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MEASUREMENT OF NOISE EMISSION VALUES OF BIG MACHINES AND CALCULATION OF NOISE LEVELS AT WORK PLACES

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1 INTRODUCTION

The noise emission of machines can be measured by the procedures described in the standards of the ISO 3740 series. In most cases the machine specific standards recommend the measurement of the sound power level (SPL) with the envelopping surface method of ISO 3744. Unfortunately this method is very time consuming, when the machines are big and the emission varies with time.

For big machines with an operators position nearby it is often the case, that the owner of the machine is more interested in the noise emission at this operators position than in the sound power level. In this cases it is interesting to use procedures for the determination of this sound power level, that don't require such a lot of time and therefore cost.

One of these procedures with less expenditure is the ISO 3747 technique by comparing the immission levels of the machine with those produced by a reference sound source (rss). One problem of this method are the uncertainties that are introduced by the unknown distribution of the emission over the machine surface, because different rss-positions contribute with equally weighting to the final result.

In the frame of a project, that was financed by the „Bundesanstalt für Arbeitsschutz", we developped and investigated a method, that takes into account the real distribution of noise sources at different parts of the machine[1]. An other advantage of the method is, that it yields the sound power level of the different parts of the machine structure separately. The energetic sum of these partial sound power levels is the total sound power level of the machine.

The so determined sound power level of the machine can be used to calculate the room correction k_3 for the emission sound pressure level at the operators position.

2 DESCRIPTION OF THE METHOD OF SOUND POWER MEASUREMENT

In some special cases, e.g. where the conditions of diffuse field theory are fulfilled, the sound pressure level at greater distance from a machine is a function of the total sound power output exclusively (and does not depend on the distribution of the emission over the surface).

In most cases of real situations a given sound power level results in a sound pressure level at distant points, that depends on the relative position of radiating surface element of the machine and immission point. This influence can be very high for the emission from opposite sides of an acoustically not transparent and therefore screening big machine structure in a highly damped room with high absorption - the transmission from the side of the machine that is opposite to the immission point is much weaker than that of the other sides. Unfortunately it is not possible to calculate this transmission by taking into account the self-screening of the machine with sufficient accuracy. If it could be calculated, the emission of the different parts of the machine could be determined from the far field levels by calculating back with the sound decay curve. The described procedure is therefore based on a measurement of this transmission from machine surface elements to the imission point.

Theoretically we can measure this transmission from a surface element q to an immission point i, if we place a reference sound source with known sound power level $L_{W,rss}$ in front of each of these elements and measure the sound pressure level L_{qi} at the immission point i.

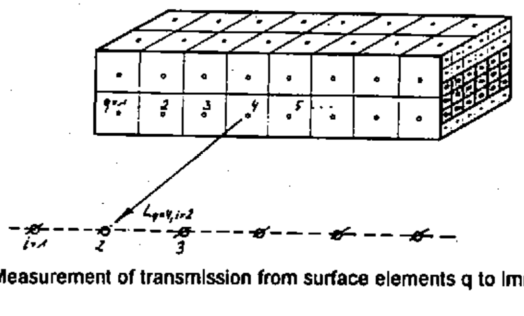

Fig.1 Measurement of transmission from surface elements q to immission points i.

If we want to determine the sound power level with an accuracy of dL (e.g. dL = 2 dB), we have to move the radiating rss along the machine circumference, till the deviation of the sound pressure level at the immission point reaches this value - this position of the rss defines a new surface element. This measurement is carried out with a stopped and therefore not radiating machine.

With the machine operating all the surface elements radiate together. The sound pressure level, that is caused by the operation of the machine at an immission point i, can be expressed by the equation

$$\sum_{q=1}^{n}(10^{(L_{qi}-L_{w,rss})/10}\times 10^{L_{wq}/10}) = 10^{L_{mi}/10}$$

where L_{wq} is the unknown sound power level of surface element q and $L_{m,i}$ is the sound pressure level with the machine operating measured at immission point i.

With n immission points around the machine we get a system of n equations

$$a_{11}\,x_1 + a_{12}\,x_2 + \ldots\ldots\ldots\, a_{1n}\,x_n = y_1$$
$$a_{21}\,x_1 + a_{22}\,x_2 + \ldots\ldots\ldots\, a_{2n}\,x_n = y_2$$
$$\ldots\ldots$$
$$a_{n1}\,x_1 + a_{n2}\,x_2 + \ldots\ldots\ldots\, a_{nn}\,x_n = y_n$$

where the coefficients

$$a_{qi} = 10^{(L_{qi}-L_{w,rss})/10}$$

are the transmission coefficients, that can be measured with the rss, and the terms

$$y_i = 10^{L_{mi}/10}$$

are the energy densities at the immission points when the machine is operating.

If the system of equations can be solved - e.g. with the well known gauß-elimination-procedure - the result are the terms that describe the sound power level of the different elements

$$x_q = 10^{L_{wq}/10}$$

and the total sound power level of the machine

$$L_W = 10\times\log\sum_{q}10^{L_{wq}/10}$$

3 THE PROCEDURE IN PRACTICE

With big machines the described procedure is much less time consuming than the envelopping surface method, if it is applicable. This application restriction means, that it must be possible to operate the machine without other sources and that the background noise is low enough to measure in the far field of the machine.

In most cases it is enough to choose one immission point at each of the four directions. With machines at a wall we use three, with a machine in an edge two directions.

If in normal cases four immission points are chosen, we have four measurements with the rss operating at the four sides of the machine and one measurement with the machine operating - the same for all immission points.

We tested the procedure with real machines and with a big „model machine". This was a pile of massive metal rods of extension 16m x 4m x 3m in a hall of size 70m x 25m x 10m. We distributed an arrangement of 30 loudspeakers over the surface of this pile. The loudspeakers radiated broadband noise with known sound power level in every frequency band. The pile ended at a wall of the hall, so we used three immission points to measure the sound pressure levels in the far field.

The table shows the differences dL of the sound power level of the model machine determined by the described procedure and those measured with the loudspeaker arrangement alone installed in a reverberation chamber.

frequency (Hz)	125	250	500	1000	2000	4000	8000	A
dL (dB)	10.5	-2.2	-0.3	-0.3	0.3	1.7	0.2	0.5

Further investigations showed that it doesn't raise the uncertainties by the given dimensions of the model machine if only two directions for the immission measurements are used. If we take into account that only 6 measurements (with two rss-positions and with the machine operating at each of the two immission points) replace a measurement with 81 measuring points (the correct envelopping surface method) , the advantage of the method is evident, if it can be used. We made these measurements with big machines even in halls with absorbent ceilings - this proved that it is not restricted to reverberant fields.

4 CALCULATION OF NOISE LEVELS AT WORK PLACES

If the noise levels at work places must be calculated, we must distinguish between work places that are operator positions of machines and other work places in the far field of machines.

For a work place, that is the operators position of a machine, we have to add the following contributions:

1) Direct field of the own machine number k - this is the emission sound pressure level $L_{pA,k}$
2) Room influence to the emission of the own machine - this can be calculated with the k_3 technique from $L_{pA,k}$ and $L_{WA,k}$ by taking into account the absorption area of the room
3) Background noise from the emission of all other machines - this can be calculated from $L_{WA,n}$ of all other machines n and the sound decay curve for the room.

In the case of a work place in the far field of all machines only the third contribution has to be added for all machines in a hall.

If one takes into account all the uncertainties in room descriptors, emission values and working conditions of machines, this approach seems to be adequate to handle the noise problems in factories with machines. It is necessary to reduce the expenditure of noise assessment, if the noise situation shall be taken into account in all industrial activities.

5 REFERENCES

[1] Probst,W. „Bestimmung der Geräuschemission großer Maschinen mit einfachen Verfahren", Forschungsbericht Fb 680 der Bundesanstalt für Arbeitsschutz, Dortmund, 1993