Edinburgh, Scotland
EURONOISE 2009
October 26-28

Experiment and model calculation of sound level distribution in industrial room

Janusz Piechowicz
Department of Mechanics and Vibroacoustics
AGH-UST University of Science and Technology Cracow

ABSTRACT

Research on the sound field with an application of modelling is specially utilised in activities correcting an acoustic climate in industrial rooms. Possibilities of the geometrical modelling of noise sources (machines and equipment), selection of proper building and finishing materials as well as analysis of the room furnishing allow for modifications of the already existing or newly designed industrial premises. Distribution of the sound pressure levels was determined for real conditions and for the acoustics model calculations. The results of investigations were compared. Measurements were completed using a multimicrophone system for multichannel signal acquisition.

1. INTRODUCTION

The basic parameter of an acoustic climate in an industrial hall is a sound level distribution in the working space of the place. Under industrial conditions, apart from high overall dimension halls, there are often rather small rooms acting as workshops or auxiliary premises, in which several machines are operating. Noise sources can mutually influence each other and certain places in the room and this influence can be additionally controlled by shapes and decorations of the inside.

Acoustic climate forecasting is related to various methods of examinations of an acoustic field inside industrial premises. Such halls and rooms form amplitude and phase characteristics of the signal introducing - in addition - effects related to their space character decisive for the acoustic pattern in the observation point. Inversion methods are often applied in model investigations [1-4]. Applied measurement techniques, methods of result analysis as well as simulation investigations often allow to reconstruct the acoustic field in industrial halls also in those being newly designed. Experimental and simulation investigations of acoustic parameters of a rather small industrial room (V=106 m^3), comparison of a distribution of acoustic pressure levels obtained by means of computer simulations and acoustic measurements – are presented in the hereby paper.

2. EXPERIMENT PREPARATION

Experiments were performed in a paralelepiped welding shop sized 5.65 m x 5.6 m x 3.35 m. Apart from the welding table two machines: grinder and miller as well as various kinds of accessories were inside this room. Measurements were divided in two stages. The first

Email address. piechowi@agh.edu.pl

stage – a verification of the room model correctness performed by means of the omni-directional sound source of the known acoustic power. Various placement variants of the model source were tested. The source was placed in the middle of the room and in places where grinder and miller machines were fixed. The second stage – acoustic pressure measurements in the room at various variants of machine operations. The measurements were done with the application of the multi-channel simultaneous recording system of acoustic signals from 12 measuring microphones (G.R.A.S. 40PQ) arranged in the appropriate measuring grid of measurement points determined in the room space 1.5 m above the floor [6 7]. Simultaneous acquisition of the sound pressure was performed using LabVIEW software and a data acquisition system. A real-time PXI chassis (PXI-1042Q National Instruments), which was installed with two dynamic signal acquisition cards (PXI-4472B, National Instruments) was used to acquisition signals. Signal values, averaged after switching on and stabilising operations of noise sources, were recorded in frequency bands of a constant bandwidth of 10 Hz in the range from 100 Hz to 12600 Hz.

Phase shift angles between the acoustic pressure measured by the microphone M1 and the remaining 11 microphones (M2 – M12) were determined on the basis of the simultaneous measurements of acoustic signals. The sound pressure amplitude was determined from the function of spectral density of signals from measuring microphones M1 – M12.

$$\overline{p^2} = G_{nn} \tag{1}$$

where:

$$G_{nn} = \int_{f-\frac{1}{2}\Delta f}^{f+\frac{1}{2}\Delta f} G_{nn}(f)\,df \tag{2}$$

$G_{nn}(f)$ - function of spectral density [N²/m⁴],
f - frequency under testing [Hz],
Δf - bandwidth [Hz].

Phase shift angle Ψ was determined from the ratio of imaginary to real part of the function of cross-spectral density G_{1n}:

$$\psi = \arctan\left(\frac{\mathrm{Im}(G_{1n})}{\mathrm{Re}(G_{1n})}\right) \tag{3}$$

where:

$$G_{1n} = \int_{f-\frac{1}{2}\Delta f}^{f+\frac{1}{2}\Delta f} G_{1n}(f)\,df$$

G_{1n} –function of cross-spectral density.

The spatial model of the welding shop, together with the arrangement of its inside, was prepared for model examinations (Fig.1)[8]. Acoustic parameters of materials of surfaces surrounding the place: plastered walls and ceiling and concrete floor – were checked. Sound powers of the grinding and milling machines were determined according to the survey method using an enveloping measurement surface over a reflecting plane (PN-EN ISO 3746).

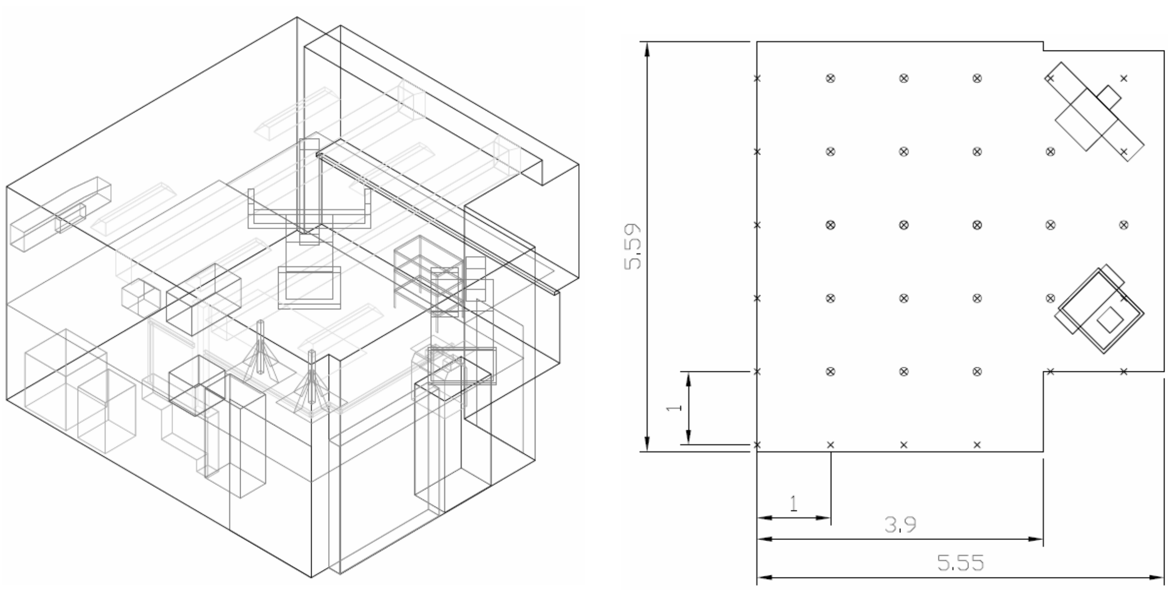


Figure 1. Geometrical model of the welding shop

Then acoustic field distributions for the reference noise source located in places of machine placements were experimentally determined. The reference omnidirectional noise source was localised in various places of the room (in 6 reference points). Distributions of acoustic pressure levels determined experimentally and by simulation were compared. Next, the real sound sources (machines) were engaged and distributions of sound pressure levels were determined for various variants of machine operations. Values of the acoustic pressure levels were measured simultaneously in 12 points of the measuring grid, which allowed to obtain results for the same conditions of the sound source operations.

3. COMPARISON OF THE SOUND PRESSURE DISTRIBUTION BETWEEN MEASUREMENTS AND ROOM ACOUSTIC MODEL

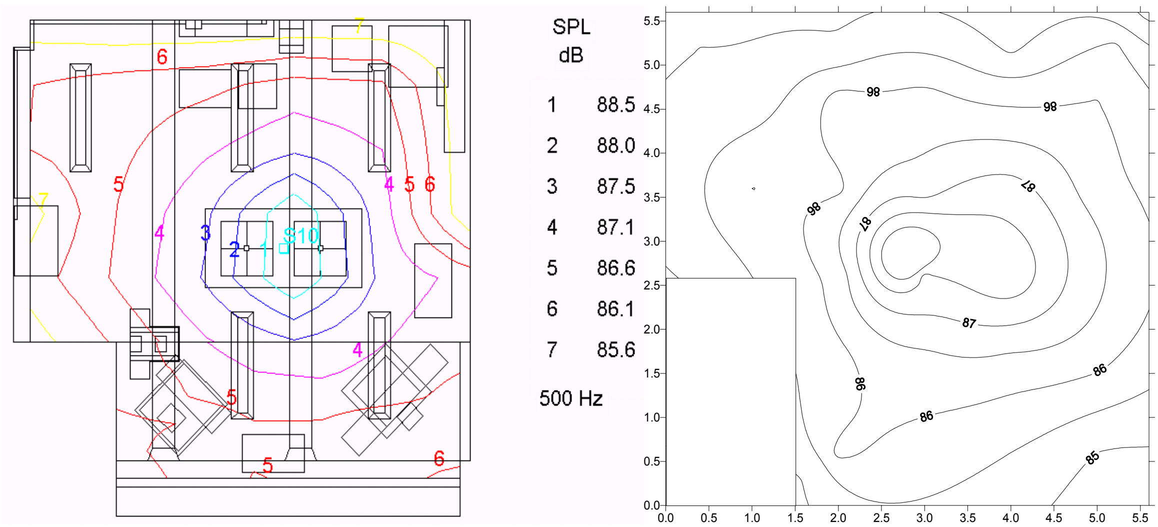
The Raynoise software, into which the spatial model of the room (Fig. 1) was implemented, was used in modelling the acoustic field distribution. The model contained the structure of the room, its fittings as well as acoustic parameters of surrounding surfaces. The preliminary verification of the correctness of input parameters of the acoustic-geometrical model of the room was done on the basis of the reverberation time measurements in the welding shop and comparing them with model calculations (Table1).

Table 1. Comparison of reverberation times – in the welding shop - obtained from measurements and by computer simulation.

No	Mid-band frequency of octave band, Hz	Reverberation time – calculated from measurements	Reverberation time – obtained by computer simulations
		RT, s	RT, s
1	250	1.12	1.29
2	500	1.64	1.74
3	1000	1.45	1.52
4	2000	1.14	1.24
5	4000	0.96	1.22
6	8000	0.80	0.98

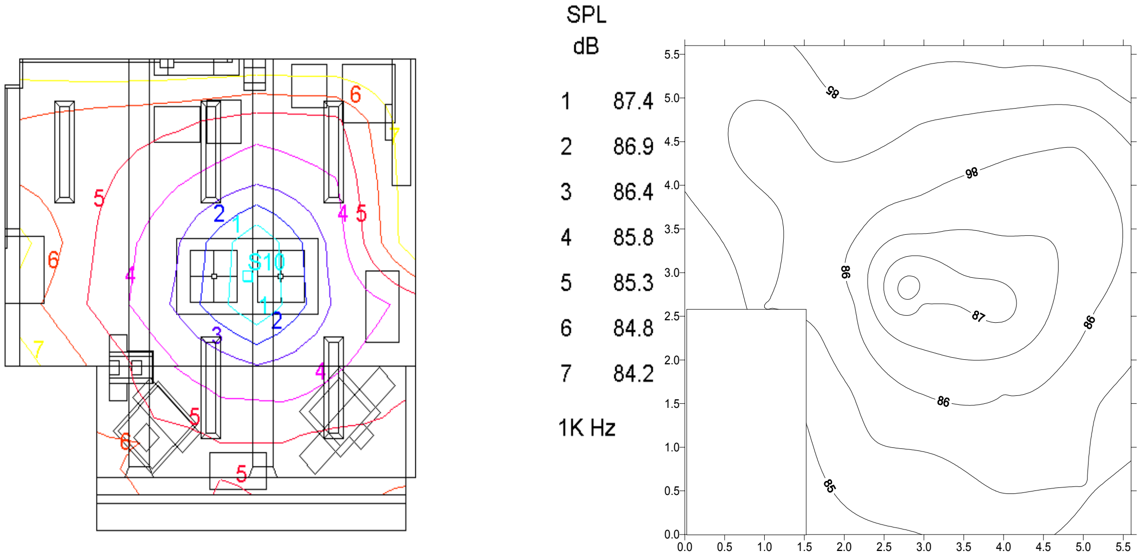
The geometrical model did not take into account small objects being elements of fitting in the welding shop. Therefore in computer simulations their influence on the reverberation time value was omitted. This might be a reason of certain differences of times presented in Table 1. The simulation of the sound level distribution was done in octave frequency bands for various placements of the omni-directional reference sound source of the acoustic power determined by an engineering method in an essentially free field over a reflecting plane (PN-EN ISO 3744). Distributions of the acoustic field pressure level were determined, both experimentally and by calculations, for the reference noise source placed at the centre of the room and in places of machine locations.

Comparison of equal loudness contours of acoustic pressure for individual frequencies of octave bands (Fig. 2 – 500 Hz and Fig.3 – 1000Hz) and distributions of isophone lines of sound level A, enabled to answer a question in which manner computer modelling complies acoustically with the real room.



Computer simulation | Experiment

Figure 2. Reference source at the centre of the room. Distribution of sound pressure level for the centre frequency of the octave band: 500 Hz



Computer simulation

Experiment

Figure 3. Reference source at the centre of the room. Distribution of sound pressure level for the center frequency of the octave band: 1000Hz

The obtained comparison results allowed to introduce certain corrections into the model of the room and to prepare the acoustic field modelling for the machine noises.

Determined *in-situ,* using survey method, values of sound power levels of the grinding and milling machines constituted input data for the model. Coordinates of machine localisations were identical as under the real conditions. The distribution of acoustic pressure levels above the floor in the welding shop, for all variants of machine operations, were obtained as the result of modelling.

Distributions of acoustic pressure levels in octave frequency bands were prepared as equal loudness contours and distribution maps. Then the real acoustic field distributions for various machine operations were compared with the corresponding distributions obtained by model calculations. The achieved results constitute the basis for assessment the acoustic climate in the welding shop.

4. CONCLUSIONS

Examinations of the acoustic field with an application of modelling is specially utilised in activities correcting an acoustic climate in industrial halls. Possibilities of the geometrical modelling of noise sources (machines and equipment), selection of proper building and finishing materials as well as analysis of the room furnishing allow for modifications of the already existing or newly designed industrial premises. Prediction an efficiency of acoustic protection measures under the real industrial conditions provides a significant economic justification of applying model investigations. The multi-channel system of data collection is also used for determining acoustic parameters by means of the inverse method.

The results of computer simulations are consistent with the results obtained experimentally. In the comparative analysis of the obtained results the correspondence of acoustic pressure level distributions for the selected frequencies is seen, however, certain discrepancies occur in dependence of a noise sources configuration. The background of differences can be found in two stages of examinations. The first stage – the accuracy of the geometrical-acoustic model of the industrial room. The second one – the accuracy of the determination of the machine sound power (approximate *in situ* method). In the first case a lot of work is required as well as the same arrangement of the room during the whole time of operations, which is very difficult to be obtained under the industrial conditions. In the second case the good solution constitutes the determination of appropriate acoustic models of machines, the determination of space locations and acoustic power levels of partial sound sources with the application of the inversion method [9 10].

ACKNOWLEDGMENTS

This research has been supported by the Department of Mechanics and Vibroacoustics of University of Science and Technology (AGH) and the research project N N504 342536.

REFERENCES

1. W.Batko, Z.Dąbrowski, Z.Engel, J.Kiciński, S.Weyna, *Nowoczesne metody badania procesów wibroakustycznych - cz.I*, Wyd.ITE-PIB 2005.[in Polish].
2. Z.Engel, J.Piechowicz, L.Stryczniewicz, *Podstawy wibroakustyki przemyslowej.* Wyd.WIMIR AGH, Kraków 2003. [in Polish].
3. Z. Engel, L. Stryczniewicz, „Acoustic Modeling of Machines", *Archives of Acoustics,* 24, 4, p.413-424, 1999.
4. Z. Engel, L. Stryczniewicz, J. Piechowicz, *Application of the inversion method for the determination of partial acoustic powers of machines*. Proc. L OSA, Szczyrk-Gliwice, 2003, p. 70-73 [in Polish].
5. Z.Engel, L. Stryczniewicz, J. Piechowicz, "*Application of the inversion method for the determination of sound parameters of machines in industrial room"*, in Proceedings XXXII WSZZW, Gliwice – Szczyrk 9-13.02.2004, pp. 9-14 [in Polish].
6. J.Piechowicz, „Determination of acoustic fields in industrial room", *Archives of Acoustics*, Vol.32, No 2, 2007, p.313-319.
7. J.Piechowicz, „Acoustic field in the mechanical workshop", *Archives of Acoustics*, Vol.32, No 4, 2007, p.221-226.
8. J.Piechowicz, „Komparacja badań modelowych i eksperymentalnych rozkładu poziomu dźwięku w pomieszczeniu". *Proceedings Wibrotech 2008* (CD), [in Polish].
9. J. Piechowicz, „Regularisation problems at the determination of the acoustic power of sound sources", *Archives of Acoustics*, Vol.31, No 4, 2006, p.287-294.
10. L.Stryczniewicz, "Identification of zones of increased vibroacoustic emission by means of the inverse method", *Archives of Acoustics*,Vol.29, No 4, 2004, p.563-576.