The Calculation of Sound Propagation in Rooms to determine Noise Exposure at Workplaces

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Introduction

Sound propagation in workrooms is generally calculated using the techniques described in VDI guideline 3760 /1/. The advantage of this procedure is a very quick modelling of even complex situations and the possibility to use exactly the emission data of machinery and other sources that are available according to the European Machine Directive. According to this VDI guideline rooms are simulated by box shapes, absorptions are used in the calculation as mean values averaged over each of the 6 surfaces and the calculation is based on the mirror image method according to the basic work of Kuttruff and Jovicic.

In a research project funded by BAuA /2/ possible improvements of the method have been investigated. The radiation of real machines and other sources is not omnidirectional and it must be possible to include different emission in dependency of the direction. From the sound pressure levels measured in a simple way around a machine a directivity must be derived and used for the direct sound and for all reflections. A further improvement was the integration of screening effects, because barriers and partial walls as well as the structure of large machines change the sound distribution. Noise levels at work places can only be predicted with acceptable accuracy if these screening effect are simulated. In the abovementioned study it was found that reflected rays up to 2^{nd} order should be included in the screening calculation. These improvements have been integrated in the software package CadnaR /3/ and some of these applications have been presented /4/.

Screening

The calculation method is a real 3-dimensional mirror image method. In the existing software realization all surfaces are parallel to the x-y, y-z and x-z planes – this means the real industrial environment is simulated by a world composed of boxes. While sound propagation outside is generally based on 2,5-D calculations where the possible direct and reflected rays are constructed in top view and afterwards the height information with z-coordinates is added, the indoor calculation is completely in 3D.

All sources – even complex machines – are simulated by boxes covered with point sources. For area sources one, for line sources two and for point sources three dimensions of the box are 0.

The resulting sound pressure level is calculated at defined receiver positions and on grids. The latter are shown as coloured noise maps and give an overview about the distribution of noise in an area.

To calculate the screening effect a modified Maekawa approach – described in /2/ - is applied. As it is shown in Figure 1, the line from source to receiver is used to define two planes and to detect the shortest way between them.

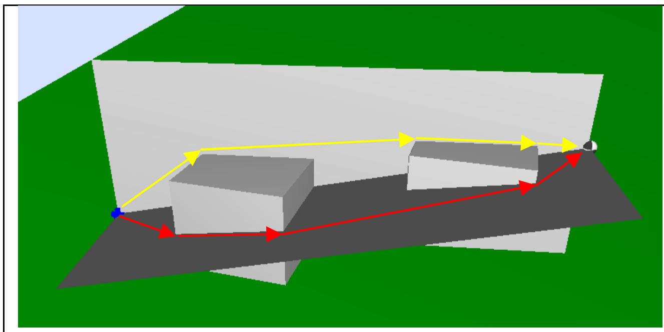

Figure 1: The straight ray from mirror source to receiver is part of the two planes that are used to define the shortest path around the objects.

The source in figure 1 can be a real or a mirror image source. The procedure is fast enough to perform calculations for realistic problems in acceptable times and it is planned to integrate also reflections at the screening structures in near future.

Local absorption

In the VDI 3760 approach the real intersection of the ray from the mirror image source to the receiver was not known – therefore the mean absorption of the complete room surface instead of the absorption at this point was used. This has been improved. The local absorption at the intersection point is used and therefore all these important measures like an absorbent coating of the wall directly behind a machine e. g. in connection with an optically transparent screen in front of it can be included.

Directivity

Directivity is an important property of the sound radiation of machinery that cannot be neglected. Figure 2 shows a typical example of machines in packaging and bottling plants – they look like enclosures with an open roof. Such a machine radiates most of the sound energy upwards – if an absorbent ceiling is installed in this workroom it will show a much better noise reduction than in case of omnidirectional radiation.

Figure 2: Machines with directivity.

This directivity is defined in octav-bands with two angles in steps of 5 degree. The import and definition of such directivity patterns is effectively supported to avoid that all these hundreds of values must be calculated and typed.

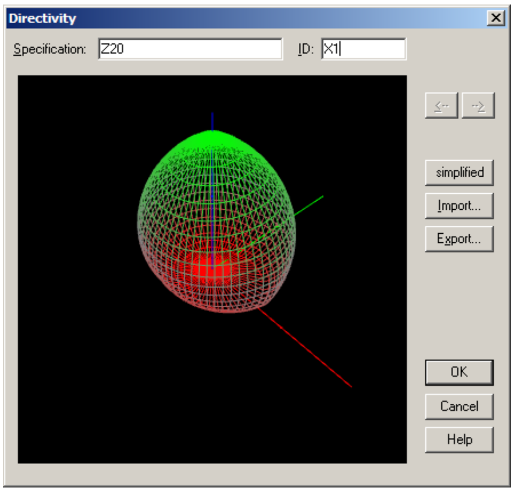

Figure 3 Directivity defined in 2 angles with 5 degree steps

The directivity above shown in figure 3 and representing the machines shown in figure 2 is generated by the simplified input shown in figure 4.

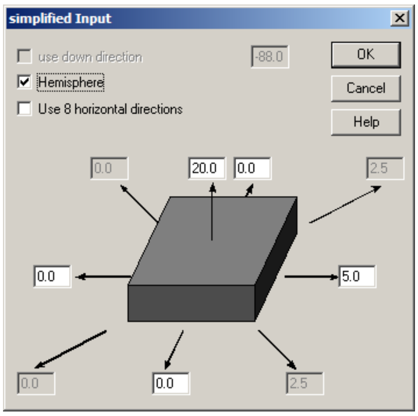

Figure 4 Simplified input of directivities

This simplifies the input of emission values for machinery extremely. Minimum necessary input is the sound power level LWA and – if there is an operators position – the emission sound pressure level LpA. Both values have to be declared by the machine manufacturer according to the machine directive. Additionally an octave band spectrum can be defined – the band related sound power levels are then adjusted so that the defined sound power level remains unchanged. To determine a directivity the simplest method is to measure the sound pressure levels in 4 directions and above the machine. If half sphere radiation is activated, the directivity downwards is automatically set to neglectable values.

Such a machine can now be located at any position and the relevant imission is calculated taking all the abovementioned effects into account.

Simulation of Sound Power Determination

The coordinates of receiver positions can be defined and imported. This allows to arrange them spherical, on box type or even on cylindrical surfaces. Figure 5 shows the simulation of a measurement of the sound power level using the spherical measuring surface.

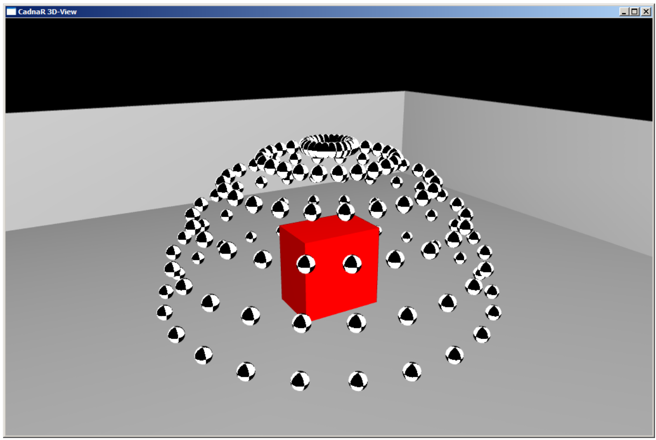

Figure 5 Spherical surface with receiver points

This opens a powerful toolkit for determination of the sound propagation in workrooms. Some examples for machine halls, offices and other applications are demonstrated.

Literature

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

[2] Probst, W.: Schallausbreitung in Arbeitsräumen III, Fb 841 der BAuA, Dortmund 1999

[3] CadnaR: Program for noise prediction in rooms, DataKustik GmbH (www.datakustik.de)

[4] Probst W.: “Sound Propagation in Workrooms”, Proceedings DAGA 2008