Effect of flight schedule and fleet mix on the ground noise around airports based on a multi-level, multi-fidelity approach

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Abstract

One of the central objectives within the strategic paper Flightpath 2050 is to reduce the aircraft ground noise. A recently published approach introduces a three-level system in order to assess and predict the effect of low-noise vehicles along their individual flight onto the overall ground noise around an airport. Three aircraft types, the reference aircraft (V-R), the modified reference aircraft (Retrofit) and the modified low noise configuration (Gamechanger) have been transferred into the airport scenario. The initial assessment was limited to a fixed airport scenario, as described in [3]. Each scenario includes multiple aircraft, the runway system, individual flight paths and flight routes over ground (departure and approach). This contribution will now apply modifications to the basic scenario, i.e., adapting the number of flights, the ground routing, and the flight procedures. Two scenarios are defined and assessed in detail. The total sound exposure level in different scenarios will be given and compared.

Introduction

Ground noise assessments have played an important role in recent decisions in preventing airport expansion and in supporting costly relocations [5]. A schematic picture of future airport has been shown in Fig. 1. A multi-level, multi-fidelity approach is used to assess the noise exposure on the ground caused by present and future aircraft [3]. This approach couples existing tools of different complexity for different levels (component, single aircraft, airtraffic scenario). It leads to an integral description of the entire problem that preserves the relevant physical relations though the model is coarsened from one level to the next. It enables the correlation of changes in the aircraft design and noise exposure levels on the ground and gives the opportunity to assess and optimize aircraft design.

Based on this approach, here a ground noise assessment of two scenarios in the vicinity of an airport is evaluated. Moreover, it is demonstrated how the ground noise exposure in process of the expansion of an airport such with increasing number of runways, of daily aircraft movements, and of flight paths can be assessed.

Method

Reducing the noise emissions requires comprehensive systems approach, therefore a multi-scale and multi-fidelity noise assessement approach comprising three levels from

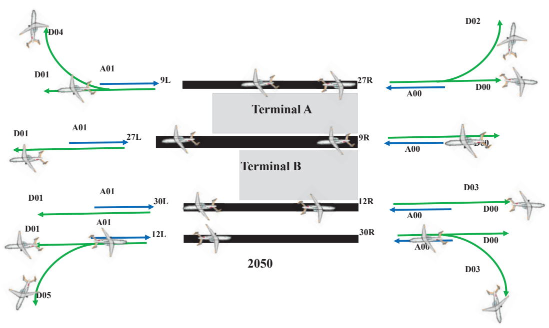

Figure 1: A schematic picture of future airport.

component level (level 1) over single aircraft level during all phases of operation (level 2) to system scenario level (level 3) is presented [3]. Effects of new aircraft designs in combination with low noise technologies on component level can be evaluated with the established noise prediction chain using Computational Fluid Dynamics (CFD) code TAU and Computational Aeroacoustics (CAA) code PIANO [4] on level 1, Parametric Aircraft Noise Analysis Module (PANAM) [1] tool for noise emission on level 2, and sonAIR [6] for ground noise exposure level on level 3 (see Fig. 2).

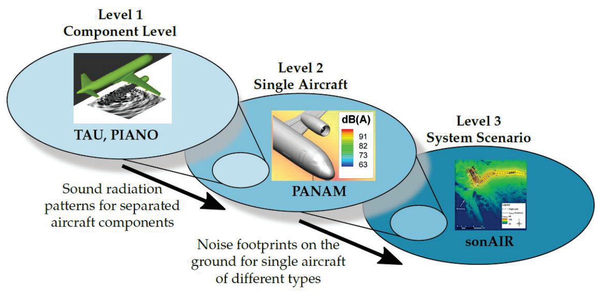

Figure 2: Ground noise predictiona chain: Multi-fidelity, mulit-level approach [3].

The process of coupling has been applied to two reference aircraft, one is an aircraft similar to a conventional A319 aircraft and another is a low-noise design aircraft [3] (see Fig. 3). Three modifications including landing gear mesh fairing, porous flap side edge, and low noise slat technologies have been applied into the both reference aircraft. Thus, the modified reference aircraft, in the following referred to as "Retrofit" and the modified low noise configuration, in the following referred to as

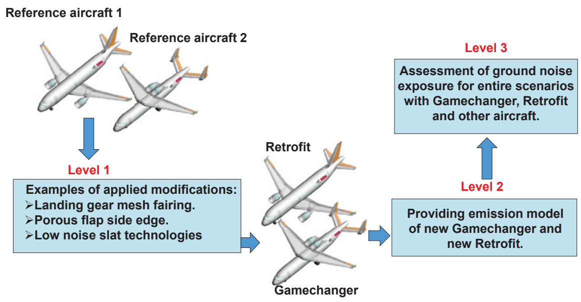

Figure 3: A schematic picture of the modification process applied on two reference aircraft in a three-levels framework.

Gamechanger are investigated within this study.

Objectives

Three groups of ICAO aircraft codes are considered in a virtual airport (SANC-TE). SANC-TE topography can be found in [3]. Two scenarios are defined in order to assess the effect of new aircraft design on ground noise exposure in a large scenario system. Percentage of operations in each scenario are given in table 1. Scenario 2 including Gamechanger and Retrofit which are categorized in C-modified ICAO code contains low noise technologies while scenario 1 does not. Percentage of operations for ICAO code D and E are considered to be constant. The software SonAir [6] is used to evaluate the total ground noise exposure for both scenarios for the years 2010 (one runway) and 2020 (two runways) as it is depicted in Fig. 4. The runway is defined by SANC-TE with length of 2500m and the sound exposure is calculated on an area of 24km across 24km with a receiver mesh size of 200m. Six departures and two approaches in the airport with one runway is assumed while eight departures and four approaches are considered in the airport with two runways. One of the runways is located in the center of coordinate system and another parallel runway is 500m far away of the first runway, see Fig. 4. The pattern of flight paths in 2020 is changed due to avoiding flight accidents. Daily aircraft movements in one runway in year 2010 are 290 and in year 2020 are 580. Flight path distributions are shown in Fig. 4. The sound propagation is calculated by the use of propagation model which is available in sonAir, called sonX [7] although the sound propagation is based on homogeneous atmosphere in [3].

Table 1: Percentage of operations per ICAO code. C-modified includes Gamechanger and Retrofit.

ICAO Code	Scenario 1	Scenario 2
C(A319)	60%	0%
C-modified	0%	60%
D(B767)	35%	35%
E(B747-400)	5%	5%

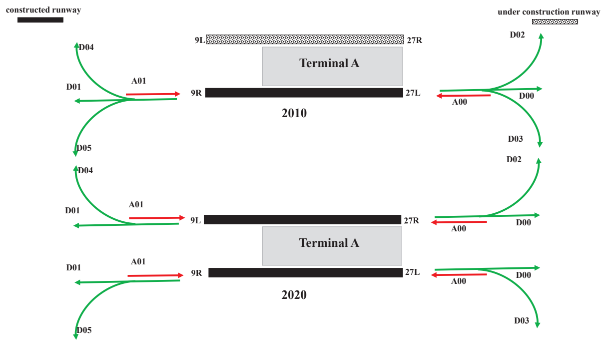

Figure 4: A schematic picture of two runways.

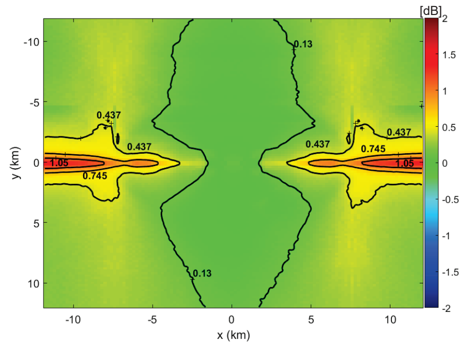

Figure 5: Level differences of the ground noise exposure of scenario 1 minus scenario 2 are presented for year 2010.

Results

The total sound exposure level based on the yearly movements and averaged over 16 hours of the day (6 to 22 o'clock) is calculated in this study. The influence of the modified airframe sources of Retrofit and Ggamechanger in a yearly scenario is investigated. Level differences of the ground noise exposure between scenario 1 and scenario 2 (see table 1) are presented for year 2010 and 2020 in Fig. 5 and Fig. 6, respectively. The areas with the highest exposure levels are located in the vicinity of the runway. About one exposure level reduction is observed when Gamechanger and Retrofit are used.

Identical route distribution has been used for all aircraft in order to enable a fair and appropriate comparison in both scenarios. The difference of the ground noise exposure levels is symmetry along runway axis in year 2010

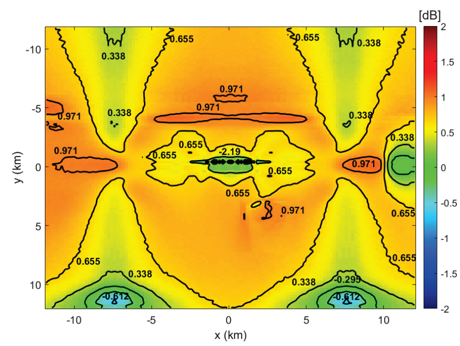

Figure 6: Level differences of the ground noise exposure of scenario 1 minus scenario 2 are presented for year 2020.

while an asymmetrical result is observed in year 2020 because of an asymmetrical computational grid.

The ground noise exposure is increased in the vicinity of runways if we use Gamechanger and Retrofit as it is seen in Fig. 6. The levels differences of the ground noise exposure between scenario two and one is about 2dB in year 2020 in the runway area.

Conclusions

One major goal of Flightpath 2050 is the reduction of the perceived noise by 65% for flying aircraft [2]. Thus, the noise emission of future aircraft designs with the consideration of effective low noise technologies in the vicinity of airport is necessary to be assessed. A three level approach [3] based on numerical simulation has been used to assess ground noise exposure. This paper focuses on level 3 in which the prediction of ground noise for entire scenarios with many aircraft is important. The emission model of the Gamechanger and Retrofit as the modified aircraft have been obtained in level 2 and are imported into sonAir as the input data.

Ground noise exposures of a virtual airport (SANC-TE) in a process of development in year 2010 and 2020 with the consideration of new aircraft design have been assessed. Two scenarios of many aircraft movements averaged over a year of operation are considered. If we use C-modified ICAO aircraft types (Gamechanger and Retrofit), ground noise exposure decreases about one decibel in the vicinity of airport. The difference of the ground noise exposure between scenario one and two increases with enlarging the distance between the middle of the runway and the listener.

Acknowledgments

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References

[1] Lothar Bertsch. *Noise Prediction within Conceptual Aircraft Design*. PhD thesis, 2013.

[2] Marek Darecki, Charles Edelstenne, Tom Enders, Emma Fernandez, Peter Hartman, Jean-Paul Herteman, Michael Kerkloh, Ian King, Patrick Ky, Michel Mathieu, Giuseppe Orsi, Gerald Schotman, Colin Smith, and Johann-Dietrich Wörner. Flightpath 2050. *Flightpath 2050 Eur. Vis. Aviat.*, page 28, 2011.

[3] Jan Delfs, Lothar Bertsch, Christoph Zellmann, Lennart Rossian, Ehsan Kian Far, Tobias Ring, and Sabine Langer. Aircraft Noise Assessment - From Single Components to Large Scenarios. *Energies*, 11(2):429, 2018.

[4] Jan W Delfs, Marcus Bauer, Roland Ewert, Herwig A Grogger, Markus Lummer, and Thomas G W Lauke. Numerical Simulation of Aerodynamic Noise with DLR's aeroacoustic code PIANO. pages 1–116, 2008.

[5] Maryam Kiani Sadr, Parvin Nassiri, Seyyed Mohsen Hosseini, Masoud Monavari, and Alireza Gharagozlou. Assessment of land use compatibility and noise pollution at Imam Khomeini International Airport. *J. Air Transp. Manag.*, 34:49–56, 2014.

[6] C. Zellmann, B. Schäffer, J. M. Wunderli, U. Isermann, and C. O. Paschereit. Aircraft Noise Emission Model Accounting for Aircraft Flight Parameters. *J. Aircr.*, pages 1–15, 2017.

[7] Christoph Zellmann and Jean Marc Wunderli. Influence of the atmospheric stratification on the sound propagation of single flights. *Inter-noise 2014*, pages 1–10, 2014.