FIFTH INTERNATIONAL CONGRESS ON SOUND AND VIBRATION
DECEMBER 15-18, 1997
ADELAIDE, SOUTH AUSTRALIA

SIMULATION TESTS IN THE INDICATORY ACOUSTIC ASSESSMENT OF MACHINES

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ABSTRACT

The authors worked out two indices of the acoustic assessment of machines: a power index and an emission index, as well as indicatory methods of acoustic assessment of machines. The worked out indices are functions of several parameters such as e.g., variants of the operational conditions of the machine, the acoustic properties of the room. The results of the simulation tests, illustrating the effects of variations of different parameters on the values of the indices of the acoustic assessment, are presented in the paper.

1. INTRODUCTION

The efficiency of an acoustic assessment of a machine determines whether a machine which can be dangerous for man because of excessive noise emission is approved for use or not. The methods used for acoustic assessment until now, have not taken into consideration, among others:

- the real operation variants of the machine and their duration,
- the parameters of the operation room and their influence on the noise level at a work station.

Furthermore, sound power level limit values have not been established for most machines. Therefore, the authors have worked out two alternative indices of an acoustic assessment of machines: a power index W_E and an emission index W_I. These indices were presented during the INTER-NOISE'96 Congress in Liverpool [1]. In connection with these indices, the authors have proposed two new quantities to characterize the noise emitted by a machine: the real global A-weighted sound power level and the real global A-weighted sound pressure level from the machine at the work station [2, 4].

The W_E and W_I indices are functions of the parameters characterizing both the machine and the operation room and also influencing the value of the sound pressure level at the work station. For a given machine to be installed in specific operational conditions, the power index W_E, in dB, is defined by the following formula:

$$W_E = L_{WRGA} - L_{Wref} \tag{1}$$

where: L_{WRGA} is the real global A-weighted sound power level, in dB,

L_{Wref} is the reference sound power level, in dB.

The real global A-weighted sound power level L_{WRGA} and the reference sound power level L_{Wref} are described by the following equations:

$$L_{WRGA} = 10\lg \frac{1}{\sum_{i=1}^{k} \Delta t_i} \left(\sum_{i=1}^{k} \Delta t_i 10^{0,1 L_{WAi}} \right) \tag{2}$$

$$L_{Wref} = 10\lg \frac{10^{0,1 L_L} - 10^{0,1 L'_{Aeq}}}{\frac{Q}{4\pi d^2} + \frac{4}{A}} \tag{3}$$

where: L_{WAi} is the A-weighted sound power level in the i-th variant of the operation of the machine, in dB,

- k is the number of the variants,
- Δt_i is the duration of the i-th variant of the operation of the machine, in s,
- L_L is the admissible value of the equivalent A-weighted sound pressure level at the work station, in dB,
- L'_{Aeq} is the equivalent A-weighted sound pressure level characterizing the primary acoustic climate at the work station, in dB,
- Q is the radiation index characterizing the machine location in the operation room ($Q = 1–8$ for basic machine locations),
- A is the equivalent sound absorption area of the operation room, in m^2,
- d is the distance between the machine and the work station, in m.

The emission index W_I, in dB, is defined by the following formula:

$$W_I = L_{PRGA} - L_{Pref} \tag{4}$$

where: L_{PRGA} is the real global A-weighted emission sound pressure level, in dB,

L_{Pref} is the reference emission sound pressure level, in dB.

The real global A-weighted emission sound pressure level L_{PRGA} and the reference emission sound pressure level L_{Pref} are described by the following equations:

$$L_{PRGA} = 10\lg \frac{1}{\sum_{i=1}^{k} \Delta t_i} \left(\sum_{i=1}^{k} \Delta t_i 10^{0,1 L_{PAi}} \right) \tag{5}$$

$$L_{Pref} = 10\lg \frac{10^{0,1 L_L} - 10^{0,1 L'_{Aeq}}}{1 + 4\frac{2\pi d^2}{A}} \tag{6}$$

where: L_{PAi} is the equivalent A-weighted emission sound pressure level from the machine, at the work station, in the i-th variant of the operation of the machine, in dB.

2. INDICATORY ACOUSTIC ASSESSMENT OF MACHINES

To carry out an acoustic assessment of a machine, it is sufficient to determine the value of either the power index or the emission index. The assessment requires active co-operation of the potential user of the machine with the acoustic laboratory carrying out the measurements. The potential machine user should have information on:

- the location of the machine and the work station in the operation room,
- the operation variants of the machine,
- the duration of those variants,
- the equivalent sound absorption area of the operation room,
- the primary acoustic climate.

The principle of an acoustic assessment of a machine on the basis of the power index W_E or of the emission index W_I is as follows:

- the machine will be acoustically safe (i.e. the equivalent A-weighted sound pressure level at the work station in the operation room during its operation does not exceed the admissible value) if the condition W_E (or W_I) ≤ 0 dB is fulfilled;
- the machine will be acoustically dangerous (i.e. the equivalent A-weighted sound pressure level at the work station in the operation room during its operation exceeds the admissible value) if the condition W_E (or W_I) > 0 dB is fulfilled.

3. DISTANCE CORRECTION

On the basis of formulas (4), (5) and (6), it is possible to calculate the value of the emission index W_I only for such distance d between the machine and the work station, for which the real global A-weighted emission sound pressure level L_{PRGA} from the machine at the work station was determined in laboratory conditions. Because the real global A-weighted emission sound pressure level from the machine at the work station depends on the distance between the machine and the work station, it was necessary to modify formula (4) for the simulation tests. Therefore, the authors have introduced a distance correction DC, in dB, which takes into account the drop in the emission level with the change of the distance.

The fact that the emission level from the source is determined by the sound pressure level is the starting-point for working out the distance correction DC. For the sound pressure level of the source, it is possible to assume that its value is inversely proportional to the square of the distance from the source in the free field (in the far field). At the same time, it is possible to accept that this relation is valid for indoor environment if the measurement points are located in the area restricted by the limiting distance, i.e. the distance from the source where there is equilibrium of the sound intensity determined by the reverberant field and the sound intensity determined by the free field. Consequently, assuming that if the range of the variability of the distance between the assessed machine and the workstation is in the area restricted by the limiting distance, the distance correction DC, in dB, will be described by the formula:

$$DC = -20 \lg \frac{d_1 + \Delta d}{d_1} \tag{7}$$

where: d_1 is the distance between the machine and the work station at which the real global A-weighted emission sound pressure level was determined experimentally, in m,

Δd is the change of the distance between the machine and the work station in relation to the distance d_1.

Thus, the formula modified for the simulation tests, which makes the determination of the value of the emission index W_I possible is:

$$W_I = L_{PRGA} + DC - 10lg \frac{10^{0,1L_L} - 10^{0,1L'_{Aeq}}}{1 + 4\frac{2\pi(d_1 + \Delta d)^2}{A}} \quad (8)$$

4. SIMULATION TESTS

The indices of the acoustic assessment of machines are functions of parameters characterizing the noise emitted by a machine and the operational conditions. In order to determine the influence of these parameters on the values of the indices, the authors have carried out a number of simulation tests in addition to the experimental tests. A standard program Mathcad PLUS 5.0 was used and the results of these tests are discussed below.

4.1. SIMULATION TESTS RESULTS OF THE POWER INDEX

The influence of the distance d between the machine and the work station and the radiation index Q is presented in Figure 1.This figure shows that an increase of the distance between the machine and the work station as well as an increase of the value of the radiation index cause a decrease of the value of the power index.

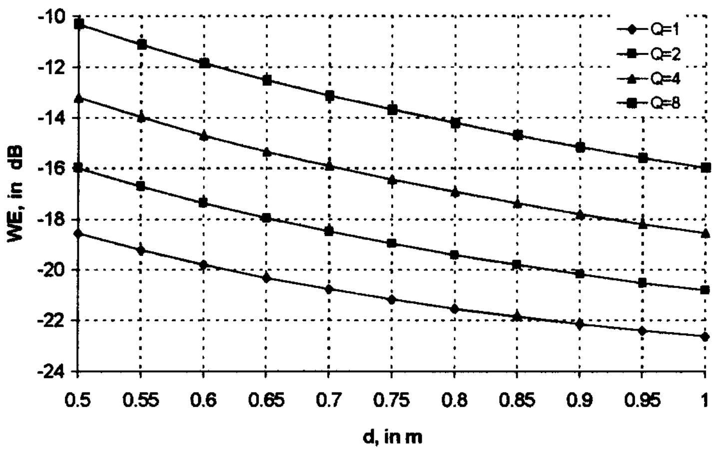

Figure 1.

Influence of the distance d and the radiation index Q on the power index W_E ($A=54\ m^2$, $L'_{Aeq}=35.4$ dB, $L_L=85$ dB, $L_{WRGA}=84.7$ dB).

Simulation test results showing the influence of the primary acoustic climate L'_{Aeq} in the operation room and the distance d between the machine and the work station are presented in Figure 2. In this case, on the basis of the obtained results it is possible to state that an increase of the value of the power index follows an increase of the equivalent A-weighted sound pressure level characterizing the primary acoustic climate in the operation room and the reduction of the distance between the machine and the work station. At the same time, the results show that the influence of the equivalent A-weighted sound pressure level characterizing the primary acoustic climate will be especially significant if the difference between the value of this level and the admissible value of the equivalent A-weighted sound pressure level at the work station is less than 15 dB (e.g. in the case when the admissible value of the equivalent A-weighted sound pressure level at the work station is 85 dB, the influence of the equivalent A-weighted sound pressure level characterizing the primary acoustic climate will be significant if its value exceeds 70 dB).

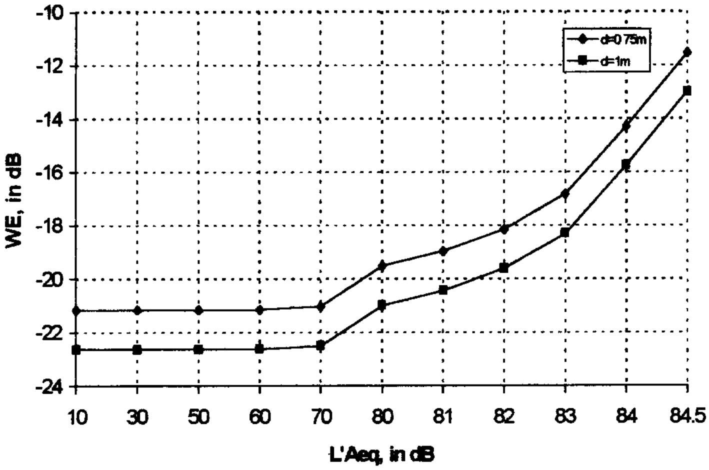

Figure 2.
Influence of the primary acoustic climate L'_{Aeq} and the distance d on the power index W_E ($A=54\ m^2$, $Q=1$, $L_L=85$ dB, $L_{WRGA}=70.5$ dB).

Figure 3 presents the influence of the equivalent sound absorption area of the operation room A and the distance d between the machine and the work station on the value of the power index W_E. On the basis of the obtained results it is possible to state that an increase of the value of the equivalent sound absorption area of the operation room causes a decrease of the value of the power index. The most significant influence of the changes of the values of the equivalent sound absorption area of the room on the changes of the values of the power index is observed in the range under 70 m^2. At the same time, the acoustic assessment result will be more favourable if the distance between the machine and the workstation is greater.

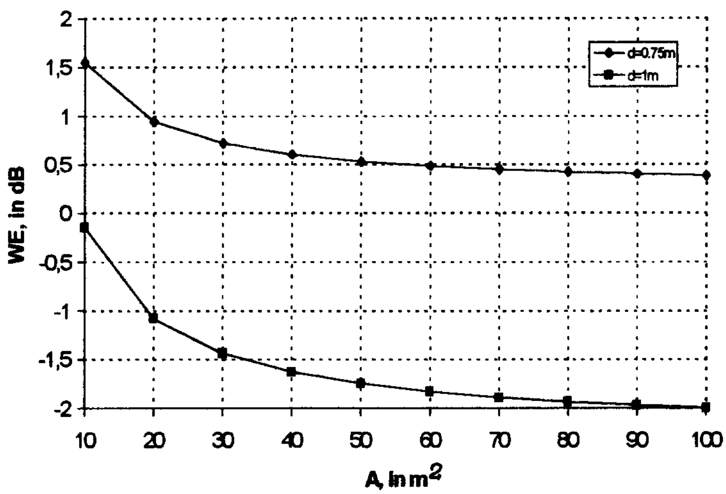

Figure 3.
Influence of the equivalent sound absorption area of the room A and the distance d on the power index W_E ($Q=8$, $L'_{Aeq}=35.4$ dB, $L_L=85$ dB, $L_{WRGA}=85$ dB).

The influence of the changes of the values of the real global A-weighted sound power level L_{WRGA} on the value of the power index W_E is presented in Figure 4. This figure shows that an increase of the value of the real global A-weighted sound power level causes a linear increase of the value of the power index.

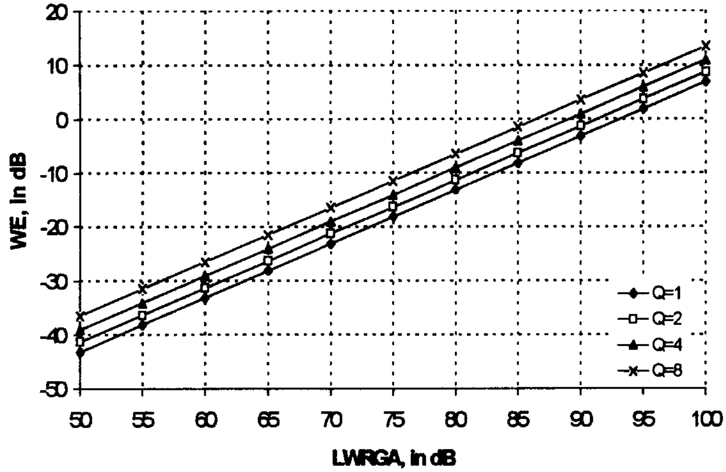

Figure 4.
Influence of the real global A-weighted sound power level L_{WRGA} on the value of the power index W_E ($A=54\ m^2$, $d=1$ m, $L'_{Aeq}=35.4$ dB, $L_L=85$ dB).

4.2. SIMULATION TESTS RESULTS OF THE EMISSION INDEX

Figures 5 and 6 present the simulation tests results of the emission index W_I as a function of the real global A-weighted emission sound pressure level from the machine at the work station L_{PRGA} and the change of the distance between the machine and the work station Δd. The test results obtained in this case show that an increase of the value of the emission index follows an increase of the value of the real global A-weighted emission sound pressure level from the machine at the work station and the reduction of the distance between the machine and the work station. At the same time, there is linear dependence of the emission index on the value of the real global A-weighted emission sound pressure level from the machine at the work station.

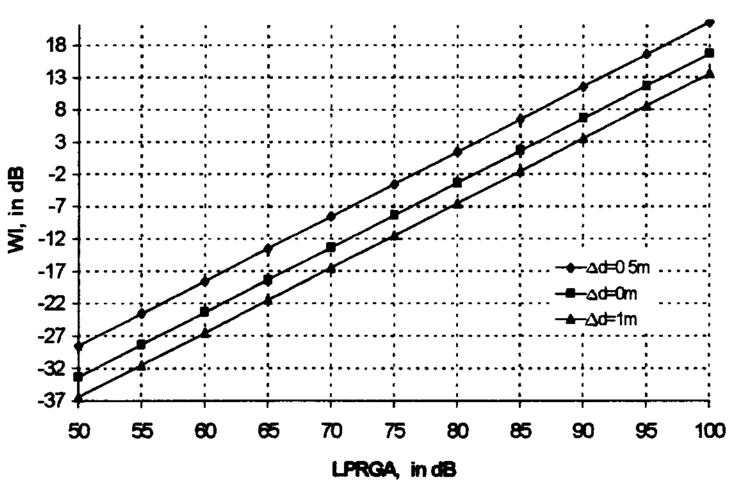

Figure 5.
Influence of the real global A-weighted emission sound pressure level L_{PRGA} on the value of the emission index W_I ($A=54\ m^2$, $L'_{Aeq}=35.4$ dB, $L_L=85$ dB).

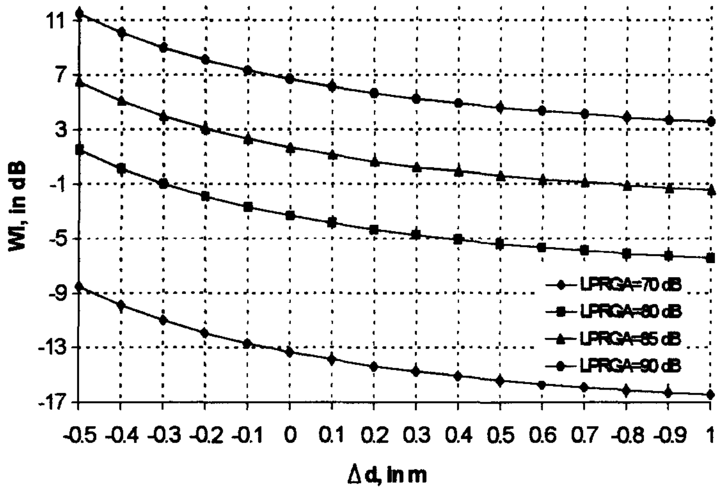

Figure 6.
Influence of the change of the distance Δd on the value of the emission index W_I (A=54 m^2, L'_{Aeq}=35.4 dB, L_L=85 dB).

Simulation test results showing the influence of the primary acoustic climate L'_{Aeq} in the operation room and the change of the distance between the machine and the work station Δd are presented in Figure 7. On the basis of the obtained results it is possible to state that an increase of the value of the emission index follows an increase of the equivalent A-weighted sound pressure level characterizing the primary acoustic climate in the operation room. In the same way as in the case of the power index, this influence of the equivalent A-weighted sound pressure level characterizing the primary acoustic climate will be especially significant if the difference between the value of this level and the admissible value of the equivalent A-weighted sound pressure level at the work station is less than 15 dB.

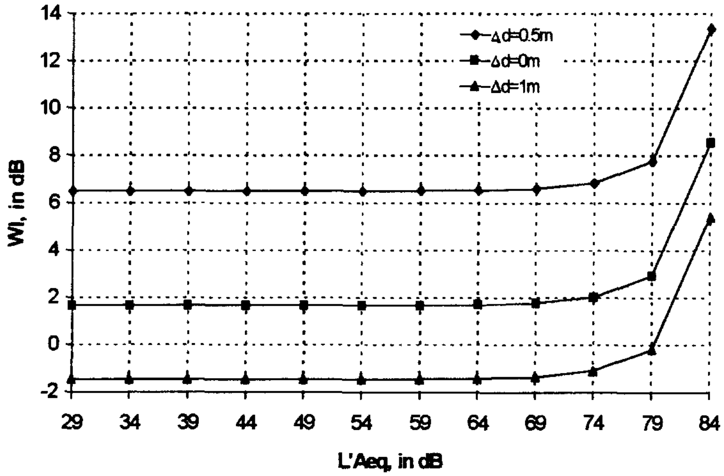

Figure 7.
Influence of the primary acoustic climate L'_{Aeq} and the change of the distance Δd on the value of the emission index W_I (A=54 m^2, L_L=85 dB, L_{PRGA}=85 dB).

Figure 8 presents the influence of the equivalent sound absorption area of the operation room A. The obtained tests results show that an increase of the value of the equivalent sound absorption area of the operation room causes a decrease of the value of emission index.

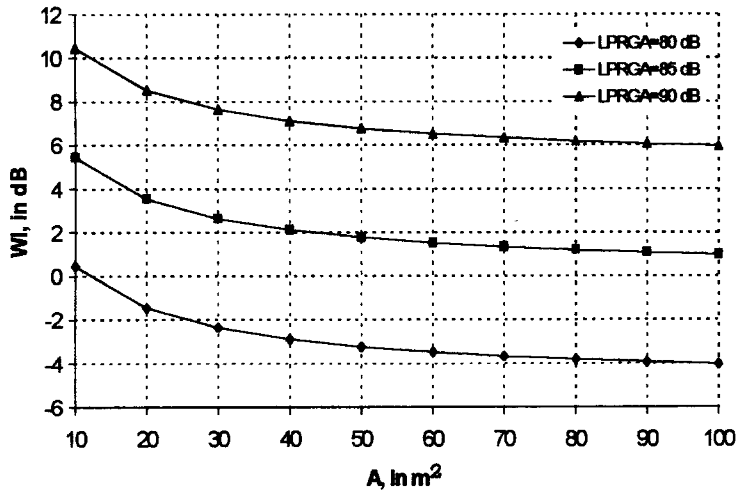

Figure 8.
Influence of the equivalent sound absorption area of the operation room A on the value of the emission index W_I (L'_{Aeq}=35.4 dB, L_L=85 dB, d=1 m).

5. SUMMARY

The simulation tests results are consistent with the experimental tests results [4], with the general principles of sound waves propagation and with noise control methods. It is possible to achieve a favourable acoustic assessment result (i.e. the value of the assessment index will not be greater than 0 dB) in the following ways:

- fundamentally by reducing noise emission from the machine and, as a result, by decreasing the real global A-weighted sound power level (the real global A-weighted emission sound pressure level), and
- by appropriate shaping of operational conditions, i.e. increasing the equivalent sound absorption area of the operation room, changing the machine location in the room, by increasing the distance between the machine and the work station and decreasing the equivalent A-weighted sound pressure level characterizing the primary acoustic climate.

ACKNOWLEDGEMENTS

This study is part of the National Strategic Programme "Occupational Safety and Health Protection in the Working Environment", supported in 1995–1998 by the State Committee for Scientific Research of Poland.

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