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# MAIN DIRECTIONS OF NOISE LOAD REDUCTION OF PASSENGER ROLLING STOCK

**Nikolay Kasyanov, Vyacheslav Malov, Nikolay Pitelguzov**

*Volodymyr Dal East-Ukrainian National University, Lugansk, Ukraine*

**Summary.** The dependences, on the basis of which it is recommended to use special facings with application resonant sound absorber on the passenger rolling-stock, are received in clause. In this case standing waves are not generated and there is a significant reduction of noise, which penetrate into a motorman cabin and passenger compartment from various sources.

**Keywords:** noise, vibration, sound load reduction.

## INTRODUCTION

Constantly increasing volume of passenger transportation requires considerable growth of railway carrying and freight capacity. The basic direction of the successful decision of this task is the increase of comfort of compartments of carriages and speed of train movement, that in turn is impossible without perfection of existent and creation of new types of locomotives and in particular diesel engine and electrical trains.

The development of the passenger rolling-stock is characterized by increase of comfort of the passengers and constructional speed, increase of effectivily, maintenance of high reliability of units, increase of run between repairs and improvement of attendants work conditions. All this is closely connected to continuous increase of the requirements reduction of noise level and vibrations. Last influence reliability and durability both assemblies and details, reduce their resistance, decrease working ability of the equipment and devices, cause the additional charge of power on maintenance, for example, vibrating processes. The noise and vibration worsen working conditions of locomotive brigades and passengers, cause numerous undesirable reactions in body of the man, result in the increased fatigability, specific occupational diseases, nervous and cardiovascular systems disorder.

Thus, the struggle with noise together with vibration is not only a technoeconomic problem, but also social, as both progress in the field of engineering and health of people depends on it's solving.

Development of new highly effective means of protection from noise in industry and on transport are recognized by priority by the national and branch programs of the Ministry of Industrial Policy of Ukraine about improvement of the status of labor protection on 2001-2005 years (is authorized by the Order of the Ministry of Ukraine 10.10.2001 №1320), and also Conceptual directions of the Program of improvement of status, safety, labor hygiene and industrial environment on 2006-2010 years [Lisyuk 2005]. Therefore, the realization of works on research of effective means of noise reduction in motorman cabins and passenger carriage compartments both diesel engine and electrical trains is one of the important questions in the decision of a problem of working conditions improvement of the attendants and safety of live activity of passengers.

## RESEARCH OBJECT

Various kinds of the passenger rolling-stocks (PRS), each of which has the specific sources of noise differ in levels and frequency constituents, at presence of a number of common features are issued by holding company "«Luganskteplovoz":

1. There are two ways of penetration of noise to a motorman cabin passenger carriage compartments both diesel engine and electrical trains: air - by air and structural - on designs.
2. The noise levels of PRS have significant temporary fluctuations, which depend on operating mode of equipment and speed of movement.
3. The working and passenger premises of PRS have the limited sizes within the limits of rolling-stock gabarit.
4. The railway vehicles move in space on the strictly established route - on railway lines.
5. The vehicles have two kinds of running gears: with railway motors and without them.
6. The vehicles have opening windows and doors.
7. Presence of significant amount of auxiliaries.
8. Presence of reflected sound waves influence from protections and screens located near the railway lines.

According to sanitary norms [SSC 3.3.6.037-99] noise levels on workplaces of diesel engines trains in octave bandwidths from 31,5 up to 8000 Hz shouldn’t exceed [GOST 12.1.050-86, GOST 12.1.003-89, GOST 12.2.056-81, DSTU 2867-94, DSTU 2325-93, Industry-specific standard 24.050.18-82] 107 … 69 dB, equivalent level - 80 dBA, and electrical trains - 99 … 64 dB and 75 dBA, in carriages - 99 … 49 dB and 60 dBA, accordingly. Actually noise levels, on the data of measurements received during tests of the specified kinds PRS, are in these limits. However excess of the established norms, dependable on operating mode of PRS, status of the top railway way and term of operation are observed in exploitation process. Proceeding from this, actual noise levels in motorman cabins and passenger compartment of the basic sources should be on 5 … 10 dB below established norms on new PRS.

The sanitary services of Ukraine, using the long-term experience and experience of the countries of CIS, watch on status of noise load of the attendants of various categories of industry, establishing level limit of noise on octave bandwidth from 31,5 up to 8000 Hz [SSC 3.3.6.037-99].

Therefore there was a necessity for realization of experimental researches according to air and structural constituents of noise of both basic equipment and auxiliaries of diesel engine and electrical trains, which results are submitted below.

## RESULTS OF EXPERIMENTAL RESEARCH

The sound fluctuations on railway vehicles are distributed from a place of wheel and rail contact and from forceful and auxiliary mechanisms by air (air component) and over elements of metalwares, forming working or passenger space inside a vehicle (structural component).

Most adverse, from the point of view of influence on the attendants, are the standing sound waves in octave bandwidths 31,5; 63 and 125 Hz, multiple main harmonic fluctuations at work of forceful and auxiliary mechanisms by diesel engines trains. Significant fluctuations at work of brake compressors and fans arise in electrical trains and trams there are.

At movement of vehicles the common picture for all kinds of the rail rolling-stock is observed. The noise in this case arises from the shock phenomena about joints and because of wavy deterioration of rails at long operation of the top structure of a way. Having studied the basic sources of noise and way of distribution, it is possible to offer effectual measures on its decrease at the passenger rolling-stock.

These problems are difficult at diesel engine trains, as the amount of sources is much more because of autonomy of a movement source - diesel engine generator and auxiliary mechanisms.

At the analysis of ways of noise distribution on the definite rolling-stock the possible influence of various variants of its sources is established:

1. The basic components are the air ways of penetration, because of insufficient sound insulation of protections, presence of leakages, cracks, open windows, doors in tambours etc.

2. The basic component of common noise level is structural, caused by the vibrating phenomena of framework and protections transmitted from forceful, auxiliary mechanisms and undercarriage.

3. The variable influence of sources on an air and structural components because of change of operational mode, loading and speed of movement, that in general more often takes place.

The size of noise levels inside the passenger rolling-stock is defined by the greatest components and consequently the work on its decrease adduces a rather difficult task and requires an apprisel of size of influence of separate sources and their components in a spectrum of noise.

Having data on sources of noise and allowable norms of noise inside the rolling-stock on workplaces and in passenger compartments, it is possible to define the size of noise reduction of each source on its components:

$$\Delta L_i = L_u - L_g \,, \tag{1}$$

where: $L_u$ - maximal component i-th of a source of noise in octave bandwidth, dB; $L_g$ - allowable noise level on a workplace or in compartment of the passenger rolling-stock in the same bandwidth, dB.

Considering separate constructive elements and sites available on the passenger rolling-stock, it is possible to allocate the following premises:

- cabin of management (motorman cabin),
- machine premises for diesel engine trains,
- passenger compartments in the motor-coach,
- passenger interiors trailing cars without forceful and auxiliary mechanisms.

The components of radiation of air and structural noise on the passenger rolling-stock have a various nature of occurrence, however there are general provisions in volume of air conditions, gage restriction of the rolling-stock at its distribution.

The body PRS can be presented as some homogeneous equivalent cylindrical shell with radius equal:

$$r_к = 0{,}56\sqrt{F_к} \le 1{,}300 \div 1{,}700 \text{ м} \,, \tag{2}$$

where: $F_к$ - cross section area of a body PRS, м$^2$.

Thus the limiting value of $r_к$ depends on a design and can change, for example: for trams $r_к$ makes 1,3; for diesel engine trains - 1,7 m.

For the analysis of model of a sound field in conditions of some shell is used the wave theory of sound fluctuations, which found wide application during last years in the practice of acoustic accounts of vehicles.

The distribution of sound fluctuations in limited volume PRS can be described by the wave formula [Hekl 1980, Malov 2005], in which harmonical fluctuations look like:

$$\frac{\partial^2 P}{\partial x^2} + \frac{\partial^2 P}{\partial y^2} + \frac{\partial^2 P}{\partial z^2} = -\frac{\omega^2}{c^2} \cdot \overline{P} \,, \tag{3}$$

where: $\overline{P}(x, y, z)$ - amplitude of fluctuations of sound pressure; $\omega$ - angular velocity; $c$ - speed of a sound in air, m/s.

On border of the protection, conditionally accepted by absolutely rigid protective structures, it is possible to write down the following conditions:

$$\frac{\partial \overline{P}}{\partial B_н} = 0 \,, \tag{4}$$

where: $B_н$ - some vector of external normal, directed to the border of a structure.

For the accepted cylindrical form the decision of a boundary value problem can be submitted by product of the decisions one-dimensional and two-dimensional tasks:

$$\overline{P} = P(x, y, z) cos \frac{\pi \cdot n \cdot x}{l_x} \,, \tag{5}$$

where: $n$ =0, 1, 2, 3; $l_x$ - size of researched space along an axis $x$ on the passenger rolling-stock length.

By substitution of expression (5) in (3) and (4) it is possible to receive a boundary value problem for definition of speed and vebrational frequency in two directions *y* and *z*:

$$\frac{\partial^2 V}{\partial y^2} + \frac{\partial^2 V}{\partial z^2} + \frac{\omega_y{}^2}{c^2} \cdot V = 0, \tag{6}$$

$$\frac{\partial V}{\partial B_б} = 0, \tag{7}$$

where: $B_б$ - vector external normal to a lateral surface of a structure; $\omega_y$ - the angular vebrational frequency, depends on angular disturbing frequency;

$$\omega = \sqrt{\omega_y^2 + \frac{\pi^2 n^2 c^2}{l_x^2}}. \tag{8}$$

The decision of a boundary value problem submitted by expressions (6) and (7), can be converted to simplification at realization of the final elements method with the linear law of distribution of sound pressure.

For standing waves sound pressure in internal air space of PRS according to boundary conditions can be submitted as:

$$\frac{\partial P}{\partial B_н} = -\rho \cdot a. \tag{9}$$

The decision of expression (9) looks like:

$$\overline{P} = \rho \cdot c^2 \sum_{m=1}^{\infty} \frac{E_м}{\omega^2 - \omega_м^2} \cdot P_м(x, y, z), \tag{10}$$

where: $E_м$ - energy parameter of an elementary particle of fluctuations

$$E_м = \iint_S P_м(S) \cdot a(S) dS, \tag{11}$$

where: $S$ - current coordinate on an internal surface of PRS protections; $\omega_м$ - frequency of own fluctuations of air volume; $P_м$ - sound pressure in limited volume of PRS.

The decomposition of expression (10) shows, that the established mode of fluctuations on the certain frequency depends on the size of angular frequencies and size of energy parameter.

## CONCLUSION

On the basis of received dependences, it is possible to recommend use of special facings with application of resonant sound absorbers, which vary the parameter $E_м$, which should be equal to zero on the passenger rolling stock. In this case standing waves are not generated and significant reduction of noise takes place, which penetrate into a motorman cabin and passenger compartment from various sources.

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## ОСНОВНЫЕ НАПРАВЛЕНИЯ СНИЖЕНИЯ ШУМОВОЙ НАГРУЗКИ НА ПАССАЖИРСКОМ ПОДВИЖНОМ СОСТАВЕ

**Касьянов Н.А., Малов В.А., Пительгузов Н.А.**

**Аннотация.** В статье получены зависимости, на основе которых рекомендовано использовать на пассажирском подвижном составе специальные облицовки с применением резонансных звукопоглотителей. В этом случае стоячие волны не возбуждаются и происходит значительное снижение шума, проникающего в кабину машиниста и пассажирский салон от различных источников.

**Ключевые слова:** шум, вибрация, пассажирский подвижной состав, условия труда, снижение звуковой нагрузки.