Recent Trends in Noise Prediction at Workplaces

Florian Völk, Wolfgang Probst
DataKustik GmbH, 86926 Greifenberg, Germany, {florian.voelk,wolfgang.probst}@datakustik.com

Introduction

With the VDI-Guideline 3760 (internationalized with DIN EN ISO 14257, [1,2]), a computational method for indoor sound propagation applied to the acoustic evaluation of work places had been standardized. The employed mirror-source-based approach has been combined with a ray-tracing model recently, largely extending possible fields of application. These new use cases cover especially the modeling of complex sound sources such as machinery and other noise-emitting technical devices, the possibility of taking into account the emission indicators according to the machine directive [3], as well as the computation of complex room geometries, allowing the realistic modeling of work places within the planning phase. By the instrumental prognosis of speech intelligibility, taking into account the noise of technical equipment [4], important aspects of acoustic communication and the recognition of acoustic warning signals became possible. The techniques introduced are discussed by the examples of the layout and room acoustical treatment of production facilities and open-plan offices [5].

Basics of Noise Immission Prediction

The fundamental task in predicting noise immissions at workplaces is computing the sound-pressure levels at receiver positions from the emissions of noise sources. The emissions are commonly specified by the sources' sound-power levels, representing the radiated energy. Knowing the positions of sources and receivers, each contribution at a receiver (each partial level) depends on the positions of sources and receiver and on the specific room-acoustic conditions. In the simplest case, omnidirectional point sources are employed, but other directivities are possible. The immissions are then computed by superposition of all partial levels at the receiver, usually energetically, assuming incoherent contributions.

Most current prediction algorithms are based on statistical or geometrical acoustics, and are therefore valid only with restrictions: statistical approaches assume a diffuse sound field; geometrical methods are correct if the dimensions of relevant objects are large compared to the wavelengths; they fail at low frequencies in small and medium sized rooms.

VDI 3760 (DIN EN ISO 14257)

In order to simplify the computation, room-acoustic conditions are sometimes described approximately by means of statistical models, assuming a diffuse sound field: the actual geometrical arrangement of objects in the scenario is neglected and the partial levels are computed assuming superposed free-field and diffuse-field contributions, taking into account solely the source-receiver distances and the environment's equivalent absorption area A (see VDI 3760 for details). This procedure is obviously invalid for non-diffuse sound fields, which means in most situations in practice.

With the aims of overcoming the restriction to diffuse sound fields, but still providing simple means of calculating noise immissions at work places from source emissions, an additional procedure is defined by VDI 3760: Without taking into account the actual positions of objects and assuming approximately cuboid rooms, an image-source method, globally taking into account scattering, is used to compute the so-called sound-decay curve (SDC, cf. figure 1).

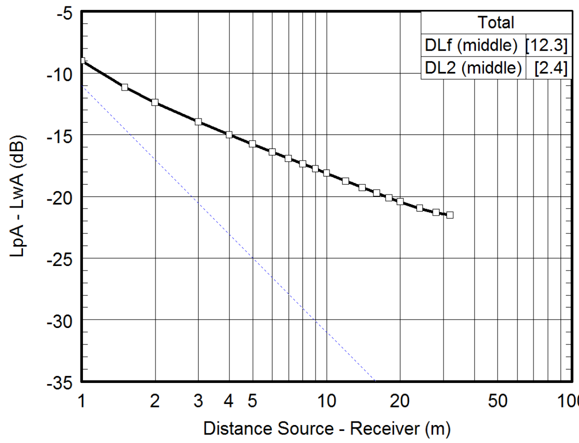

Figure 1: Sound-decay curve (SDC) according to VDI 3760 for an exemplary factory hall (30m × 20m × 6m, cf. figure 2, computed as described by [5]).

The SDC represents, on a level scale, the source-distance-dependent intensity normalized to the source power for a defined receiver path across the room. Average boundary-surface absorption coefficients are taken into account per boundary surface. Objects large compared to the wavelength are incorporated in the image-source model by position independent average fitting density and absorption.

However, objects (machinery, furniture, and wall panels) are still not taken into account with their correct spatial positions. The partial levels are computed regardless of the actual geometric arrangement based on the SDC level at the actual source-receiver distance (cf. figure 2).

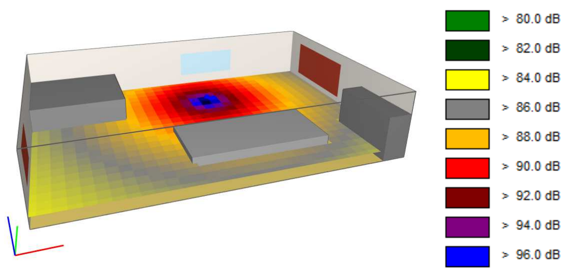

Figure 2: Sound-pressure level distribution according to VDI 3760 of a point source (L_{WA}=106dB) in a factory hall (30m×20m×6m, computed as described by [5]).

Extended Computational Model

In order to overcome the limitations discussed above, a computation strategy combining an extended image-source algorithm and a ray-tracing was proposed for the noise prediction at workplaces (cf. [5]). Combining the advantages of both approaches, such a procedure provides means of computing diffraction, scattering, and transmission effects at reasonable computational cost (cf. [6]), especially taking into account the actual geometrical positions of objects such as machinery and absorbers.

The sound-pressure level distribution predicted using the hybrid model (figure 3) consequently differs from that according to VDI 3760 (figure 2) since objects are taken into account with their acoustic properties and spatial positions.

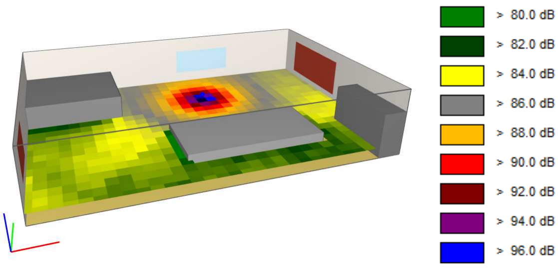

Figure 3: Sound-pressure level distribution calculated using a hybrid image-source and ray-tracing model of a point source (L_{WA}=106dB) in a factory hall (30m × 20m × 6m, situation of figure 2, computed as described by [5]).

Consequently, screening and diffraction effects are visible (compare e.g. the lower right corners of figures 2 and 3), and the actual positions of patches at the walls are reflected in the calculation process and therefore in the level distribution. This allows the prediction of noise immissions at workplaces even in complex scenarios, as for example a bottling plant with an absorbing ceiling, realized by a baffle construction (as shown by figure 4).

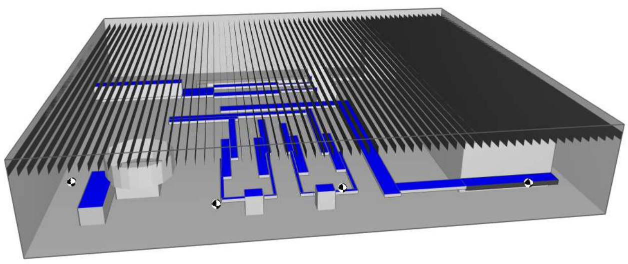

Figure 4: Model of a bottling plant with a baffle ceiling construction, containing all objects relevant for the hybrid propagation model of [5]. Black-and-white spheres indicate workplaces, blue objects sound-emitting machinery.

Furthermore, the prediction of the spatial distribution of reverberation times and speech-intelligibility measures as for example the speech-transmission index (STI, [4]) becomes possible. Figure 5 show as an example predicted areas of equal STI for a female talker (red dot, with background noise) in an open-plan office. The geometric arrangement and acoustic properties of the screens between the working groups is reflected in the STI distribution and consequently in the resulting areas of equal STI.

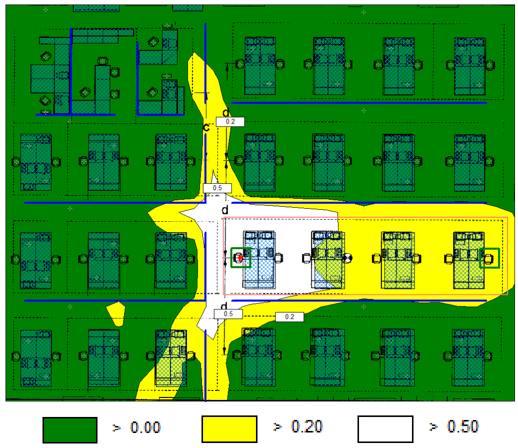

Figure 5: Areas of equal speech-transmission index (STI, DIN EN 60268-16) for a female talker (red dot) in an open-plan office (cf. [5]). The blue screens between working groups are taken into account with their actual positions.

Conclusions

Exceeding the functionality of currently standardized methods for the noise prediction at work places, state-of-the-art sound-propagation models are able to predict spatial sound-pressure level distributions as well as octave-band reverberation times and speech-intelligibility measures. In order to exploit this lately available more realistic planning tools for noise-immission protection, standards regulating complex computational models are required and are already on their way. Combined with existing planning guidelines and limiting values (e.g. [7]), standardized state-of-the-art prediction methods will provide a common basis for workplace layout, room optimization, and action planning in general.

References

[1] VDI 3760: Berechnung und Messung der Schallausbreitung in Arbeitsräumen. Beuth, Berlin, 1996

[2] DIN EN ISO 14257: Akustik – Messung und Parametrisierung der Schallausbreitungskurven in Arbeitsräumen zum Zweck der Beurteilung der akustischen Qualität. Beuth, Berlin, 2011

[3] DIN EN ISO 11200: Akustik – Geräuschabstrahlung von Maschinen und Geräten – Leitlinien zur Anwendung der Grundnormen zur Bestimmung von Emissions-Schalldruckpegeln am Arbeitsplatz und an anderen festgelegten Orten. Beuth, Berlin, 2012

[4] DIN EN 60268-16: Elektroakustische Geräte – Teil 16: Objektive Bewertung der Sprachverständlichkeit durch den Sprachübertragungsindex. Beuth, Berlin, 2012

[5] DataKustik GmbH: CadnaR – Prediction of Noise Levels inside Rooms. User Manual. Greifenberg, Germany, 2014. URL: `http://www.datakustik.com`

[6] Vorländer M.: Computer simulations in room acoustics: Concepts and uncertainties. J. Acoust. Soc. Am., 133 (2013), 1203-1213

[7] DIN 18041: Hörsamkeit in kleinen bis mittelgroßen Räumen. Beuth, Berlin, 2004