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Theoretical Study of the Elements` Vibrations of the Diesel Shunting Locomotive Cabins

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Abstract. The article is devoted to the creation of the high-capacity transport vehicles, in which the use of vibro-active organs is increasingly used, inevitably leads to the increase in the levels of vibration and noise that are harmful to locomotive crews, and in the operation of the transport vehicles in the dwellings and to the acoustic environment pollution. This problem is relevant for the rail vehicles. First of all, according to the EU, it is necessary to implement measures for extinguishing noise in the places where it occurs, i.e. from the movement of the rolling stock. In this direction, the domestic and foreign experts carried out certain research. However, the formation process of the vibro-acoustic characteristics has not been studied enough. It should also be noted that the theoretical research of the vibro-acoustic dynamics of the rolling stock and methods for calculating vibration and noise spectra are limited that makes it difficult to substantiate engineering solutions for reducing the intensity of the sound emission from dominant noise sources. It is considered in the negative effect of the high level noise on workers of the locomotive crews, machinists and the environment, it is necessary to create rail vehicles with appropriate vibro-acoustic characteristics that meet the requirements of the international standards. For the locomotive`s cab, the significant influence of the structural noise component is characteristic. Therefore, this article presents the results of the theoretical studies of vibro-acoustic characteristics of the locomotives` cabins based on traditionally used method of the energy balance for plate structures. In addition, the system of equations observes the elements of the glazing of the cabins as a "weak link" of the supporting structure. The obtained results determine the expected sound pressure levels in the design of the cabins and compare them with the maximum permissible values. The values of the excesses in the according frequency ranges are the main information for choosing engineering solutions for reducing noise levels at the design stage of such machines.

1. Introduction

The power installation of the locomotives uses the internal combustion engine which is set up closely to the cabin. The impact of the vibrations and sound emissions of the power installation identifying by power will be differed in intensity with almost identical arrangement of the vibration sources and noise in the relative calculation points for different types of the locomotives.

Therefore, the theoretical background, the calculation and design of such group of machines according to the vibro-acoustic safety criteria is carried out with the same methodological positions.

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2. Object and methods of research

The typical characteristics of the general vibro-acoustic system of the locomotives are:
1. A crane is installed on the roof of the locomotive cabin, where the drive is the source of the sound radiation and vibrations.
2. The diesel shunting locomotive as the loading transport locomotive LTL-6 (Fig. 1) is equipped with a removable workshop with a set of machines and tools which create a sound field in a closed volume with rigid enclosing walls.
3. The cabins of the diesel shunting locomotives have a larger glazing area than the locomotives. These features must be considered in calculating the air noise component at the engine operator's workplaces.

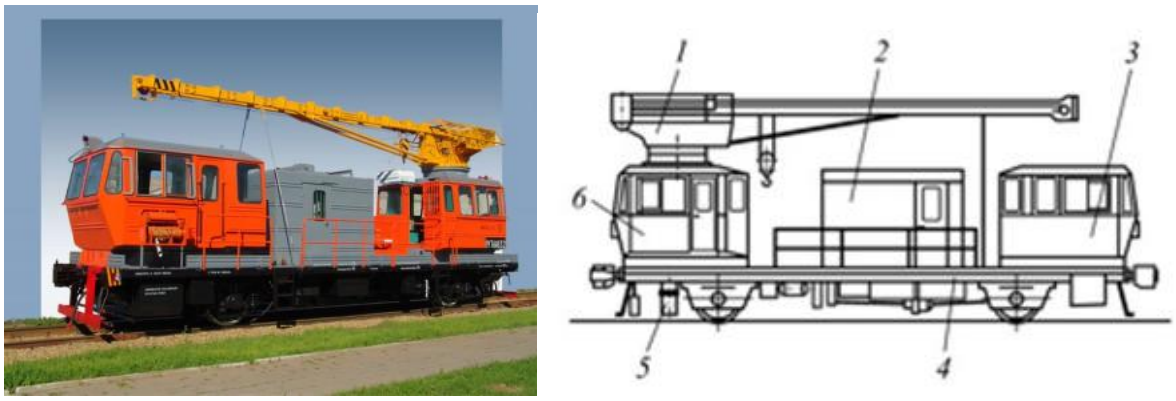


Figure 1. The loading transport locomotive LTL-6
(Overview): 1 - the jib of the crane; 2 – the locksmith's workshop; 3 – the cabin for transportation of the mechanized brigades; 4 – the platform of the locomotive; 5 – the outriggers; 6 – the control foot-plate

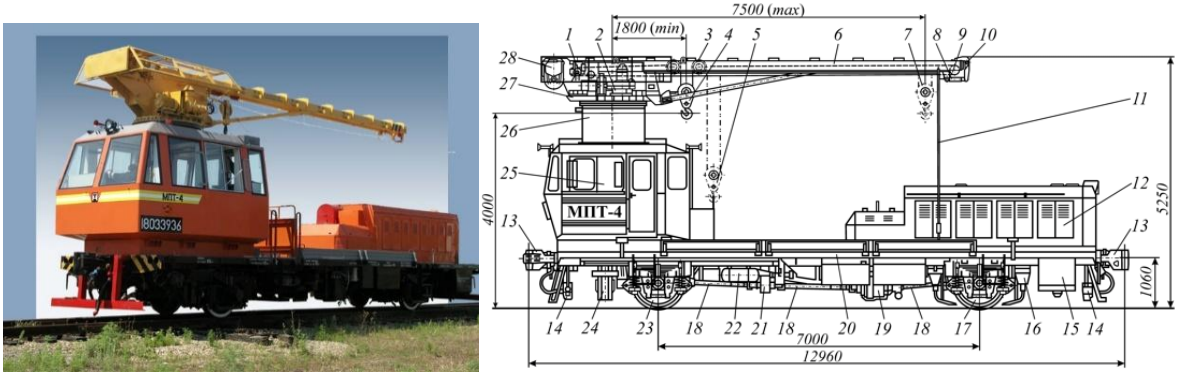


Figure 2. The configuration of the loading transport locomotive LTL-4:
1 – the pulling winch; 2 - the jib swing drive; 3-the loading trolley; 4, 7 - the extreme positions of the hook block; 5 - the transport position of the hook block; 6 – the jib of the crane; 8 - the warping; 9 – the bypass block; 10 – the load limiter; 11 – the transport spacers; 12 – the diesel generator; 13 – the automatic couplers; 14 – the coils of CLUB-OC; 15 – the fuel tank; 16 – the sandbox; 17, 23 –the driven wheel pairs; 18 – the drive shafts; 19 -the universal hydraulic transmission LT-300; 20 – the platform; 21 – the intermediate support; 22 – the pneumatic system; 24 – the outriggers; 25 – the control foot-plate; 26 -the intermediate crane support; 27 - the base of the crane; 28 – the cargo winch.

As a research object, the loading transport locomotive LTL-6 and LTL-4 were chosen, the loading transport locomotive LTL-6 is equipped with two cabs. The study of the formation of the vibro-

acoustic characteristics at the workplace of the driver was carried out for the cabs on the roof where the crane was installed. The calculation of the structural noise component is based on the energy balance methods traditionally used for such structures. However, it should be noted that in [1-20] the above-mentioned specificity of the research objects as locomotives cabins aren`t observed. Therefore, in the scheme of the locomotive cabin, presented in Fig. 1 and Fig. 2, the door, the glazing and the features of the input vibrational power are considered in.

The authors present the notation according to the arrangement of the locomotive cabin (Fig. 2): 1 - floor, 2 - front panel, 20 - glazing elements of the front panel, $2_{Д}$ – door, 3 - front panel, 3_0 - front panel glazing, 4 - rear panel, 4_0- the glazing of the rear panel, 5 - the left panel, 5_0 - the glazing of the left panel, 6 - the ceiling of the cabin.

For such scheme of the cabin the equations system has the form:

$$\delta_1 S_1' q_1 + \alpha_{12} l_{12} q_1 + \alpha_{13} l_{13} q_1 + \alpha_{14} l_{14} q_1 + \alpha_{15} l_{15} q_1 + \alpha_{1g} l_{1g} q_1 = \alpha_{21} l_{12} q_2 + \alpha_{32} l_{13} q_3 + \\ + \alpha_{41} l_{14} q_4 + \alpha_{51} l_{15} q_5 + \alpha_{1g} l_{1g} q_1 + \sum N_1 l_1$$

;

$$\delta_2 S_2' q_2 + \sum_1^{k2} \alpha_{20} l_{20} q_2 + \alpha_{2g} l_{2g} q_2 + \alpha_{21} l_{12} q_2 + \alpha_{23} l_{23} q_2 + + \alpha_{26} l_{26} q_2 = \alpha_{22} l_{22} q_1 + \\ \sum_1^{k2} \alpha_{02} l_{20} q_{02} + \alpha_{2g} l_{2g} q_g + \alpha_{32} l_{23} q_3 + \alpha_{52} l_{25} q_5 + \alpha_{62} l_{26} q_6$$

;

$$\sum_1^{k2} \delta_0 S_{02}' q_{02} + \sum_1^{k2} \alpha_{02} l_{20} q_{02} = \sum_1^{k2} \alpha_{20} l_{20} q_2;$$

$$\delta_g S_g' q_g + \alpha_{g2} l_{2g} q_g + \alpha_{g1} l_{1g} q_g = \alpha_{2g} l_{2g} q_2 + \alpha_{1g} l_{1g} q_1;$$

$$\delta_3 S_3' q_3 + \alpha_{31} l_{13} q_3 + \sum_1^{k3} \alpha_{30} l_{30} q_3 + \alpha_{32} l_{23} q_3 + \alpha_{34} l_{34} q_3 + \alpha_{36} l_{36} q_3 = \\ \alpha_{13} l_{13} q_1 + + \sum_1^{k3} \alpha_{03} l_{30} q_{03} + \alpha_{23} l_{23} q_2 + \alpha_{43} l_{34} q_4 + \alpha_{63} l_{36} q_6;$$

$$\sum_1^{k3} \delta_0 S_{03}' q_{03} + \sum_1^{k3} \alpha_{03} l_{30} q_3 = \sum_1^{k3} \alpha_{30} l_{30} q_3;$$

$$\delta_4 S_4' q_4 + \sum_1^{k4} \alpha_{40} l_{40} q_4 + \alpha_{41} l_{14} q_4 + \alpha_{43} l_{34} q_4 + \alpha_{45} l_{45} q_4 + \alpha_{46} l_{46} q_4 = \sum_1^{k4} \alpha_{04} l_{40} q_{04} + \\ + \alpha_{14} l_{14} q_1 + \alpha_{34} l_{34} q_3 + \alpha_{54} l_{45} q_5 + \alpha_{64} l_{46} q_6;$$

$$\sum_1^{k4} \delta_{04} S_{04}' q_{04} + \sum_1^{k4} \alpha_{04} l_{40} q_{04} = \sum_1^{k4} \alpha_{40} l_{40} q_4;$$

$$\delta_5 S_5' q_5 + \sum_1^{k5} \alpha_{50} l_{50} q_5 + \alpha_{51} l_{15} q_5 + \alpha_{52} l_{25} q_5 + \alpha_{54} l_{45} q_5 + \alpha_{56} l_{56} q_5 = \sum_1^{k5} \alpha_{05} l_{50} q_{05} + \\ + \alpha_{15} l_{15} q_1 + \alpha_{25} l_{25} q_2 + \alpha_{45} l_{45} q_4 + \alpha_{65} l_{56} q_6;$$

$$\sum_1^{k5} \delta_{05} S_{05}' q_{05} + \sum_1^{k5} \alpha_{05} l_{05} q_{05} = \sum_1^{k5} \alpha 5_{50} l_{05} q_5;$$

$$\delta_6 S_6' q_6 + \alpha_{62} l_{26} q_6 + \alpha_{63} l_{36} q_6 + \alpha_{64} l_{46} q_6 + \alpha_{65} l_{56} q_6 = \\ = \alpha_{26} l_{26} q_2 + \alpha_{36} l_{36} q_3 + \alpha_{46} l_{46} q_4 + \alpha_{56} l_{56} q_5 + \alpha_{1g} l_{1g} q_1 + N_6 l_6$$

where $q_{02}, q_{03}, q_{04}, q_{05}$ – the streams of the vibration power in the glazing of the according panels of the locomotive cabin, W / m;

$k2, k3, k4, k5$ – the number of glazing elements;

S_i' - the area of the corresponding glazing elements, м^2;

index «g» - refers to the door in the second panel of the cabin;

$\sum_1^2 N$ – the vibration power transmitted to the floor of the cab from the wheelsets and powerplant, W;

N_6 – the vibration power transmitted to the cockpit ceiling from the tap, W;

l_1 – the distance between fixing the cab to the frame, m;
$l_6 = \pi d_k$, d_k – the diameter of the crane platform installed on the roof of the cabin, m.

At glazing thicknesses h=5-6 мм even with double glazed windows $f_{dif} = \frac{10^4}{S'}$, i.e. for the entire normalized frequency range, the impendence of the glazing elements can be determined by the formula

$$z_0 = 1{,}5\eta f M = 45 h S' f, \text{ kg/s.}$$

For the elements of the cabin, even when the vibrational energy loss coefficient is reached $\sim 10^{-2}, f_{диф} = \frac{4 \cdot 10^4}{S'}$, i.e. for the cab elements it is also possible to use the dependence for the impedance in the whole normalized frequency range

$$z_0 = 1{,}5\eta f M.$$

Then the speed of vibration of each element of the cabin is defined as

$$V_i = \sqrt{\frac{q_i}{z_i}}.$$

The absorption coefficient

$$\delta = \frac{\pi f \eta}{2C_u} = \frac{\pi f \eta}{2\sqrt{c_п h f \cdot 1{,}8}};$$

For glazing

$$\delta = \frac{3{,}14 \cdot 2{,}5 \cdot 10^{-2}\eta}{2\sqrt{\sqrt{\frac{4{,}3 \cdot 10^9}{1{,}2 \cdot 10^8}} h f \cdot 1{,}8}} = 68 \cdot 10^{-4}\sqrt{\frac{f}{h}};$$

For body construction

$$\delta = 0{,}33\eta_\Sigma \sqrt{\frac{f}{h}},$$

where η_Σ – the total effective loss factor of the vibrational energy of the cabin elements.

The diffuse boundaryline

$$f = \frac{8h}{\pi \eta S}\sqrt{\frac{E}{3(1-\mu^2)\rho}}$$

For glazing

$$f_{dif} = \frac{8h}{3{,}14 \cdot 2{,}5 \cdot 10^{-2} S}\sqrt{\frac{4{,}3 \cdot 10^9}{3 \cdot 1{,}2 \cdot 10^8}} = 1{,}12 \cdot 10^5 \frac{h}{S}$$

For supporting structure

$$f_{dif} = \frac{7{,}8 \cdot 10^8 h}{\eta S}$$

When the thickness of the glazing elements, even double-glazed windows, the dependence for calculating the impedance will look like:

$z_0 = 0{,}27 f S$

From the system of energy balance equations, the energy flows of each element of the cabin (q_i), which the vibration velocities are calculated

$V_i = \sqrt{\frac{q_i}{z_i}}$ and the vibration levels

$$L_v = 20lg\frac{V_i}{5\cdot10^{-8}}$$

The vibration velocities` calculation of each element in the locomotive cabin system is advisable to perform a matrix method using Microsoft Excel. As a consequence of the cumbersome nature of the solution system of equations for the velocities of oscillations, it is not given in this research paper.

3. Conclusion

The obtained dependencies consider whether in geometric and physic -mechanical parameters of all elements of the locomotive cabin, but they also have dissipative function given by effective coefficient of the vibrational energy losses. Only this physical quantity is the main choice for the reducing means of the structural noise component, which is one of the main reasons for exceeding the sound pressure levels in the driver cabs above standard values for diesel locomotives and locomotives. It should be noted that the obtained dependences make it possible to substantiate theoretically the choice of the vibration-absorbing materials based on the limiting spectra at the stage of designing the research cabin facility.

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