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A METHOD FOR DETERMINING THE EQUIVALENT LEVEL OF NOISE GENERATED BY A SYSTEM OF SOURCES IN AN ENCLOSURE

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This paper proposes and subsequently verifies a method for determining the equivalent noise level L_{eq} of noise in an enclosure. This method requires the identification of "elementary signals" related to single "acoustic events" and measurements permitting the calculation of numerical values of some parameters a_i for each of these signals. This methods permits the determination of the values of L_{eq} for any time interval when the value of a_i and the number of "elementary signals" reaching the observation point are known.

1. Introduction

In many cases of noise encountered in the human environment it is possible to notice that the resultant signal consists of a number of repeated "elementary signals". E.g. noise registered in the vicinity of a motorway consists essentially

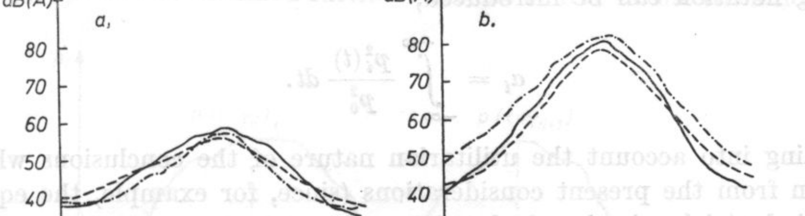

Fig. 1. Sound level variations, in dB (A), due to the traffic of single light (a) and heavy (b) vehicles

of two classes of "elementary signals": those generated by light vehicles and those generated by heavy vehicles. Single light and heavy vehicles generate distinctly different "elementary signals", while differences among signals emitted by particular light and heavy vehicles are considerably smaller (Fig. 1).

It is therefore possible to consider, in the first approximation, only two kinds of "elementary signals", corresponding to two different "acoustic events" caused by the passages of a light vehicle and a heavy vehicle, respectively. Considering different types of vehicle, their different speeds (more generally, ways of operation), traffic lanes etc., it is possible to increase the number of kinds of "elementary signals" (acoustic events) [4]. It is, however, necessary then to establish a precise criterion of the similarity of "elementary signals".

This similarity can be measured using the index of noise evaluation which is called the *Single Event Noise Exposure Level* [2],

$$L_{AX}^{(i)} = 10 \log \int_{t_p}^{t_k} 10^{0.1L_i(t)} dt, \tag{1}$$

where $L_i(t)$, in dB (A), is the time history of the "elementary signal" of the ith kind, t_p and t_k are the limits of the time interval in which the instantaneous value of $L_i(t)$ is not lower by 10 dB (A) than its maximum value. It is possible to assume in (1) that $t_p = -\infty$ and $t_k = +\infty$ which involves error below 1 dB. On the basis of the definition of sound level

$$\int_{-\infty}^{+\infty} \frac{p_i^{2(t)}}{p_0^2} dt = 10^{0.1L_{AX}^{(i)}}, \tag{2}$$

where $p_i(t)$ is the pressure corrected by the curve $A-40$ phons and p_0 is the reference pressure.

The integral on the left side of equation (2) is related to the energy of "an elementary signal" of the ith type. It will be shown below that this integral occurs in formulae for predicting the equivalent level. For simplification the following notation can be introduced,

$$a_i = \int_{-\infty}^{+\infty} \frac{p_i^2(t)}{p_0^2} dt. \tag{3}$$

Taking into account the utilitarian nature of the conclusions which can be drawn from the present considerations (since, for example, the equivalent level of industrial noise is calculated here for eight hours), one hour as taken is the unit time. Since the parameter a_i concerns a single "acoustic event", it is expressed by a product [hour/event].

Formula (2) shows a close relation between the quantity a_i (calculated and measured on the basis of formula (3)) and the index L_{AX} which can be measured using the latest, i.e. least available, Brüel-Kjaer equipment.

In a general case of noise being a superposition of individual acoustic events (particularly, industrial noise which is the object of consideration in the present paper), division of "elementary signals" into particular classes is determined by the value of the parameter a calculated from formula (3). (This problem is disscused in greater detail in section 2.1).

One of the numerous indices currently used for noise evaluation is the equivalent level L_{eq} [2],

$$L_{eq} = 10 \log \frac{1}{T} \int_0^T 10^{0.1L(t)} dt, \tag{4}$$

where T is the averaging time and $L(t)$ the instantaneous sound level of the resultant signal in dB (A).

According to definition (2), this expression can be rewritten in the form

$$L_{eq} = 10 \log \frac{\langle p^2 \rangle}{p_0^2}, \tag{5}$$

where

$$\langle p^2 \rangle = \frac{1}{T} \int_0^T p^2(t)\, dt. \tag{6}$$

Papers [5,6] gave a method for the determination of the time average intensity of the resultant signal which is a superposition of "elementary signals". This method can be used to determine $\langle p^2 \rangle$ and subsequently the equivalent level L_{eq} of signals generated by the noise sources in an enclosure.

2. Theory

It can be assumed that the "elementary signals" reaching the observation point within an arbitrary bounded region can be divided into several kinds ($i = 1, 2, \ldots,$). It can be assumed further that the source of the ith kind emits

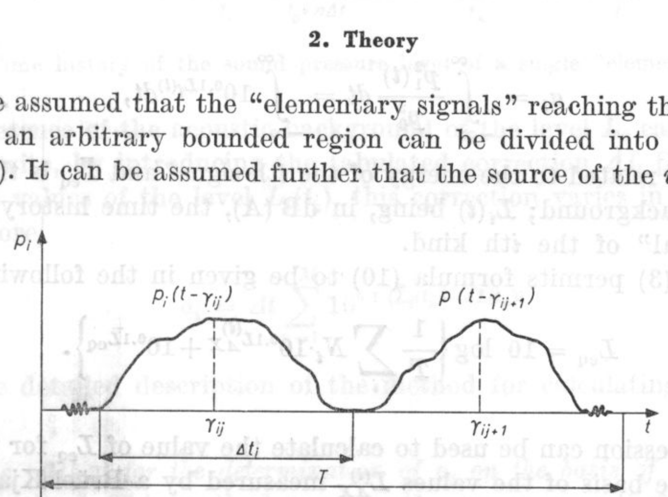

Fig. 2. Pressure variations in elementary signals of the ith kind, $p_i(t)$, displaced in time with respect to one another

an "elementary signal" at the times $\gamma_{i,1}, \gamma_{i,2}, \gamma_{i,j+1}, \ldots$, of the pressure time history $p_i(t)$ (Fig. 2). The instantaneous value of the pressure of the resultant signal is the sum of the pressures of all "elementary signals"

$$p(t) = \sum_i \sum_j p_i(t-\gamma_{i,j}) + \overline{p}(t), \tag{7}$$

where $\overline{p}(t)$ is the pressure of the acoustic background and the quantity $\gamma_{i,j}$ denotes the time shift of the jth "acoustic event" of the ith kind.

When "elementary signals" are incoherent, formula (7) yields

$$p^2(t) = \sum_i \sum_j p_i^2(t-\gamma_{i,j}) + \overline{p}^2(t). \tag{8}$$

Assuming that N_i "accoustic events" of the ith kind occurred in the time T, i.e. N_i "elementary signals" characterized by $p_i(t-\gamma_{i,j})$, where $0 < \gamma_{i,j} < T$, reached the observation point, formulae (6)-(8) give

$$\langle p^2 \rangle = \frac{1}{T} \sum_i N_i \int_{-\infty}^{\infty} p_i^2(t)\,dt + \langle \overline{p}^2 \rangle, \tag{9}$$

where $\langle \overline{p}^2 \rangle$ is the time average square background pressure.

Relation (9) is valid when the duration of the resultant signal, T (the averaging time), is much longer than the duration of the elementary signal Δt_i (Fig. 2).

It follows from the definition of the equivalent level (5) and (6) that

$$L_{eq} = 10 \log \left\{ \frac{1}{T} \sum_i N_i a_i + 10^{0.1\overline{L}_{eq}} \right\}, \tag{10}$$

where

$$a_i = \int_{-\infty}^{\infty} \frac{p_1^2(t)}{p_0^2}\,dt = \int_{-\infty}^{\infty} 10^{0.1 L_i(t)}\,dt, \tag{11}$$

is a parameter related to the energy of the ith signal and $\overline{L}_{eq}$ is the equivalent level of the background; $L_i(t)$ being, in dB (A), the time history of the "elementary signal" of the ith kind.

Relation (3) permits formula (10) to be given in the following form

$$L_{eq} = 10 \log \left\{ \frac{1}{T} \sum_i N_i \cdot 10^{0.1 L_{\Delta X}^{(i)}} + 10^{0.1\overline{L}_{eq}} \right\}. \tag{12}$$

This expression can be used to calculate the value of L_{eq} for the any time interval on the basis of the values $L_{\Delta X}^{(i)}$ measured by a Brüel-Kjaer 2218 type sound level meter. When this instrument is not available, relation (10) can be used to determine the value of L_{eq}. In such a case, it is necessary to know the values of the parameters a_i.

2.1. The method for the determination of a_i on the basis of measurement of the sound level of a single "elementary signal". The method described below requires knowledge of the sound level $L_i(t)$, in dB (A), of a pure "elementary signal", i.e. only connected with the ith "acoustic event". When in the time of measurement the acoustic background is characterized by the mean level L_0, the signal $\tilde{L}_i(t)$ registered is slightly higher, since

$$\tilde{L}_i(t) = 10 \log\{10^{0.1L_i(t)} + 10^{0.1L_0}\}.$$

If $\{t_p, t_k\}$ is a time interval defined in the same way as for L_{AX} (formula (1)), relation (11) using discrete values gives

$$a_i = \Delta t \sum_{n=1}^{M} 10^{0.1\tilde{L}_i(t_n)} - \{t_k - t_p\} 10^{0.1L_0}, \tag{13}$$

where $t_n = t_p + n\Delta t$ and $t_k = t_p + M\Delta t$ (Fig. 3).

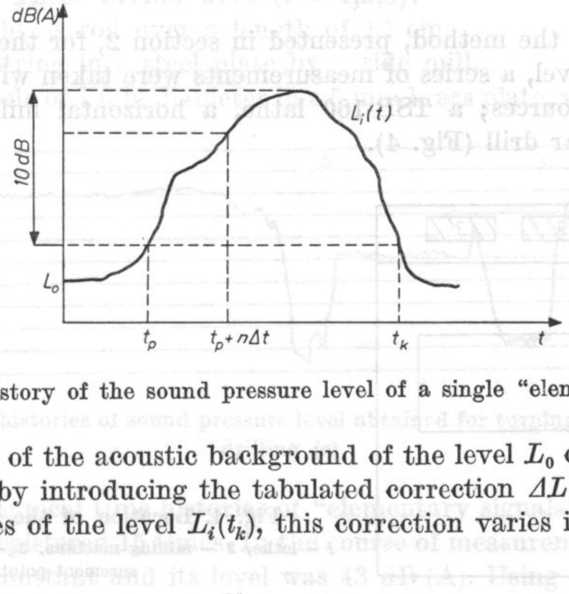

Fig. 3. Time history of the sound pressure level of a single "elementary signal"

The presence of the acoustic background of the level L_0 can also be considered otherwise, by introducing the tabulated correction ΔL [1]. Like the instantaneous values of the level $L_i(t_k)$, this correction varies in time $-\Delta L(t_k)$ and, therefore,

$$a_i = \Delta t \sum_{n=1}^{M} 10^{0.1\,\{\tilde{L}_i(t_n) - \Delta L(t_n)\}}. \tag{14}$$

A more detailed description of the method for calculating a_i is given in paper [4].

2.2. The method for the determination of a_i on the basis of measurement of the equivalent level. This method requires the measurement of the equivalent level L_{eq} of a signal consisting of one or more "elementary signals" of the same kind.

When a background is constant in time and has the level L_0, its equivalent level $\bar{L}_{eq} = L_0$. Formula (10) gives

$$a_i = \frac{T}{N_i}\{10^{0.1L_{eq}} - 10^{0.1L_0}\}. \tag{15}$$

Knowing the averaging time T, the number of the "acoustic events" N_i which occurred in this time, L_{eq} and L_0, it is possible to determine the value a_i more easily than by the method based on relations (13) or (14).

Since the "elementary signals" related to the same event are not fully identical, it is necessary, to measure at least several time pressure histories related to events of the same kind.

This method is given in greater detail in the following section of this paper.

3. Data on the parameter

To illustrate the method, presented in section 2, for the determination of the equivalent level, a series of measurements were taken within the enclosure with the noise sources; a TSB-160 lathe, a horizontal milling machine and a WS — 13 pillar drill (Fig. 4).

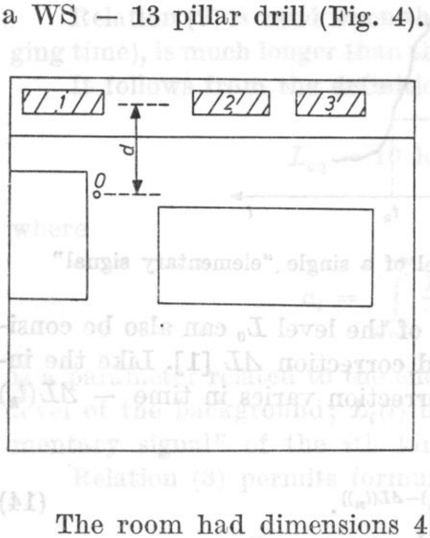

Fig. 4. Location of the noise sources
1 — lathe, 2 — milling machine, 3 — drill, and of the measurement point 0

The room had dimensions $4.10 \times 4.80 \times 3.50$ m³. The measurements were taken using a Brüel-Kjaer instrument: a 4145 condenser microphone of $2.54 \cdot 10^{-2}$m (1″) diameter, a 2204 sound level meter and a 2304 level recorder with a 50 dB potentiometer. The microphone was placed at a height of 0.8 m. The distance of the observation point 0 from the noise sources was $d = 0.9$ m (Fig. 4).

As could be expected, the "elementary signals" emitted during the work of a single machine resembled each other very much when the same job was performed on the same material. Fig. 5 shows the "elementary signals" registered at the observation point 0 when drilling a 7 mm diameter hole in a brass plate 5 mm thick.

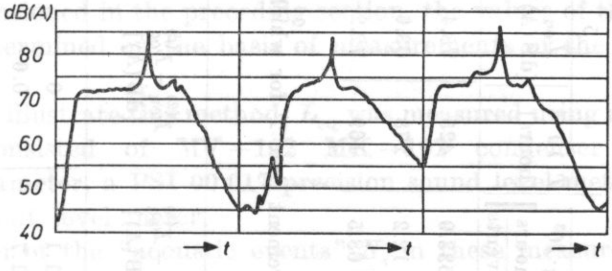

Fig. 5. Typical time histories of sound pressure level obtained for drilling

It was assumed initially, for the sake of simplicity, that each of these machines was the source of only one "elementary signal" related to only one "acoustic event". These events were ($i = 1,2,3$):

1. turning a brass rod over a length of 12 cm,
2. milling a string in a steel plate by a side mill,
3. drilling a hole of 7 mm diameter in a 5 mm brass plate, with manual feed.

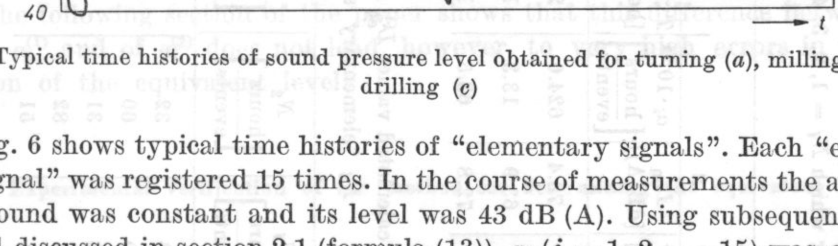

Fig. 6. Typical time histories of sound pressure level obtained for turning (*a*), milling (*b*) and drilling (*c*)

Fig. 6 shows typical time histories of "elementary signals". Each "elementary signal" was registered 15 times. In the course of measurements the acoustic background was constant and its level was 43 dB (A). Using subsequently the method discussed in section 2.1 (formula (13)), $a_{ij} (j = 1, 2, \ldots, 15)$ was calculated for each signal and the mean value $m_i = 15$ was determined from the formula

$$a_i^{(1)} = \frac{1}{m_i} \sum_{j=1}^{m_i} a_{ij}. \tag{16}$$

The following values of $a_i^{(1)}$ were obtained for the "acoustic events" $i = 1, 2, 3$:

$$a_1^{(1)} = (781 \pm 46) \cdot 10^3 \text{ hours/events}, \quad a_2^{(1)} = (15.7 \pm 1.7) \cdot 10^3 \text{ hours/events},$$
$$a_3^{(1)} = (78 \pm 27) \cdot 10^3 \text{ hours/events}, \tag{17}$$

Table 1. L_{eq} values for the time T for which $N_i = 1, 2, 3, 4, 5$ "elementary signals" reached the point 0. The values of a_i were calculated from formula (15)

i	N_i = 1: $T \cdot 10^{-4}$ [hours]	1: L_{eq} [dB(A)]	1: $a_i \cdot 10^{-3}$ $\left[\frac{\text{hours}}{\text{events}}\right]$	2: $T \cdot 10^{-4}$ [hours]	2: L_{eq} [dB(A)]	2: $a_i \cdot 10^{-4}$ $\left[\frac{\text{hours}}{\text{events}}\right]$	3: $T \cdot 10^{-4}$ [hours]	3: L_{eq} [dB(A)]	3: $a_i \cdot 10^{3}$ $\left[\frac{\text{hours}}{\text{events}}\right]$	4: $T \cdot 10^{-4}$ [hours]	4: L_{eq} [dB(A)]	4: $a_i \cdot 10^{3}$ $\left[\frac{\text{hours}}{\text{events}}\right]$	5: $T \cdot 10^{-4}$ [hours]	5: L_{eq} [dB(A)]	5: $a_i \cdot 10^{3}$ $\left[\frac{\text{hours}}{\text{events}}\right]$
1	88	78	578.4	181	78.4	624.6	265	78.2	584.2	350	78.6	533.9	425	78.4	588.1
2	58	63.5	13.1	108	63.9	13.3	169	63.3	12.1	222	63.4	12.2	278	63.6	12.7
3	42	70.8	50.1	67	72.8	63.5	111	72	58.7	144	72.7	68.5	169	72.2	57.5

Table 2. Comparison of the calculated values $L_{eq}^{(1)}$, $L_{eq}^{(2)}$ and those measured $L_{eq}^{(z)}$ in the measurement time T for which N_i "elementary signals" reached the observation point

Measurement	$L_{eq}^{(z)}$ [dB(A)]	N_i $\left[\frac{\text{hours}}{\text{events}}\right]$	N_2 $\left[\frac{\text{hours}}{\text{events}}\right]$	N_3 $\left[\frac{\text{hours}}{\text{events}}\right]$	$T \cdot 10^{-4}$ [hours]	$L_{eq}^{(1)}$ [dB(A)]	$L_{eq}^{(2)}$ [dB(A)]	$L_{eq}^{(1)} - L_{eq}^{(z)}$ [dB(A)]	$L_{eq}^{(2)} - L_{eq}^{(z)}$ [dB(A)]
1	70.8	16	32	32	622	71.9	70.8	1.1	0
2	72.9	30	60	60	333	74.6	73.5	1.7	0.6
3	75.4	62	31	31	322	77.1	76	1.7	0.6
4	72.8	27	82	54	368	74.3	73	1.5	0.2
5	74.8	51	51	51	590	76.5	75.4	1.7	0.6

characterizing successively the processes: of turning $a_1^{(1)}$; of milling $a_2^{(1)}$ and of drilling $a_3^{(1)}$. (The standard deviations are given in the brackets.) It can be seen that the highest value of Δa_i, compared to the value of a_i, occurs for drilling $(i = 3)$.

As was mentioned in the preceding section, the values of the parameters a_i can also be determined on the basis of measurements of the equivalent level (section 2.2).

In order to illustrate this method, L_{eq} was measured using a system of RFT instruments consisted of MV−102 MK−102 condenser microphone of $2.28 \cdot 10^{-2}$ m diameter, a PSI 00 017 precision sound level meter and PSM 101 00 005 equivalent level meter.

The number of the "acoustic events" N_i in these measurements was 1-5, respectively. The duration of measurement T was registered each time. The constant sound level of the background was 45 dB (A).

The measured results and also the values of the parameters $a_i^{(2)}$ calculated according to relation (15) are shown in Table 1.

The mean values of the parameters $a_i^{(2)}$ (formula (16)) with $m_i = 15$) for each of the "acoustic events" discussed here and their standard deviations are:

$$a_1^{(2)} = (602 \pm 26) \cdot 10^3 \text{ hours/events}, \quad a_2^{(2)} = (12.66 \pm 0.54) \cdot 10^3 \text{ hours/events},$$
$$a_3^{(2)} = (59.7 \pm 7.0) \cdot 10^3 \text{ hours/events}. \tag{18}$$

Comparison of the above results (obtained by the two methods here) shows that values $a_i^{(2)}$ (18), calculated by the method for the determination of L_{eq} of a signal composed of several "elementary signals" of the same kind (section 2.2), are lower than the values $a_i^{(1)}$ (17) obtained by the method of registering the sound level of a single "elementary signal".

The following section of the paper shows that this difference between the values $a_i^{(1)}$ and of $a_i^{(2)}$ does not lead, however, to very high errors in the calculation of the equivalent level.

4. Experimental verification of the method for determining the equivalent level

Formula (10), derived in section 2, permits to determine the equivalent level L_{eq} of the resultant signal in an enclosure when the numbers of the "acoustic events" N_i, the time T, the values of the parameters a_i and the background equivalent level $\bar{L}_{eq}$ are known.

In order to verify this relation, five direct measurements of $L_{eq}^{(z)}$ were taken at the point 0 (Fig. 4), using the same instruments as in the measurements of a_i (section 3). Substitution into formula (10) of numerical values of $a_i^{(1)}$ and $a_i^{(2)}$ and the quantities T and N_i corresponding to measurement conditions gave the values of $L_{eq}^{(1)}$ and $L_{eq}^{(2)}$. The results are shown in Table 2.

This table shows that a better agreement between theory and experiment can be achieved when the values $a_i^{(2)}$ (18) obtained by the method proposed in section 2.2. are inserted into formula (10). This fact can be explained by that direct measurements of $L_{eq}^{(2)}$ and measurements permitting the determination of the values $a_i^{(2)}$ (15) were performed by the same measuring system. As was mentioned above, the sound level time history on the basis of which $a_i^{(1)}$ were calculated had been registered by other instruments.

In general case, differences between the measured values $L_{eq}^{(2)}$ and the calculated ones $L_{eq}^{(1)}$, $L_{eq}^{(2)}$ are caused by that the "acoustic events" of the same kind (turning, milling and drilling) are different from one another. This signifies that the "elementary signals" reaching the observation point in the measurements permitting the calculation of a_i are different from the signals registered in direct measurements of the equivalent level, which is caused by differences in the processes of turning, milling etc. themselves.

Table 2 shows that differences between measured values and those calculated according to formula (13) do not exceed 1.7 dB (A). Assuming that this deviation is admissible, it can be claimed that the method proposed here for determining the equivalent level in an enclosure is valid.

5. Remarks on the measuring procedure

The method proposed in this paper requires measurements of the sound level of single "elementary signals" (section 2.1), or measurements of the equivalent level of several "elementary signals" (section 2.2), or measurements of L_{AX} (formula (12)). The accuracy of the present method increases as the number of these measurements increases, since for $m_i \to \infty$ formula (16) defines the most probable value of the mean $\bar{a}_i$. For a finite number of m_i the values of a_i obtained from (16) are different from $\bar{a}_i$, which causes error in the case when the values of L_{eq} are determined from formula (10). This error increases as the difference $\delta a_i = a_i - \bar{a}_i$ increases. On the other hand, an increase in the number of measurements, m_i, causes the method to become very time-consuming and, therefore, hardly useful in practice.

This difficulty can be avoided by defining a minimum number of measurements m_i for which error committed in determining L_{eq} is less than k dB with the probability p.

According to the law of error propagation [3], the error ΔL_{eq} depends on the quantity δa_i in the following way

$$\Delta L_{eq} = \left[\sum_{i=1} \left(\frac{\partial L_{eq}}{\partial a_i} \delta a_i \right)^2 \right]^{1/2}. \tag{19}$$

It follows from formula (10) and the condition $L_{eq} < k$ that

$$\frac{10(\log e)\left[\sum_i (N_i \delta a_i)^2\right]^{1/2}}{\sum_i N_i a_i + T\cdot 10^{0.1\bar{L}_{eq}}} < k. \tag{20}$$

When the values of a_{ij} ($j = 1, 2, \ldots, m_i$) have a normal distribution, the following relation is satisfied [3]

$$\delta a_i = \frac{t_p^{(i)} \Delta a_i}{m_i}, \tag{21}$$

where $t_p^{(i)}$ is the value obtained from the t distribution for the probability p with $m_i - 1$ degrees of freedom (m_i is the number of measurements of a_{ij}), while Δa_i is the standard deviation.

Substitution of (21) into (20) gives the following inequality

$$\sum_i \frac{a_i}{m_i^*} < A, \tag{22}$$

where

$$a_i = (N_i t_p^{(i)} \Delta a_i)^2,\ A = \left[0.1(\ln 10)k\left(\sum_i N_i a_i + T\cdot 10^{0.1\bar{L}_{eq}}\right)\right]^2. \tag{23}$$

It is possible to derive from inequality (22) the number of measurements of "elementary signals", m_i^*, for which the mean values of a_i (formula (16)) are different from the values $\bar{a}_i$ by δa_i, where the value $L_{eq}(a_i)$ calculated from formula (10) is different from the real quantity $L_{eq}(\bar{a}_i)$, with the probability p, by, at most, k[dB].

In order to determine m_i^*, it is necessary to take a pilot series of measurements of a_{ij} ($j = 1, 2, \ldots, m_i$) and define a_i according to formula (16). It is subsequently necessary to find the values $t_p^{(i)}$ for given k and p. When the number N_i of "acoustic events" in the time T is known, it is possible to calculate a_i, A and m_i^* from formulae (22) and (23).

EXAMPLE. It can be assumed that the values a_i (formula (17)) are the results obtained from the pilot series. The number of measurements of a_{ij} of each "elementary signal" was $m_i = 15$ for both turning ($i = 1$), milling ($i = 2$) and drilling ($i = 3$). It can be assumed that it is necessary to define such values of m_i^* for which L_{eq} calculated from formula (10) will differ by $k = 0.5$ dB from the real value $L_{eq}(\bar{a}_i)$ with the probability $p = 0.999$. Let the number of "acoustic events" in 8 hours be $N_1 = 500$, $N_2 = 600$ and $N_3 = 700$, respectively, and the background equivalent level $\bar{L}_{eq} = 40$ dB A.

From the t distribution for $m_i - 1 = 14$ degrees of freedom $t_{0.999}^{(i)} = 4.14$. Insertion of numerical values into formulae (23) gives

$$a_1 = 9.06\cdot 10^{15},\quad a_2 = 1.78\cdot 10^{13},\quad a_3 = 6.12\cdot 10^{15},\quad A = 2.73\cdot 10^{15}.$$

Inequality (22) takes the form

$$\frac{9.06}{m_1^*}+\frac{1.78\cdot 10^{-2}}{m_2^*}+\frac{6.12}{m_3^*}<2.73.$$

Assuming that $m_1^* = m_2^* = 10$, then $m_3^* = 4$. This result means that the pilot series of measurements of a_{ij} ($j = 1, 2, \ldots, 15$) performed here is sufficient for determination of the mean values of a_i on the basis of which the value of the equivalent level L_{eq} differs from its real value by 0.5 dB. The probability of obtaining this value of L_{eq} is $p = 0.999$.

6. Conclusions

The aim of this paper was an illustration (section 3) and a verification (section 4) of the method proposed in section 2 for determining the equivalent level L_{eq} in an enclosure. For a given room the values of the parameters a_i do not only depend on the operations performed on particular machines (these operations being called here "acoustic events") but also on the location of the observation point (x, y). It can be assumed that there are M different "acoustic events". Thus, formula (10) can be generalized to the form

$$L_{eq}(x, y) = 10 \log\left\{\frac{1}{T}\left(\sum_{i=1}^{M} N_i a_i(x, y) + 10^{0.1\bar{L}_{eq}}\right)\right\}. \tag{24}$$

It can be assumed that numerical values of $a_i(x, y)$ and the equivalent level of the background are given. Let L_{eq}^* be the value of the equivalent level for T hours which must not be exceeded. Thus, from formula (24),

$$\sum_{i=1}^{M} N_i a_i(x, y) = T(10^{0.1L_{eq}^*} - 10^{0.1\bar{L}_{eq}}). \tag{25}$$

It is possible to obtain from this equation the numerical values N_i^* which define the admissible number of "acoustic events". In other words: when the inequality $N_i < N_i^*$ ($i = 1, 2, \ldots, M$) is satisfied, the value of L_{eq} over T hours in the observation point (x, y) is less than L_{eq}^*.

It can be seen that the present method for determining the equivalent level may be useful in controlling technological processes so that the conditions of good acoustic climate are met in industrial interiors.

EXAMPLE. The numerical values of the parameters a_i, given in section 3 (18), were obtained at the point 0 (Fig. 4). It can be assumed that $L_{eq}^* = 80$ dB (A) is an equivalent level which should not be exceeded for $T = 8$ hours of work. Let the equivalent level of the background be $\bar{L}_{eq} = 60$ dB (A). There are three kinds of machinery: lathe, mill and drill on which turning, milling and drilling can be performed. The respective technological processes related to these three kinds of machinery are characterized by the numbers N_1^*, N_2^* and N_3^*.

For instance, the production of screws in hall would require N_1^* turnings, N_2^* millings and N_3^* drillings. To answer the question whether the production of screws will not cause the standard $L_{eq}^* = 80$ dB (A) to be exceeded, it is sufficient to put N_1^*, N_2^*, N_3^* and $L_{eq}^* = 80$ dB (A), $L_{eq} = 60$ dB (A), $T = 8$ hours and $M = 3$ into formula (25). This gives

$$781N_1^* + 15.7N_2^* + 78N_3^* \approx 792\cdot 10^3. \quad (26)$$

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