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AUTOMATION OF NOISE FIELDS CALCULATION IN INDUSTRIAL BUILDINGS

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Abstract: In planning the noise protection strategies in industrial buildings, the main component is calculating the noise field energy parameters. Efficiency of noise protection depends on the degree of objectivity of a mathematical model, describing the sound energy distribution over a room with different volume and planning and acoustic parameters on the basis of the real conditions of the noise field foundation. In this article an automatic estimate program for a noise condition when planning the noise protection strategies, is presented. Calculation of noise levels in a room is made by the statistical energy methods.

Nowadays, there has been developed sufficiently effective strategies for noise reduction in industrial buildings. However, their application in industry has some difficulties as practice shows. One of them is that planners regard them with pessimism. First of all this results from the fact that it is difficult to calculate energy parameters of a noise condition in a room and to estimate the noise reduction efficiency when planning the noise protection strategies.

In order to make an optimum choice of volume and planning and building decisions, ensuring acoustic comfort of a room, a polyalternative planning is to be performed. This can be done by increasing and improving planning automation. The planning automation of noise protection strategies is effective if there is a model, objectively describing the noise foundation conditions in an industrial room, and carrying it out methods, that meet the requirements of modern computing technology. Such a model and carrying it out methods were developed on the basis of the statistical energy approach to estimate of me sound energy distribution over quasi-diffusible noise fields in a room [1].

The method of carrying out the statistical energy model, obtained by separation of variables, is the most acceptable for practical calculations. In this case the total levels of sound pressure at the calculation points in a room with a separate noise source working, is defined as

$$L_i = L_P + 10\lg\left[\Pi e^{-m_a r_i} + c(1-\tilde{\alpha})\sum_{m=-k}^{m=k}\sum_{n=-k}^{n=k}\sum_{q=-k}^{q=k}\frac{\varphi_m\varphi_n\varphi_q\varphi_m^0\varphi_n^0\varphi_q^0}{B_m B_n B_q U_{mnq}}e^{-U_{mnq} r_i/c}\right], \quad (1)$$

where r_i – the distance between the source and the calculation point i; $\tilde{\alpha}$ – the average coefficient of the room sound absorption; L_P – octave level of the source sound power;

k – the order of the equation members considered; Π – function of the direct sound distribution, definable as $\Pi_{dis} = \Phi/\Omega r_i^2$ and $\Pi_n = \Phi/S_i$ (if the distance between the source and the calculation point $r \ge 2l_{\max}$, $\Pi = \Pi_{dis}$, and if $r < 2l_{\max} - \Pi = \Pi_n$); $l_{\max}$ – maximal size of the source; S – imaginary surface of rectilinear form, surrounding the source and passing through the calculation point [2]; Ω – space angle of sound radiation; Φ – source directivity factor; c – sound velocity; φ_m, φ_n, φ_q – the system of orthogonal trigonometrical eigenfunctions; $\varphi_m^0, \varphi_n^0, \varphi_q^0$ – the value of eigenfunctions at the source point; U_{mnq} – the damping coefficient of particular solution amplitudes; $B_i = \int\limits_0^{l_j} (\varphi_i)^2 dx_j$ – rating cofactor; l_j – room size in the j-direction.

The sound pressure levels in a room with several noise sources working are obtained from

$$L = 10\lg\left[\sum_{j=1}^{a} \Lambda_j \Pi_{ij} e^{-m_a r_{ij}} + c\sum_{j=1}^{d} (1-\tilde{\alpha})\Lambda_j \times \right.$$
$$\left. \times \sum_{m=-k}^{m=k} \sum_{n=-k}^{n=k} \sum_{q=-k}^{q=k} \frac{\varphi_{m_j} \varphi_{n_j} \varphi_{q_j} \varphi_{m_j}^0 \varphi_{n_j}^0 \varphi_{q_j}^0}{B_m B_n B_q U_{mnq}} e^{-U_{mnq} r_{ij}/c} \right]. \quad (2)$$

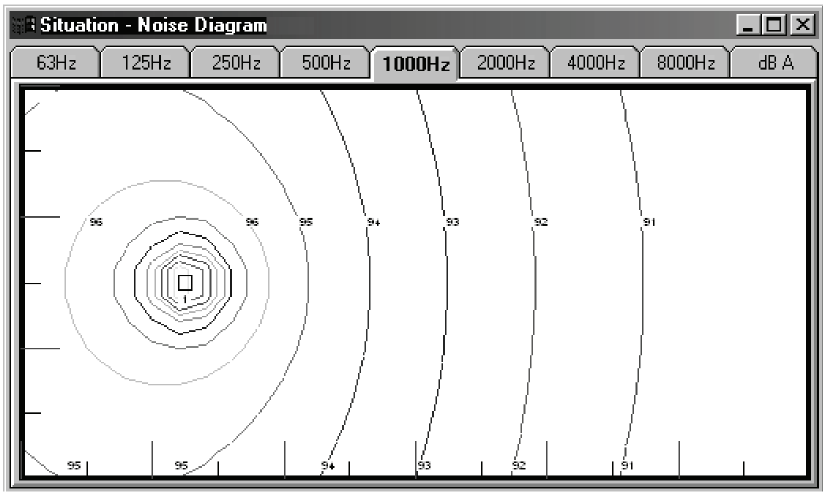
Here $\Lambda_j = 10^{0,1 L_{P_j}}$; L_{P_j}, Π_{ij}, r_{ij} – the same as in formula (1) but for the j-source; a - number of working sources, seen from the calculation point; d – number of simultaneously working source in a room.

A program for personal computers, controlled by the operation system for Windows 95 and higher, was designed to put the formulas into practice. The program is written in the Visual Basic language, debugged and compiled in exe. files. There has been used the language potentialities, ensuring work conveniences for users and a friendly interface.

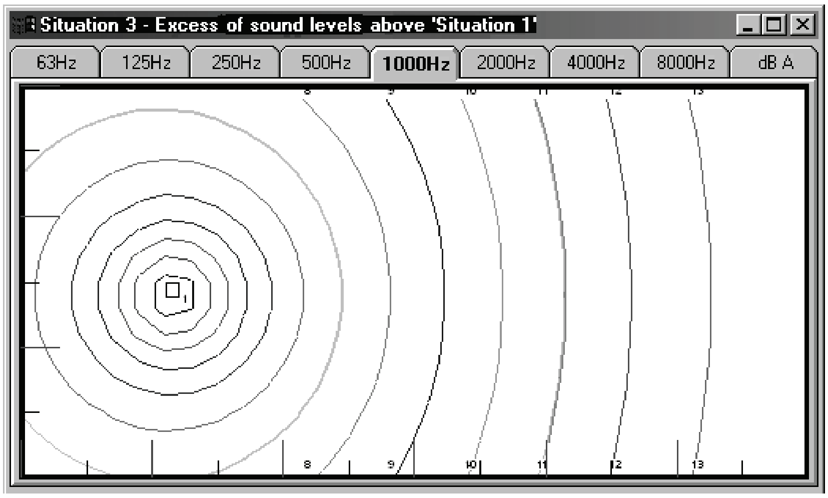
The program makes it possible to calculate the total noise levels (direct and reflect) in the frequency band of one and several simultaneously working sources. Calculation of the sound pressure levels of the reflected noise component and the diagrams of the reflected sound field may be made as well.

It is available to estimate the influence of sound absorption variations of the boundaries and to screen the noise source for the sound pressure levels. The calculated efficiency is presented in the form of files, charts of the definitely sectioned room as well as diagrams of the noise reduction efficiency. The level changes of the sound pressure over a room with the place of the noise source change are estimated analogously. The diagrams are given as an example in Fig. 1. It is evident that the efficiency of decisions may be estimated by separate strategies as well as by the totality of the ones. The level changes of the sound pressure over a room with the place of the noise sources changed are estimated in the same way.

Using the program, one may make and keep data files. They include data basis of noise source, sound absorbing constructions, the noise levels permissible in industrial rooms and some other information used in projecting the rooms with noise protection.



a)



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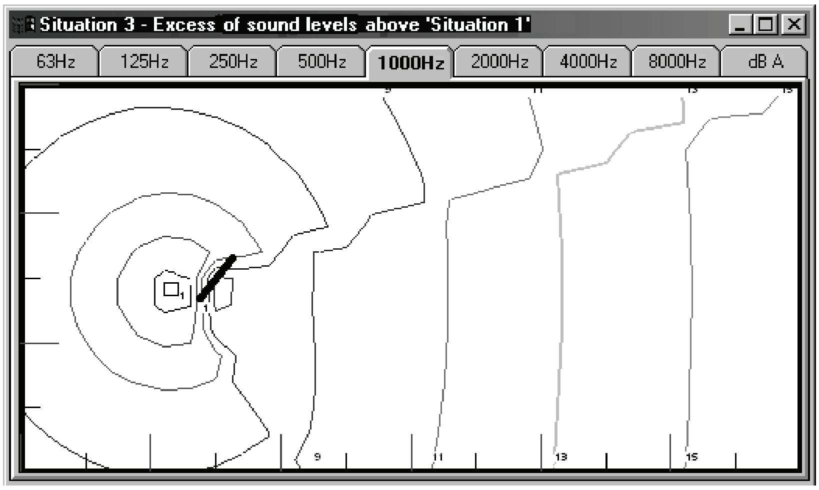

c)

Fig. 1 Noise diagram (*a*) and charts of acoustic efficiency of sound absorption (*b*) and sound absorption in a room with a screen (*c*) and the noise source working

Situation 1 - Statistics

Limiting spectrum 55

	63Hz	125Hz	250Гц	500Hz	1000Hz	2000Hz	4000Hz	8000Hz	dB A
Area, where noise level does not exceed the permissible value, m^2	1800,0	1792,0	468,0	0,0	0,0	0,0	344,0	1736,0	0,0
% of the total area	100,0	99,6	26,0	0,0	0,0	0,0	19,1	96,4	0,0
Area, where noise level exceeds the permissible value, m^2	0,0	8,0	1332,0	1800,0	1800,0	1800,0	1456,0	64,0	1800,0
% of the total area	0,0	0,4	74,0	100,0	100,0	100,0	80,9	3,6	100,0
Area, where noise level does not exceed the permissible value, more then 7 dB, m^2	0,0	8,0	1316,0	914,0	472,0	1668,0	1432,0	64,0	954,0
% of the total area	0,0	0,4	73,1	50,8	26,2	92,7	79,6	3,6	53,0
Area, where noise level exceeds the permissible value more then 7 dB, m^2	0,0	0,0	16,0	886,0	1328,0	132,0	24,0	0,0	846,0
% of the total area	0,0	0,0	0,9	49,2	73,8	7,3	1,3	0,0	47,0
Area, where direct sound level exceeds the permissible value, m^2	0,0	0,0	76,0	292,0	352,0	188,0	84,0	24,0	0,0
% of the total area	0,0	0,0	4,2	16,2	19,6	10,4	4,7	1,3	0,0
Number of workplaces:									
where noise level does not exceed the permissible value	2	1	0	0	0	0	0	1	0
% of the total amount	100,0	50,0	0,0	0,0	0,0	0,0	0,0	50,0	0,0
where noise level exceeds the permissible value	0	1	2	2	2	2	2	1	2
% of the total amount	0,0	50,0	100,0	100,0	100,0	100,0	100,0	50,0	100,0
where noise level does not exceed the permissible value more then 7 dB	0	1	1	1	0	1	1	0	1
% of the total amount	0,0	50,0	50,0	50,0	0,0	50,0	50,0	0,0	50,0
where noise level exceeds the permissible value more then 7 dB	2	1	1	1	2	1	1	2	1
% of the total amount	100,0	50,0	50,0	50,0	100,0	50,0	50,0	100,0	50,0
where direct sound level exceeds the permissible value	0	0	0	0	0	0	0	0	0
% of the total amount	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0

Fig. 2 Results obtained from statistical processing of the computation data

If there is a great number of equipment in a room, estimation of its influence on the sound energy distribution over a room in the program is performed by correcting the average free path length and varying the coefficient of the floor sound absorption. Besides, sound absorbing characteristics of the equipment placed on the floor are considered. To correct the average free path length, formula (3) from (3) may be used, in which changes of room volume and area of the surface diffusers in a room with equipment are taken into account. The specially designed program, described in [4], gives more accurate results of the correct value of the average path length. It is directly included into the program as an independent module, if being used.

The program makes statistical processing of the obtained computation data possible. For example, finding out the number of work places, where noise level exceeds the permissible value, the room area, that does not meet the requirements of the permissible noise condition, etc. (Fig. 2).

Application of the developed program in solving practical tasks shows its high efficiency. Its simplicity and work conveniences give us every reason to consider that the program will be widely used in planning the noise protection strategies.

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Автоматизация расчета шумовых полей в производственных помещениях

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Ключевые слова и фразы: квазидиффузное поле; статистическая энергетическая модель; уровень шума; шумовая карта; шумозащитные мероприятия.

Аннотация: Основным компонентом проектирования шумозащитных мероприятий в производственных зданиях является расчет энергетических параметров шумовых полей помещений. Эффективность шумозащиты зависит от степени объективности математической модели, описывающей распределение звуковой энергии в помещениях с различными объемно-планировочными и акустическими параметрами, исходя из реальных условий формирования шумовых полей. Рассматривается программа автоматизированной оценки шумового режима при проектировании шумозащитных. мероприятий, использующая статистические энергетические методы расчета уровней шума в помещениях.

Automatisierung der Berechnung der Geräuschfelder in den Betriebsräumen

Zusammenfassung: Der wichtigste Komponent der Projektierung der geräuschschützenden Maßnahmen in den Betriebsgebäuden ist die Berechnung der energetischen Parameter der Geräuschfelder von den Räumen. Die Effektivität des Geräuschschutzes hängt von dem Grad der Objektivität des mathematischen Modells, das die Vorteilung der Schallenergie in den Räumen mit den verschiedenen Planierungs- und Akustikparametern beschreibt. Im Artikel wird das Pragramm der automatisierten Einschätzung des Schallregimes bei der Projektierung der geräuschschützenden Maßnahmen betrachtet. In diesem Programm werden die statistischen energetischen Berechnugsmethoden der Geräuschniveaus in den Räumen benutzt.

Automatisation du calcul des champs de bruit dans les locaux de production

Résumé: Le composant essentiel de la conception des mesures de protection sonore dans les locaux de production est le calcul des paramètres énergétiques des champs de bruit des locaux.

L'efficacité de la protection sonore dépend du degré de l'objectivité du modèle mathématique décrivant la répartition de l'énergie sonore dans les locaux avec les paramètres différents du volume, de la conception et de l'acoustique compte tenu des conditions réelles de la formation des champs de bruit. Est examiné le programme de l'automatisation de l'évaluation du régime pour la conception des mesures de protection sonore qui utilise les méthodes statistiques et énergétiques du calcul du niveau du bruit dans les locaux.