the symbol AI_{ADJ}, is applied. Acoustic impedance is defined as the product of the density of air ρ and the speed of sound c, and it is a function of temperature, atmospheric pressure, and indirectly altitude – all of them are important operation parameters of the flight.

The noise-levels in the INM NPD database are corrected to reference-day conditions: temperature 15°C, pressure 760 mm of mercury, and altitude mean sea level. The noise levels can be adjusted to airport temperature and pressure by:

$$AI_{ADJ} = 10\log[\rho c / 409{,}81];$$

$$\rho c = 416{,}86\left(\delta / \Theta^{T/2}\right),$$

where Θ is ratio of absolute temperature at the observer to standard-day absolute temperature at sea level;

δ is ratio of atmospheric pressure at the observer to standard-day pressure at sea.

The concept of acoustic impedance is used in INM to correct the reference-day NPD data to the off-reference, non-sea level conditions associated with the user specified case airport. Acoustic impedance is the product of the density of air and the speed of sound, and it is a function of temperature, atmospheric pressure, and indirectly altitude. An acoustic impedance of 409,81 newton-seconds/m^3 corresponds to the reference atmospheric conditions as defined by FAR Part 36. Acoustic impedance adjustments are made to move from reference-day sea-level conditions to airport-specific temperature and altitude. Our investigations, made with NoBel software, show that such an impedance adjustment is not enough, it is too small for account of operational contribution to the noise levels.

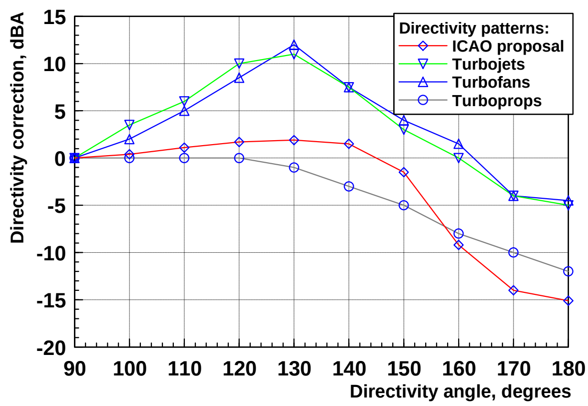

Fig. 1. Generalised directivity patterns for specific engine types

On fig. 2 the results for Iljushin-86 show the possible difference between sound pressure levels (SPL) at different air temperatures. The differences for overall SPL L_{in} and for L_A are shown in fig. 3. They (dL for L_{in} and dLA for L_A) are more than twice larger comparing with impedance adjustment (fig. 4). To include this aspect in consideration the approach of Noise Radius Generator in IsoBella software has been proposed [2].

Choice of airport and scenario

As it was proposed previously the International Airport Borispol' has been chosen for calculation of aircraft noise contours using two soft-wares – USA FAA INM 7,0 and Ukrainian IsoBella.

Scenario for calculation was defined grounding on 1998 data, because that year most part of flights was performed by aircraft of former USSR production.

Thus it was interesting to compare the calculation results for real data for aircraft flight and noise performances, used in IsoBella, and for their substitutions, used in INM.

A list of flights for 1 day under consideration is shown in tab. 1.

Only day and night periods were included, because in 1998 the evening period did not considered at all.

Concerning the indices to be calculated, the meeting recommendation to follow the EC Directive 2002/49 rules was used.

Therefore, L_{DEN} (day-evening-night equivalent level), L_{night} (night equivalent level) were calculated, plus L_{Aeq}, which is used in Ukrainian norms.

The values to be calculated are following: 55, 60, 65, 70 and 75 dB.

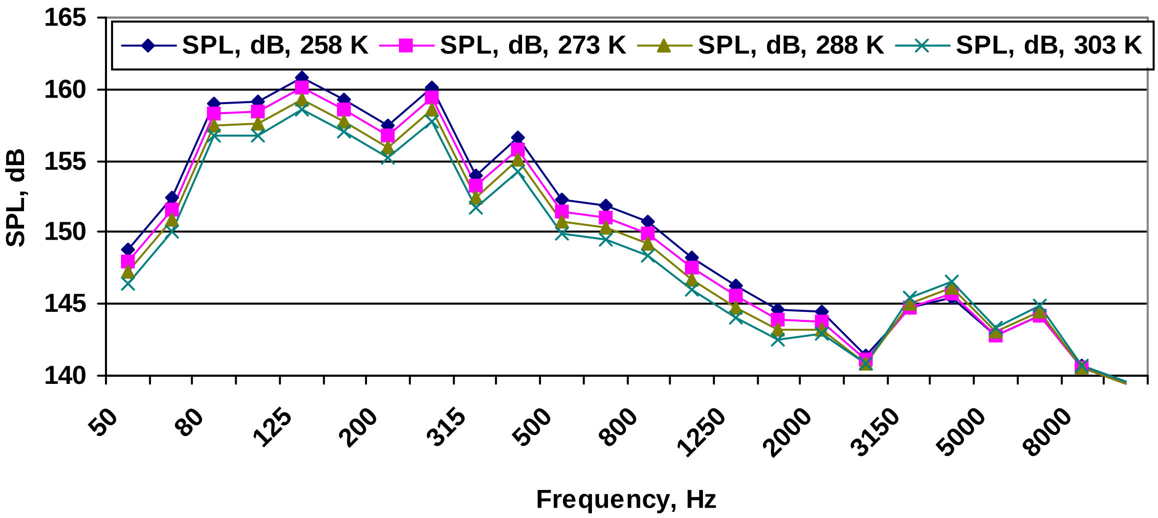

Fig. 2. Temperature influence on noise pressure levels of Iljushin-86 aircraft at distance 1 m

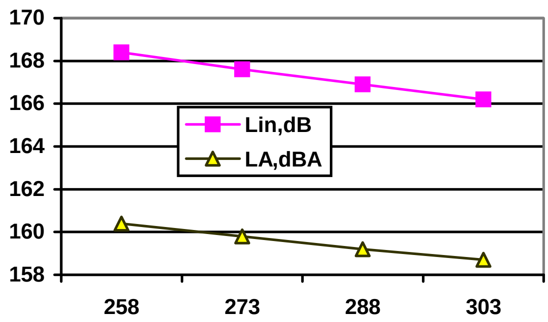

Fig. 3. Dependence for overall SPL L_{in} and L_A from air temperature

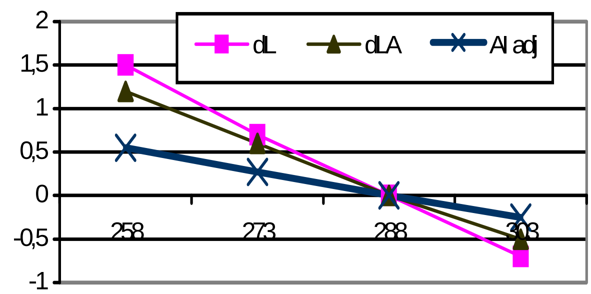

Fig. 4. Comparison of the differences for noise indices with impedance adjustment

Table 1

Flight scenario for calculation

Aircraft type	Day	Evening	Night
TU-154	12	0	2
TU-134	9	0	2
YAK-42	3	0	0
AN-124 (Ruslan)	3	0	0
AN- 24	5	0	0
IL-62	3	0	0
IL-76	3	0	0
IL-86	2	0	0

Results of calculation

For IsoBella output results NMPlot ver. 4,93 was used, to be sure that contouring is defined in a same manner as in INM.

For that Wasmer Consulting Noise Model Grid Format (NMGF) was implemented in IsoBella.

The calculated areas of the contours are shown in tab. 2–4 accordingly.

Table 2

Noise contour area (in sq. miles) for L_{Aeq}

L_{Aeq}, dBA	IsoBella	INM	IsoBella/ INM
55,0	91,973	62,270	1,47
60,0	29,705	26,397	1,125
65,0	12,422	11,829	1,05
70,0	5,543	5,614	0,99
75,0	2,772	2,597	1,07

Table 3

Noise contour area (in sq. miles) for L_{DEN}

L_{DEN}, dBA	IsoBella	INM	IsoBella/ INM
55,0	48,240	37,729	1,28
60,0	18,700	16,593	1,127
65,0	8,340	7,900	1,055
70,0	4,145	3,874	1,07
75,0	1,942	1,346	1,04

Table 4

Noise contour area (in sq. miles) for L_{Night}

L_{Night}, dBA	IsoBella	INM	IsoBella/ INM
55,0	15,336	15,196	1,01
60,0	6,198	6,894	0,9
65,0	3,002	3,437	0,873
70,0	1,348	1,190	1,133
75,0	0,572	0,502	1,14

For the contours of the main interest the difference between their areas do not exceed 10–15 %, higher results mostly are calculated by IsoBella software. This overestimation is possible because the NPD values, used currently in IsoBella, are the simple statistical values, defined from measurements made USSR-wide without strict solutions for aircraft noise model tasks.

This work is doing now, but it may be finished correctly, when the ANP database will be on-line (currently on http://www.aircraftnoisemodel.org) with all necessary requirements for such performances. Besides the theoretical ground of the calculation models are strictly compared too.

Conclusions

ANP database for IsoBella currently is re-examined, to be fully in accordance with Doc 29R methodology.

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The editors received the article on 19 October 2006.