Modelling Large Sound Sources in a Room Acoustical Calculation Program

Claus Lynge Christensen

Department of Acoustic Technology, Technical University of Denmark, Building 352, DK-2800 Lyngby, Denmark. mailto:clc@dat.dtu.dk.

Summary: A room acoustical model capable of modelling point, line and surface sources is presented. Line and surface sources are modelled using a special ray-tracing algorithm detecting the radiation pattern of the surfaces in the room. Point sources are modelled using a hybrid calculation method combining this ray-tracing method with Image source modelling. With these three source types, it is possible to model large and complex sound sources in workrooms.

INTRODUCTION

The ODEON model described in this paper has its roots in the auditoium acoustics, but recent development has been directed towards improving the model as a tool for prediction of workroom acoustics as well. Like0 auditorium acoustics, the acoustics of workrooms are often hard to predict using diffuse field theory and large errors may arise. Many types of workrooms exist - to mention a few examples: A turbine hall at a power plant, the condenser hall at a power plant and the check-in desk at an airport. These examples include the problems of modelling:

- Large and distributed sources.
- Fittings in rooms.
- Unevenly distributed absorption.
- Unevenly dimensions of the room, and possibly complicated geometry.
- Coupled rooms.

Some of the problems are somewhat known from the auditorium acoustics, however the problem of large sources and fittings deserves some extra attention.

LARGE SOURCES

Sound sources in some industrial environments, e.g. in a turbine hall are often of considerable size. This means that sources may also have a shielding effect and sound radiation may be distributed in space. If neglecting the shielding effect, the calculated levels will be overestimated.

If modelling a sound-radiating panel as a few point sources on the surface sources, Sound Pressure Levels will be overestimated in some areas and underestimated in other. In ODEON 3.x it is possible to model point sources which are implemented using a combination of the Image Source Method (ISM) and a special ray-tracing method (RTM) and surface and line sources which are implemented using the RTM.
The hybrid calculation method used in ODEON for modelling the radiation from point sources is described elsewhere [1,2,3], so this section will rather focus on the calculation method applied on line and surface sources. It should however be mentioned that the ISM implemented in ODEON takes into account the limited size of the surfaces [2]. This is important when modelling machinery using many small surfaces, where the ISM would otherwise lead to problems as the classical implementation assumes the reflecting surfaces to have infinite size.
In any case, the calculation method in ODEON is, simplified a bit, divided into two parts. The first part has the focus on tracing down the radiation pattern of the room, the second part on collecting reflections received at a specific receiving point.

TRACING DOWN RADIATION PATTERN

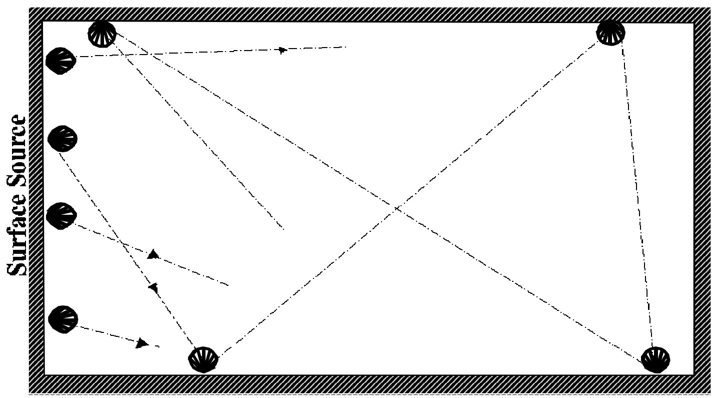

FIGURE 1. Surface source radiating four rays, of which the first four reflections are shown for the first ray.

A number of rays ***N*** are emitted from the surface (or line) source each carrying ***1/N***'th of the source power. For each ray emitted from a line or surface source, a random starting point is created on that source. At each starting point, a secondary source is located, each of the secondary sources have a directivity of $\cos\varphi$ meaning that their radiation into the room is proportional to the projection of the area of the surface source as seen from a given point. Each ray is traced around the room and each time a ray is reflected by a wall, a new secondary source is created at the point of reflection. The secondary source will have a strength due to absorption and distance travelled and it will have a delay because of the distance travelled. Directivity due to Lamberts law is assigned to each secondary source. Lamberts law is taken from the optics and suggests that radiation /reflection from a surface is proportional to the projection of the surface as seen from the receiver. The reflected directions of the rays are calculated as a weighting between the specular direction and a random direction with a probability distribution according to Lamberts Law [3]. The scattering coefficient entered by the user is used as a weighting factor. So if the scattering coefficient of a surface is exactly 0.5, the reflected direction is calculated as a weighted average between the specular direction due to Snells law and a random direction.

COLLECTING REFLECTIONS AT A RECEIVER

Having traced rays around in the room, a number of secondary sources have been located on the surfaces of the room, each with its own orientation, delay and strength. At this point reflections from the sources can be collected at a receiving point, each source contributing a reflection to the receiver if it is visible from the given receiver position. The visibility is checked by tracing the path from the receiver to the secondary source, using ray-tracing.
Compared to a more traditional RTM, one of the main advantages in tracing down the radiation patterns of the room, is that rays do not necessarily need to come close to the receiver to contribute reflections. If just a reasonable number of reflection points are visible from a receiver point, reliable results can be obtained. Consequently good results can be obtained with substantially fewer rays than from more traditional ray-tracing (typically 1000 rays per source are used to obtain reliable results).

FITTINGS

In room acoustics models used for auditorium acoustics the audience area is usually considered as one surface, with a high scattering coefficient. This way of modelling fittings may also be applied on workroom acoustics, if modelling fittings which are located on a surface and has a limited size and the fitting density is high. However this method may not prove valid in all situations as fittings in workrooms may be of considerable size and may be located at ‘any’ place in the room or are hard to describe. In such cases the fittings will have to be modelled in another way. Using a CAD program or indeed the parametric modelling language which is build into ODEON (a parametric modelling language allowing definitions of points and surfaces to be carried out using constants, variables, counters etc.), it is easy to model many obstacles (machinery, beams and columns). A special option it is allowed to assign a transparency coefficient to a surfaces in ODEON enabling fast modelling of installations which are not well defined e.g. electric installations. Future work may look into when the different approaches can be used at its optimum.

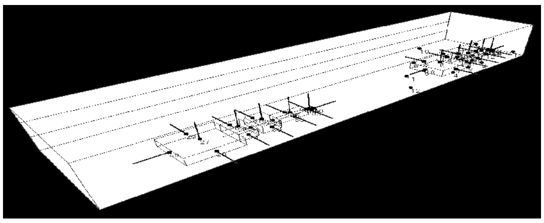

FIGURE 2 Model of turbine hall containing two turbines. The hall is modelled from 54 surfaces and contains 46 surface sources and four point sources.

EXAMPLE OF VERIFICATION

The verification example given here is a turbine hall with uneven dimensions (153 x 34 x 20 metres), uneven distribution of absorption area and sound sources (see figure 2). In figure 3 calculated versus measured A-weighted Sound Pressure Levels in the turbine hall with two turbines are shown. The turbine hall was modelled using 54 surfaces and contains 46 surface sources and four point sources (ball bearings). The absorption data used in the calculations were provided by manufacturer and in some cases guessed. Source data were measured using the intensity method. A-weighted sound pressure levels were measured and calculated at 12 receiver points, in distances of 0.7 - 20 metres from the nearest sound source [4]. The measured levels range from 81 to 96 dB(A) and the maximum deviation between the measured levels and the levels calculated using surface and point sources is 1.6 dB(A) with an

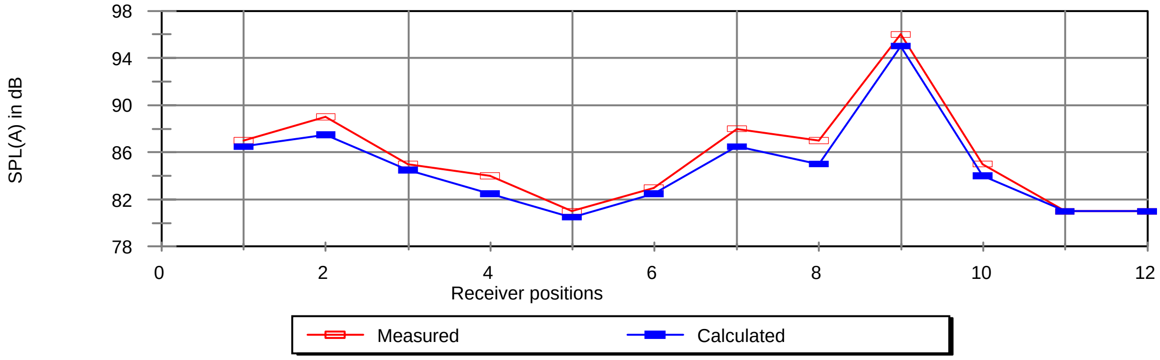

FIGURE 3. Measured and calculated SPL(A) values in 12 receiver points in a turbine hall. Maximum deviation between measured and calculated levels are 1.6 dB(A) - the average deviation is 0.83 dB(A).

average deviation of 0.83 dB (A) [5].

CONCLUSION

The ODEON room acoustical computer model has been extended to allow the modelling of large sound sources. It has been shown that this allows predictions of SPL(A) the in a turbine hall within 1.5 dB, with an average derivation from measured values below 1 dB.

REFERENCES

[1] Christensen,C. L., Odeon Room Acoustics Program, Version 3.1, User Manual, Industrial, Auditorium and Combined Editions, Department of Acoustic Technology, Technical University of Denmark, Lyngby, 1998. (55 pages).

[2] Rindel J. H,, Computer simulation techniques for the acoustical design of rooms - how to treat reflections in sound field simulation. ASVA 97, Tokyo, 2- 4 April 1997. Proceedings p. 201-208.

[3] Rindel J. H., Computer Simulation Techniques for Acoustical Design of Rooms. Acoustics Australia 1995, Vol. 23 p. 81-86.

[4] Foged, H. T., Test af program til beregning af intern støj - test af Odeon ver. 3.0 for Windows 95. Elsamprojekt, Denmark, November 1997.

[5] Christensen, C. L., Foged, H. T., A room acoustical computer model for industrial environments - the model and its verification. Euro-noise 98, München, Proceedings p.671-676, 1998.