‚Is aircraft sound propagation independent from weather conditions?

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1 Introduction

In Germany aircraft noise calculations are based on AzB [1], internationally DOC29 [2] is used. Both procedures use empirical model assumptions without referring to the different physical aspects of sound propagation. This results in large deviations for the calculated levels, when these physical effects have a significant influence, as is the case e.g. for close to the ground propagation, where refraction, ground absorption and reflection are dominant factors [3]. On the background of the effort of the EU to harmonize sound propagation predictions (CNOSOS) it is reasonable to require that AzB, DOC29, leads to the same results for close to the ground propagation as well as the obtained using of ISO-9613-2 [4] or Harmonoise [5] for other sources. This paper compares, as an exemplary example, aircraft noise model aspects for close to the ground propagation situations, which may also be obtained using other models. This also includes model calculations using Kutex [8], a wave theoretical model based on Ostashev [7].

2 Sound propagation models

Wempen: This model assumes locally reacting ground and a homogenous atmosphere and is described in detail in [9]. It describes sound propagation without meteorological influences.

ISO 9613-2: The application of this model is limited from its background to sources up to 30 m above ground and distances of up to 1000 m and little more. The influence of weather conditions is accounted for by a factor , C_{met}, which may be estimated from local weather conditions. It should be noted that for elevation angels of more than 5.7° relative to the ground, C_{met} is considered to be zero. The Harmonoise model substitutes this by using wind- and temperature profiles, but does not go beyond the application range of ISO 9613-2.

AzB: The AzB allows to calculate the level reduction accounting for the distance and the frequency dependent air and ground absorption. The latter describes the sound attenuation for close to the ground propagation. The ground absorption becomes zero for elevation angles of more than 15°. Implicitly soft ground (grass) is assumed. A direct identification of the specific physical effects is not given.

DOC 29: Doc 29, which relates to the sound propagation to SAE 5662 [6], calculates the level reduction comparable to AzB. However, it does not contain specifically air absorption. The ground effect - as a lateral attenuation - depends on frequency and includes the so called “engine installation effect”. The latter indicates oversimplification for the source description based on curve fitting of the noise-power-distance (NPD) relationship.

For obvious reasons the AzB as well as Doc 29 have no limitation for source height or distance, distinguishing between low or high or small and large distances. Both procedures show for zero elevation angles and distances up to 1000 m considerable deviations of more than 3 dB. This holds also in comparison with ISO 9613-2. An additional problem is that it does not contain any directivity corrections.

Kutex: Using the differential equation as derived in [7] for the sound propagation in an inhomogeneous moving medium numerical solutions have been derived which allow to use different wind- and temperature profiles and locally reacting ground. The used profiles are based on the stability classes as defined by the TA-Luft for the wind and by Harmonoise for the temperature. The effect of the ground roughness length is included. Cylinder symmetry with a perpendicular axis through the source is assumed for the wind direction under consideration. This assumption is fulfilled for the temperature profiles and approximately for a wind direction within ± 15°. The profiles approximate the Prandtl-layer as well as the Ekman-layer and beyond to heights up to 4000 m. The Ekman turning of the wind direction is neglected.

3 Results

Two meteorological situations are examined to demonstrate basic differences for day and night time. The first one is a typical very stable situation occurring during night time with few clouds (Stab.Kl. I TA-Luf) with temperature inversion. The other one is a very unstable day time situation with lots of sun and few clouds (Stab.Kl. V TA-Luft). Fig. 1 shows for a wind speed of 2 m/s at 10 m above ground the local radii of curvature for different wind directions as a function of height above ground.

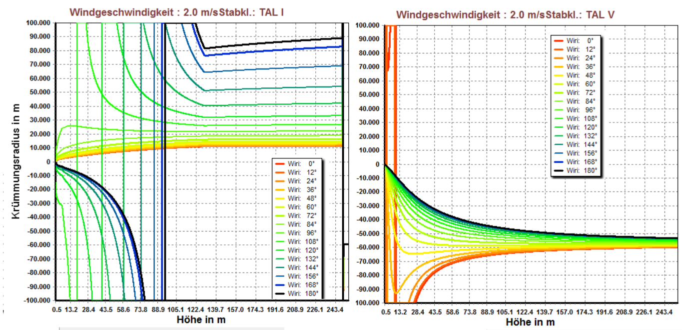

Fig.1: Local radii of curvature for stable (left) and unstable (right) weather conditions.

Under daytime conditions and for down wind conditions deviating up to ± 15 ° from the propagation direction positive radii are observed for source heights of less than 13 m. On the other hand for very stable night time conditions positive radii are observed up to ± 90° up to 250 m, and up to ±110° for lower heights down to 15 m above ground. For neutral weather conditions the down wind angle reduces to ± 45° and a source height up to 30 m, which fits with the figure given in ISO 9613-2 Chap. 5. This means that for sources close to the ground the down wind angle depends strongly on the weather conditions and is less than 45° during typical day time conditions and larger for typical night time conditions. In most cases for sources above 50 m height during day time no down wind conditions occur. At night time beyond 90 m the radii are greater than 40 km and become negative beyond 250 km with radii in the order of -60 km. This is caused by the adiabatic temperature reduction with height of about 1°C per 100 m. This means that for sources well above the ground the meteorological situation in the lower Prandtl layer is of minor importance.

Furthermore it can be seen from Fig. 1 that the radii of 5 km as given by ISO 9613-2 are only observed for heights below 30 m during inversion conditions and down wind conditions ± 30°.

The effect of the different meteorological situations is demonstrated in Fig. 2 for the stable weather conditions during night time and the unstable day time condition and a wind speed of 3 m/s at 10 m height and hard ground with a flow resistance of 5000 kPas/m2:

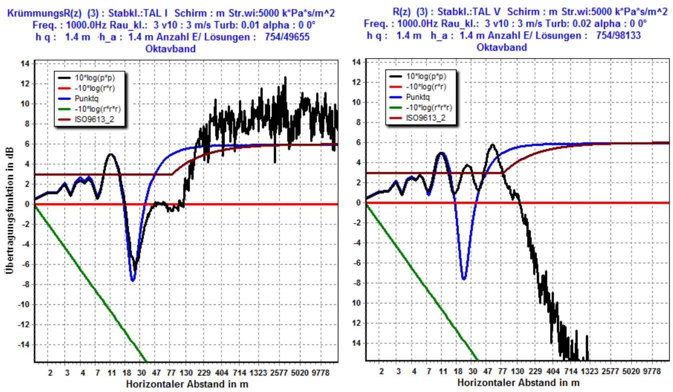

Fig.2: Dependence of sound propagation on meteorological stability 1 kHz octave band. Source and receiver height 1.4 m. 1/r2 red line,1/r3 green line, Wempen blue line, Kutex black line. No air absorption and turbulence.

During night time the additional sound attenuation is negative leading to an increase of 8 dB compared to 6 dB according to ISO 9613-2. On the other hand during day time shadowing starts at 150 m. If turbulence is included the shadow zone is shifted to 600 m, where the transfer function gets below the 1/r2 line.

Another aspect can be observed (s. Fig. 3), by looking at source heights of 100 m for hard and soft ground for day time conditions.

According to AzB for a source height of 100 m and a projected distance of 400 m the ground should have no influence, however differences of up to 5 dB are observed. ISO 9613-2 predicts a difference of 4 dB, Kutex up to 1200 m about 1 dB. Shadowing occurs beyond 2700 m and shows a dependence on ground absorption in the order of 4 to 6 dB.

For source heights of more than 250 m the influence of the different meteorological situations disappears and the sound propagation is dominated by the adiabatic temperature reduction with height, however, there exists no reason why ground absorption should not occur.

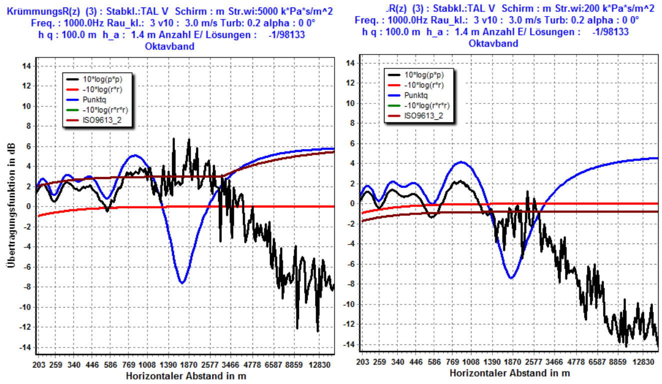

Fig.3: Transfer function 1 kHz octave band, source height 100 m hard (left) and soft (right) ground for day time (Stab.Kl. V, v10: 3 m/s with turbulence).

4 Conclusions and further prospects

The comparison shows that non negligible differences in the sound propagation exist between day and night time. Close to an airport the influence of the ground has to be incorporated. The sound propagation into the shadow zone is dominated by turbulence close to the ground, which differs between day and night considerably.

For source heights of more than 250 m the adiabatic temperature reduction with height dominates the propagation including ground reflection and absorption. Additionally, for those source heights the Ekman layer meteorology with the turning of the wind direction up to 45° might be included and in addition with the ground roughness length the displacement distance. The latter is important to incorporate the effects caused by the ground surface such as forests or similar topographical situations.

5 Literature

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