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METHOD OF EVALUATION OF THE PROBABILISTIC DISPERSION OF TRACTION AND TRANSPORT VEHICLES ESTIMATED NOISINESS

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Abstract

This paper describes questions, which are connected with possibility of obtaining the dispersion of traction and transport vehicles (TTV) noisiness computation on the stage of its development. Experimental data shows that noise around TTV and at operator workplace has wide dispersion of values for even one model produced by one factory at the same time. It concerns practically every type of TTV – new and with some operating time, at mass, individual and serial producing, and at similar operation conditions. Mathematical functions for determination of dispersion mentioned above in dependence on confidence interval of various sources noisiness were obtained. The general method for assessment of probabilistic dispersion of estimated noisiness results is presented. This general method for probabilistic dispersion of computational evaluation of TTV noisiness consists of next stages: assessment of dispersion (confident interval) of acoustic power of each separate noise source; determination of computational function (choice or compiling formulas for computation); determination of dispersion (confident interval) for sound absorption coefficients and other independent variables; determination of partial derivatives for computational function on each independent variable; obtaining of functional dependence of result dispersion of input factors (arguments); calculating of numerical assessment value of TTV noisiness determination result.

Keywords: *traction and transport vehicles, method, confidence interval, probability, statistic, noise dispersion*

Experimental data [1...3] shows that noise around TTV and at operator workplace has wide dispersion of values for even one model produced by one factory at the same time. It concerns practically every type of TTV – new and with some operating time, at mass, individual and serial producing, and at similar operation conditions.

Though, while method of statistical analysis of measurements of various technical objects noisiness is developed quite well [4, 5 and others], at present time there is no computational evaluation of possible dispersion of TTV noisiness. However, it could be useful for engineers for preliminary evaluation of TTV noisiness at the stage of its development because this method could reduce expensive fine-tuning tests.

Dispersion of noisiness with evaluation of its probabilistic dispersion in first approximation can be made because of data of separate sources noise dispersion. At the same time, it is necessary to remember that in general case noise forming in cabin and at TTV operator workplace is determined with next components:

- air (or penetrating) noise,
- structural (or vibrating and case) noise,
- reflected (secondary) noise,
- noise from internal sources (fan, heater etc.).

In addition, while noise from internal sources can be easily excluded during test and computations, first three components are tightly connected with each other, because they are characterized by the same external sources and acoustic constant of cabin.

But, so far as passive methods of struggle against air and structural TTV noise are substantially different, this paper describes only air component of noise and secondary noise connected with it (though approach for determining of noise dispersion and structural noise will be similar).

Determination of the sound pressure levels (SPL) of air noise in specified points from various sources (near separate panels) is performed in general case due to formulas with similar structure [7,8 and others]. Thus, for example of determination of calculated noise dispersion, only one formula will be considered – for SPL computation near cabin panel from engine noise that passes through lower opened aperture in hood.

$$L_n = L_{dv} + 10\lg\left(\frac{\chi_{kap.dv}}{4\pi r_{dv}^2} + \frac{4\psi_{kap.dv}}{B_{kap.dv}}\right) + 10\lg\frac{S_{pr}}{S_{kap}} + 10\lg(1-\alpha_3) - 20\lg R, \quad (1)$$

where: α_3 is average coefficient of reflective surface sound absorption,

L_{dv} is sound power radiated by engine,

S_{kap} is area of engine hood enclosures,

S_{pr} is aperture area,

$\chi_{kap.dv}$ is coefficient that takes into account the impact of engine near sound field,

$\psi_{kap.dv}$ is coefficient that takes into account breach of sound field diffusivity,

r_{dv} is distance between engine and hood panel,

h_{dv} is height of engine installation above reflective surface,

R_{dv} is distance between engine case and work place,

$B_{kap.dv} = \frac{A_{kap}}{1-\alpha_3} = \frac{S_{kap}\alpha_3}{1-\alpha_3}$ is hood constant,

$R = \sqrt{h_{dv}^2 + (R_{dv}/2)^2}$.

It is known from computational mathematic course that the function finite increment (which defines dispersion of its values) can be calculated with the formula that connects the function error with arguments errors [9 and others]:

$$\Delta_F \le \sum_{i=1}^{n}\left|\frac{\partial F}{\partial x_i}\right|\Delta_{x_i}, \quad (2)$$

where: Δ_{x_i} is argument error,

Δ_F – function finite increment,

$\left|\frac{\partial F}{\partial x_i}\right|$ is the function partial derivative on i -th argument,

n is total number of independent arguments.

Approximate values of such initial parameters as L_{dv}, α_3, $B_{kap.dv}$ are used in formula (1). Consequently, they will have finite increments $\Delta_{L_{dv}}$, Δ_{α_3}, $\Delta_{B_{kap.dv}} = \frac{S_{kap}\Delta_{\alpha_3}}{(1-\alpha_3)^2}$.

If $C = \left(\frac{\chi_{kap.dv}}{4\pi r_{dv}^2} + \frac{4\psi_{kap.dv}}{B_{kap.dv}}\right)$, then with a glance functions (1) and (2) one can obtain:

$$\Delta_{L_n} = \Delta_{L_{dv}} + \left|\frac{\partial L_n}{\partial \alpha_3}\right|\Delta_{\alpha_3} + \left|\frac{\partial L_n}{\partial B_{kap.dv}}\right|\Delta_{B_{kap.dv}}.$$

Here $\frac{\partial L_n}{\partial \alpha_3}$ is function (1) partial derivative on α_3,

$\frac{\partial L_n}{\partial B_{kap.dv}}$ is function (1) partial derivative on $B_{kap.dv}$,

$$\frac{\partial L_n}{\partial \alpha_3} = -10\, lg\, e \frac{1}{1-\alpha_3} \text{ and } \frac{\partial L_n}{\partial B_{kap.dv}} = -10\, lg\, e \frac{4\psi_{kap.dv}}{C} \frac{1}{B_{kap.dv}^2}.$$

Then
$$\Delta_{L_n} = \Delta_{L_{dv}} + 10\lg e \frac{1}{C} \cdot \frac{4\psi \Delta_{B_{kap.dv}}}{B_{kap.dv}^2} + 10\lg e \frac{\Delta_{\alpha_3}}{1-\alpha_3}. \tag{3}$$

As far as error at its known distribution law definitely, with specified confident probability, defines function confident interval, so one can estimate dispersion of SPL computation results in specified point from separate noise source based on this error.

If there are several sources, it is necessary to perform energetic summation of computation results for each one of these sources. Thus, dispersion of noise total level will be defined by the dispersion of values of each summable parameters.

For energetic summation of SPL, next function is used [7, 8 and others]:

$$L = 10\lg\left(\sum_{i=1}^{n} 10^{(0.1L_i)}\right), \tag{4}$$

where L_i is mathematical expectation of sound power values of summable sources. Dispersion of L_i (one can compute half of confident interval for L_i values) values is marked as Δ_{L_i}. Then, taking into account formula (2) we obtain:

$$\Delta_L \le \sum_{i=1}^{n} \left| \frac{\partial L}{\partial L_i} \right| \Delta_{L_i},$$

$$\frac{\partial L}{\partial L_i} = 10 \cdot lg\, e \frac{0.1 \cdot ln(10) 10^{0.1L_i}}{\sum_{i=1}^{n} 10^{(0.1L_i)}} = 10 \cdot lg\, e \cdot ln(10) \cdot 0.1 \frac{10^{0.1L_i}}{\sum_{i=1}^{n} 10^{(0.1L_i)}}.$$

As far as $\lg e \cdot \ln(10) = 1$, then $\frac{\partial L}{\partial L_i} = \frac{10^{0.1L_i}}{\sum_{i=1}^{n} 10^{(0.1L_i)}}$ and consequently

$$\Delta_L \le \frac{\sum_{i=1}^{n} 10^{0.1L_i} \Delta_{L_i}}{\sum_{i-1}^{n} 10^{0.1L_i}}. \tag{5}$$

Conclusion

This general method for probabilistic dispersion of computational evaluation of TTV noisiness consists of next stages:

- assessment of dispersion (confident interval) of acoustic power of each separate noise source,
- determination of computational function (choice or compiling formulas for computation),
- determination of dispersion (confident interval) for sound absorption coefficients and other independent variables,

- determination of partial derivatives for computational function on each independent variable,
- obtaining of functional dependence of result dispersion of input factors (arguments),
- calculating of numerical assessment value () of TTV noisiness determination result.

References

[1] Venttsel, E. S., Teoriya veroyatnostey, Nauka, Moskva, 1969.

[2] GOST 27408-87 (ST SEV 5711-86). Shum. Metodyi statisticheskoy obrabotki rezultatov opredeleniya i kontrolya urovnya shuma, izluchaemogo mashinami, IPK Izdatelstvo standartov, Moskva.

[3] Grigorev, E. A., Pobedin, A. V., Statisticheskaya otsenka shuma i vibratsiy traktorov, Mehanizatsiya i elektrifikatsiya sotsialisticheskogo selskogo hozyaystva, No. 8, pp. 36-37, 1974.

[4] Demidovich, B. P., Maron, I. A., Osnovyi vyichislitelnoy matematiki,. (3-e izd.), Nauka. Glavnaya redaktsiya fiziko-matematicheskoy literaturyi, Moskva, 1966.

[5] Ivanov, N. I., Inzhenernaya akustika. Teoriya i praktika borbyi s shumom, Uchebnik, Universitetskaya kniga, Logos, p. 424, Moskva, 2008.

[6] Kruze, A. O., Kruze, O. O., Statisticheskaya otsenka shuma avtomobiley, Avtomobilnyie perevozki, organizatsiya i bezopasnost dorozhnogo dvizheniya, MADI, pp. 28-34, Moskva, 1981.

[7] Pobedin, A. V., Kosov, O. D., Dolotov, A. A., Domolazov, F. S., Nekotoryie statisticheskie harakteristiki shumnosti korobki peredach avtomobilya GAZ-3110, Avtomobilnaya promyishlennost, No. 9, pp. 13-15, Moskva, 2010.

[8] Pobedin, A. V., Kosov, O. D., Dolotov, A. A., Dolgov, K. O., The Modelling of Noise Emission by the Gearbox of Vehicles GAZ 3110, 31105, Journal of KONES. Powertrain and Transport, Vol. 18, No. 1, pp. 453-456, 2011.

[9] Pobedin, A. V., Proektirovanie vibroshumoizolyatsii traktornoy kabinyi, ucheb. posob. (grif). Rek. UMO po avtotrak. i dorozh., VolgGTU, Volgograd, 1994.

[10] SNiP 23-03-2003 Zaschita ot shuma, Gosstroy Rossii, Moskva, 2004.