THE NOISE FROM VEHICLES AND TRANSPORT FLOW

ШУМ АВТОМОБИЛЯ И АВТОМОБИЛЬНОГО ПОТОКА

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Abstract: *Increases in road traffic lead to the expansion of areas of the acoustic discomfort, and the noises from vehicles acquire social importance. The noise as a set of sounds is characterized qualitatively and quantitatively by two main indicators: the sound pressure or intensity level, which have different effect on the human body. In addition, in terms of the effect on the human body, the prefence is given to the noise equivavlent level. The study of the noise equivalent level can be carried out in two ways. The first one consists in fact that at a given moment of time, at any point in space, there are summarized the noise level or sound energy intensity from all radiation sources, but another way implies summarizing the selected sound energy sources during a certain time period. So, in order to determine the noise equivalent level of one vehicle during that time period, which is required for passing a certain section, it is necessary to know those laws, which characterize traffic conditions and the calculated changes of the noise level in these conditions.*

KEY WORDS: *TREANSPORT FLOW; TRAFFIC CONDITION; NOISE LEVEL; SOUND ENERGY.*

1. *Introduction*

In the airspace, human being is capable of perceiving sound vibrations in a wide range: with power – $10^{-12}\div 1$W; frequency - 20÷20000 Hz. However, sound carries not only useful information. Orderless and highly-intesive sound causes fatigue and performance decrement, but its long-term effect causes the pathological changes in the internal organs.

Vehicle noise is one of significant parameters of the environmental pollution and its control is very important for specialists. Transport flow generates 60÷80% of sound affecting human health. In the conditions of growing scale of car traffic, the areas of the acoustic discomfort increase considerably and vehicle noise gains a social significance.

In all vehicles, including a moving car, energy conversion is accompanied by the acoustic emission into environment. One of such channels of this emission is represented by sound waves. They represent an oscillatory motion of wave of the elastic medium. The sources of a moving car are surfaces of the engine installation, intake and exhaust systems, surfaces of the transmission systems. Noise is also generated when interacting a moving car with an air flow, tires with road a road surface, by the oscillations of the suspension components and a car trunk, which are caused by the road irregularities, and so on.

2. *Preconditions and means for resolving the problem*

To describe the source of the emission, there is used full sound power *W*, which is emitted into into surrounding hemisphere

$$W = I\,2\pi r^2 = 2\pi r^2 \overline{P}^2 / \rho C$$

r – a radius of hemispher, is measured in unit of meter.

The values of sound pressure, sound intensity and sound power vary within a wide range. For example, the lowest sound pressure, which are perceptable to the organs of hearing, is 2×10^{-5} N/m^2, at the same time, it can reach 2×10^{4} N/m^2. The absolute values of these parameters are not convenient for using, since the range of variations is too wide. That is why it is customary to use the relative figures, which are expressed in the logarithmic units, decibels (dB). So, in order to prevent noise, there are accepted the relative figures, such as the unit of the comparing parameters – to sound pressure level, sound intensity level and to sound power level. The limiting sound pressure is accepted as a comparing unit of sound pressure, which is equal to 2×10^{-5} N/m^2, this value has been standardized. As a result, we came to a point where we accept that the mentioned relative figures take absolute values, since they identically characterize absolute values of sound pressure and sound intensity.

Sound intensity level

$$L_{\text{b}} = 10\lg\frac{I}{I_0},$$

wher I_0 – a sound limit value, when frequency f =1000 Hz, $I_0 = 10^{-12}$W/m^2.

Such sound intensity corresponds with the limiting sound pressure $P_0=2\times10^{-5}$ N/m^2. The multiplier 10 is used to obtain smaller units of noise – one tenth of a logarithm.

Sound pressure level

$$L_P = 10\lg\frac{P^2}{P_0^2} = 20\lg\frac{P}{P_0} = 10\lg\frac{I}{I_0},$$

where P_0 – the limiting value of pressure.

Therefore, noise as the totality of sound, is characterized quantitatively and qualitatively, consequently, by two basic parameters: the level of sound pressure or intensity, i.e. the totality of sound frequency, which generates noise. Its effects on an organism are different. In addition, from the objective point of view, regarding the health, preference is given to the noise equivalent level $L_{\text{eq.}}$. It is an equivalent-continuous noise level, during which, in a given fraction of time, there is released the same energy as with variable noise, in the same fraction of time.

$$L_{\text{q.}} = 10\lg\left[\frac{1}{4}\int_0^T 10^{0,1L_i}\left(dt\right)\right]$$

Thus, we came to a point where we accept that the effect of noise generated by transport flow is estimated by the value of the equvalent level L_{eq}, dB and frequency corrected by *A* chartacteristic.

Modeling of noise from one car involves serious difficulties, since state of the atmpspher is unstable by nature. Density, temperature, wind and humidity are neve constant in a given volume and time. When going through the atmosphere, sound waves are exposed to these variable parameters, if the propagation distance of sound wave is long.

Thus, sound level (in decibels) is an indicator, which has been obtained by the ratio of sound intensity logarithm to sound limit value. A minimum sound intensityy, which is perceptable to a man with good ears is $I_0 = 10^{-12}$ W/m^2.

Sound level is calculated according to the following formula:

$$L = 10\lg\frac{I}{I_0},$$

Transformation of this expression is possible, if we insert the value $I_0 = 10^{-12}$

$$L = 10\lg I - 10\lg I_0 = 10\lg I + 120$$

If sound level is known, sound intensity would be

$$I = 10^{\,0{,}1\,L-12}$$

Computational scheme for characteristics of noise generated by transport flow, is designed in the following way. First, there are determined sound indicators of vehicles in the flow. Noises from all vehicles are summarized in accordance with a certain law. The main element of the calculation of transport flow noise is the establishment of the objective laws, which allow for determining noise from each individual car. A sound field of transport flow, from the acoustic positions, is a field, which is generated by the distribution system of the point-source emitters.

General theory of the mitting system distribution provides principled approaches to the calculation of the emission, when distributing system in various conditions. The basic method is energy summation method. The capacities of energy summation method largely depend on the frequency characteristics of the emitter [1].

The picture of a quite complex interference field obtained with a fixed frequency, largely depends on the coordinates of a point and on frequency, and varies many times with slight variations in initial conditions, but, in fact, we do not notice such variations, because clear interference picture is obtained only with pure sounds.

The summation procedure itself and study of noise equivalent level can be carried out in two ways. The first one consists in fact that at a given moment of time, at any point in space, there are summarized the noise level or sound energy intensity from all emission sources.

In this case, the aggregate instantaneous values are to be taken for system noise

$$L_{\text{m.}} = 10\lg \sum_{i=1}^{N} 10^{0{,}1Li-12} + 120,$$

where N – the number of noise sources. Then, the noise equivalent level is calculated.

Also, during the calculations the second methjod of energy summation. This means summation of the sources of selected sound energy during the T time.

$$I_{\text{n}} = \sum_{i=1}^{n} I_{in},$$

where I_{n} and $I_{.in}$ – sound energy equivalent intensity for transport flow and i-th car.

The sound equivalent level of transport flow N during the intensive movement

$$L_e = \lg \sum_{i=1}^{N} I_{\text{ie}} + 120$$

To determine sound equivalent level of the *i-th* vehicle, which moves within transport flow, for the observer staying on 7,5 m from traffic lane, the following formula can be considered

$$W = I\, 2\pi r^2 = 2\pi r^2\, \overline{P}_{\varphi}^{\,2} / (\rho\, C)$$

Let's assume that the vehicle is an omnidirectional point-source power. W_i, which is located in a free semi-space, we can express its sound intensity at any r distance by, as $I_i(r_i)$, obtain, for a given condition, the calculating expression I_i (7,5)= I_{ip} on 7,5 m from traffic lane

$$W_i = I_i(r_i) 2\pi r_i^2 = I_{ip}\, 2\pi (7{,}5)^2$$

or $$I_i(r_i) = 56{,}25 I_{ip} / r_i^2$$

Noise level from the emission source at any distance

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$$L_i(r_i) = 10\lg \frac{56{,}25^2 I_{ip}}{I_0 r_i^2} = L_{ip} - 20\lg \frac{r_i}{7{,}5}$$

During the process of car movement, the distance from it to a measuring point varies in accordance with the patterns of this movement. Fig. 1 illustrates that the distance from the observation point to the emission source is

$$r_i = \sqrt{x_i^{\,2} + y^2},$$

where x_i – a current coordinate of a car $x_i = f(t)$; y – the distance from the measuring point to traffic lane.

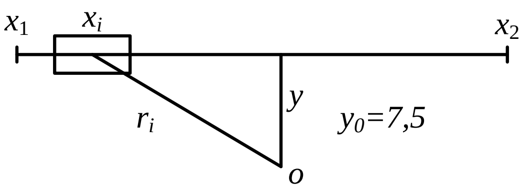

Fig.1. Computational scheme for determining the distance to the point of noise

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The current value of sound energy intensity at the oberving point

$$I_i(r) = 56{,}25 I_{i0} \big/ \left(x_i^2 + y^2\right)$$

To determine the "itegral intensity", which at point O comes on the section, or during the T time required for passing this section, which is identical from physical standpoint, it is necessary to integrate the expression $I_i(r)$ by distance or time

$$I_{\text{it}} = 56{,}25 \int_{x1}^{x_2} \frac{I_{iP}}{x_i^2 + y^2}\, dx$$

$$I_{\text{it}} = \int_0^T \frac{I_{ip}}{x_i^2(t) + y^2}\, dt$$

The equivalent intensity is derived by dividing the integral intensity by distance or time.

$$I_{\text{ie}} = \frac{I_{\text{it}}}{x_1 x_2} = \frac{I_{\text{nt}}}{T(x_1 x_2)},$$

The noise equivalent level, when passing through the section, is determined by inserting noise level into the formula I_{ie} -ს

$$L_{\text{ie}} = 10\lg \frac{I_{\text{ie}}}{I_0} = 10\lg I_{\text{ie}} + 120$$

3. Conclusion

Thus and so, in order to determine the noise equivalent level of one vehicle during the time, which is required for passing through a certain section, it is necessary to know those laws, which characterize traffic conditions and the calculating variations of noise level in given traffic conditions.

4.. References

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