Effective sound-absorbing material for transport technological machines of railway transport

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Abstract. The article discusses the types and features of the operation of transport technological machines of the railways of the Russian Federation on the example of the most frequently used track machines, and presents methods for noise reducing on the railways of the Russian Federation. The most effective method to reduce the noise arising during the operation of track machines is identified - this is the installation of a steel soundproofing hood (casing) over the electric motor. The calculation of the effectiveness of sound-absorbing materials used for cladding steel bonnet is given. According to the results of the calculation, the material «asbestos felt» turned out to be the most effective, but the other materials under consideration, and in particular, «glass wool», «mineral wool» and «construction felt», turned out to be also applicable to the lining of the steel bonnet, since the calculations revealed the applicable level of sound absorption, which is less than a decibel in terms of noise reduction to the material «asbestos felt».

1. Introduction

In the modern mobile world, the importance of railways is increasing. Only in the first quarter of 2019, passenger traffic amounted to 23.4 million people in long-distance traffic, and 235.8 million people in suburban traffic, in turn, passenger traffic was 24.8 billion passenger-kilometers. As for the freight, the importance of railways is also difficult to overestimate, since the beginning of 2019, the railways transported 318.7 million tons, and the freight turnover amounted to 651.8 billion tons of tariff tons-kilometers. Moreover, in comparison with 2018, a positive increase in both passenger and freight traffic is seen. In the first quarter of 2019 alone, compared with 2018, passenger turnover increased by 3.5%, while freight turnover increased by 2.5% [1].

For the efficiency of the passenger and the freight traffic, the Strategy for the Development of Railway Transport was adopted, which was approved by the decree of the Government of the Russian Federation, according to which by 2030 it is planned to upgrade 23 thousand locomotives, launch 1 million freight cars and more than 23 thousand passenger cars, an increase in motor-car rolling stock by 25 thousand units, it is planned to lay 16 thousand kilometers of new railways, 659 kilometers of which are in the northwestern and central federal districts, 579 kilometers are in the northwestern and Volga federal districts, 210 kilometers are in the northwestern and the Urals Federal District, it is also planned to lay new railways in the southern, north-Caucasian, Siberian and Far Eastern federal districts [2].

The implementation of this strategy, as well as the maintenance of railways, is impossible without transport technological machines. On the railroad, they are called track machines, which function is to prepare a place for laying a new railroad bed, to carry out straightening, ballasting the canvas, to ensure the replacement of sleepers and to clean the canvas from rubble, snow, industrial and domestic waste. Traveling machines are also needed for welding and grinding of rails, star collecting bases, diagnostics of the state of the track, alignment of the track and compaction of the ballast layer [3-6].
Serious importance in the issues of noise insulation is given in the works of many foreign scientists. For example: Zhang X., Jonasson Hans, Busch A., Nugent R., Peng Sun, Zhancheng Guo. Zhang X and Jonasson Hans G considered the direction of railway noise sources in their works. Busch A and Nugent R E studied the reduced coefficients of insertion loss and absorption of the railway noise barrier, and in particular compared the field measurements and forecasts. Peng Sun and Zhancheng Guo studied the preparation of steel slag of porous sound-absorbing material using coal powder as a blowing material [7-9]. The topic of the absorption studied and Russian scientists, Sychov A., Sychov M., and Rusanov E. presented to the scientific community a method of producing Youmanage protective foam concrete for use in railway transport and Pultznerová A. structured modification of items and equipment for noise control of Railways [10-11].

The purpose of the article is to identify the effective sound-absorbing material that is used to process the inside of the steel bonnet to reduce noise level from the transport technological machines of the Railways of the Russian Federation.

2. Materials and methods
The object of the article is to consider the types and features of the operation of transport technological machines of railways of the Russian Federation, as well as to identify the most effective method for reducing noise arising during the operation of track machines.

The most commonly used railway track machines are the RTM-02 tamping machine, the RTMA4-K tamping machine, the MPD-2 motor platform, the KDE-163 and KDE-253 railway cranes. Tamping machine RTM-02 is used for compaction and supply of ballast under the sleepers and is a self-propelled vehicle on the track. The main components of RTM-02 are diesel engine with transmission, mounted on the chassis frame, compressor, tamping heads with tamper collars, a mechanism for pressing rail heads, wheelset drive mechanisms, tamper wheels and a machine lifting mechanism allowing to remove it from the railway track. This machine uses a worm mechanism with screw movement of links, the advantage of which is the accuracy of the rolled products, since the number of links in the kinematic chain is reduced in this mechanism, as a result, the amount of lateral clearances and the mismatch between the positions of the input and output links are reduced. The ballast is compacted by an eccentric vibration mechanism, a method of horizontal vibration compression, which reduces vibration.

For high-quality ballast compaction, it is necessary to eliminate the vibration of the rails; for this, the machine is equipped with two pressure mechanisms with a pneumatic drive. The configuration of RTM-02 is 16 sleeper, the transport speed of this machine is on average 25.3 km / h, and the speed of movement from the sleeper to the sleeper can vary from 2.2 to 13.5 km / h. The performance of the sleepers per hour is 350-400 units. RTM-02 is used both at the stations and on the hauls with an average lifting and overhauling of the railway track. The tamping machine RTM-02 works in a semi-automatic mode from a remote control panel, the machine is also equipped with a hand brake and a hydraulic brake with a foot and remote control [12-15].

In addition to the RTM-02 tamping machine, a more modified tacking machine RTMA-4K is often used. Its main difference is the presence of automatic control, which allows you to completely eliminate the harmful effects of noise and vibration on the operator. Productivity and technical characteristics practically coincide with RTM-02, but RTMA-4K is lighter, this machine weighs 8 tons, whereas the weight of RTM-02 is 14 tons. Due to the lower weight, RTMA-4K (figure 1) can be used both on wooden and on reinforced concrete sleepers.
**Figure 1.** Tamper RTMA-4K (1 - frame; 2 - curtain; 3 - hood; 4 - the engine; 5 - fuel tank; 6 - hydraulic system tank; 7 - seat; 8 - cab; 9 - tamping lever; 10 - gear lever; 11 - control panel; 12 - lock the tamping unit; 13 - parking brake lever; 14 - hydraulic control tamping units; 15 pressure switch; 16 - hydraulic pump GP-46; 17 - hydraulic pump GP-10; 18-cap; 19 portal; 20 - unbalance shaft; 21 - headlights; 22-tamping unit; 23 - knockout; 24-guide tamping unit; 25 - hydrodiline of deepening of the tamping block; 26 - distribution valve; 27 - driveshaft; 28 - drive box; 29-box gear changes; 30 - driving wheel pair; 31 - brake and clutch pedals; 32 - lifting and turning device; 33-coupling; parking brake; 34, 35, 36 - driveshafts; 38 - transfer case; 39 - suspension pair of wheels; 40 - not driving wheel pair; 41 - brake; 42 - hydraulic tank; 43 half sleeper; 44 - coupling device).

Another necessary vehicle on the railway is the self-propelled motor platform MPD-2, used in the construction, repair and maintenance of the railway track of 1.435 mm gauge (European gauge) and 1.520 mm gauge (Russian gauge). The machine is actively used when carrying out shunting works, laying new and dismantling the old railroad tracks, in addition, the MPD-2 is equipped with a fire detection and extinguishing system for power plants. Movement control MPD-2 is carried out from the driver's cab, which, using a hydraulic drive, can be transferred from the transport position to the working position and back. The driver's cab is designed to meet the basic ergonomic requirements and is lined with sound-absorbing materials, and in particular ABS plastic and noise insulation [16-18].

ABS plastic is a polymer material, one of the most accessible and common, also called a thermoplastic resin. This material has a high impact resistance and elasticity. One of the most important characteristics for cabin facing is heat resistance, which is 103 °C. The advantages of using ABS plastic are its non-toxicity and a wide range of operating temperatures from -40 to +90 °C.

Shumoizol is a soundproof material that combines the qualities of thermal insulation and waterproofing. The shumoizol consists of two layers - the base and the bitumen layer and is a non-woven fabric produced in rolls. The operating temperature range of the noise insulation is from -25 to +85 °C [19].

Continuing consideration of the MPD-2 motor platform (figure 2), it should be noted that its main purpose is to tug the rail and sleeper links in the process of disassembling or laying the track, as well as performing shunting operations within the star collection bases. Inside the frame, under the platform floor, the MPD-2 has two power units consisting of a diesel engine, a generator, a water and oil cooler, which are mounted on an intermediate frame and attached to the frame of the platform with shock absorbers.
Figure 2. Motor platform MPD-2 (1 - biaxial traction cart; 2 - frame; 3 - winch; 4 - automatic coupler with absorbing device; 5 - control cabin; 6 - control panel; 7 - Portal stand; 8 - compressor; 9 - water and oil radiators; 10 - diesel; 11 - generator; 12 - roller conveyor; 13 - traction motor; 14 - axial gearbox; 15 - wheel pair).

The MPD-2 platform is distinguished by a large carrying capacity of 60 tons, a large traction force from 90 kN to 125 kN and a large traction force of a winch of 58.9 kN; while the train consists of 100 km / h, the weight of the MPD-2 platform is 47 tons.

Railway cranes KDE-163 and KDE-253 (figure 3) are also most often used among railroad track machines. Their purpose is to mechanize loading, unloading, installation and construction works. The KDE-163 m KDE-253 consist of a self-propelled four-axis platform, a swing frame, a diesel generator, working mechanisms, a control cabin, a boom, boom extensions (in the case of KDE-253) and load handling devices.

Figure 3. Railway cranes KDE-163 (a), KDE-253 (b).

The KDE-163 and KDE-253 cranes are distinguished, by the carrying capacity, the KDE-163 has a loading capacity of 16 tons and the KDE-253 has a loading capacity of 25 tons, and the crane KDE-253 is equipped with an additional extension of the boom and boom departure. This crane is 20 meters, while the KDE-163 is equipped with a boom of 15 meters, there are small differences in dimensions, the other mechanisms are almost the same.

On the example of the most frequently used railway cars, one should consider the problems of noise and methods for reducing the noise arising from the operation of railway cars.

In octave bands with geometric mean frequencies of 31.5; 63; 125; 250; 500; 1000; 2000; 4000; 8000 Hz (table 1) sound level during operation is:
- RTM-02 - 108 dBA;
- RTMA-4K - 108 dBA;
- MPD-2 - 93 dBA;
- KDE-163 - 110 dBA;
- KDE-253 - 80 dBA

**Table 1.** Acoustic characteristics of traveling machine noise sources.

| Traveling Cars | Sound pressure levels, dB, in octave bands with geometric average frequencies, Hz | Soundlevel, dBA |
|----------------|-----------------------------------------------------------------------------|-----------------|
| RTM-02         | 87 92 96 103 105 101 96 88 88 108                                        | 88              |
| RTMA-4K        | 96 97 99 101 103 104 102 94 87 108                                        | 108             |
| MPD-2          | - 92 90 86 87 90 86 75 65 93                                             | 93              |
| KDE-163        | - 92 101 100 102 106 108 98 96 110                                        | 110             |
| KDE-253        | 79 89 84 80 79 77 71 61 92 80                                             | 80              |

The average noise level in the city during the day is 50-60 dB, at night this value is reduced to 10 dB, it should be noted that serious hearing problems can start at a sound pressure level exceeding 150 dB [20]. Thus, the noise arising from the operation of traveling machines is not critical, but still significantly exceeds the average level familiar to human hearing.

There are several methods for reducing noise on a railway:
- installation between the subgrade and gravel ballast of polymer pads, reducing noise up to 15 dBA;
- planting forest line along a railroad reducing noise up to 20 dBA;
- acoustic grinding of rails, in which the effect of reducing noise at the source reaches 7-9 dBA;
- vibration damping pads on the rail neck, allowing to reduce noise at the source to 4-5 dBA;
- application of vibration-absorbing mastic to the neck of the rail, carriage and wheels, in which the effect of reducing the noise at the source is up to 7-8 dBA;
- installation of acoustic screens, reducing noise to 12-15 dBA;
- soundproof glazing reducing noise up to 20-30 dBA;
- excavations and embankments that reduce noise up to 8-16 dBA [21-25].

The main source of noise in railway transport is the railway transport itself, and the largest sources of noise are, previously discussed, traveling machines with sufficiently high generator power, therefore, in addition to the noise reduction methods listed above, it is proposed to install a soundproof hood (casing) over the electric motor (figure 4).

**Figure 4.** The Sound insulation hood (casing) over the motor.

The basis for making the body of the hood is steel with a thickness of 3-5 mm and a density of 7.8·10³ kg/m³. When cladding a steel bonnet, various sound-absorbing materials can be used, in
particular, glass blocks 30 mm thick, asbestos felt 10 mm thick, mineral wool 25 mm thick, and construction felt 25 mm thick.

At each geometric mean frequency, the sound insulation capacity of the hood walls, dB, is determined by the formula:

\[ P = 20 \log(G \cdot f) - 47.5 \]  \hspace{1cm} (1)

where \( G \) is the weight of the hood (kg);
\( f \) - geometric mean frequency (Hz);
47.5 - constant value.

The total sound insulation capacity of the hood walls, dB, at each geometric mean frequency, is determined by the formula:

\[ P_k = P + 10 \log \frac{A_2}{A_1} \]  \hspace{1cm} (2)

where \( A_1 \) and \( A_2 \) are equivalent absorption areas before and after bonnet lining.

In turn, the equivalent sound absorption area before and after bonnet lining is calculated by the formula:

\[ A = \alpha \cdot S \]  \hspace{1cm} (3)

where \( \alpha \) is the sound absorption coefficient of the material. \( \alpha \) is taken from SN 2.2.4 / 2.1.8.562-96, \( S \)-area, covered with sound-absorbing materials of the inner walls of the hood, m².

3. Results and discussion

When the calculations were carried out, it was found that when installing a steel bonnet on RTMA-4K with a «glass fiber» sound-absorbing material, the maximum noise reduction is possible by 49 dB. The noise reduction level is 49 dB (with a geometric mean frequency of 125 Hz), 42 dB (with a geometric mean frequency of 250 Hz), 33 dB (with a geometric mean frequency of 500 Hz), 25 dB (with a geometric mean frequency of 1000 Hz).

Steel hood with sound-absorbing material «asbestos felt» reduces noise by: 49 dB (at geometric average frequency of 125 Hz), 42 dB (at geometric average frequency of 250 Hz), 34 dB (with geometric average frequency of 500 Hz), 30 dB (with geometric average frequency of 1000 Hz), 22 dB (with a mean geometric frequency of 2000 Hz).

Steel hood with sound-absorbing material «mineral wool» reduces noise by: 44 dB (at geometric average frequency of 125 Hz), 38 dB (at geometric average frequency of 250 Hz), 31 dB (at geometric average frequency of 500 Hz), 25 dB (at geometric average frequency of 1000 Hz).

Steel hood with sound-absorbing material «construction felt» reduces noise by: 45 dB (at geometric average frequency of 125 Hz), 40 dB (at geometric average frequency of 250 Hz), 32 dB (with geometric average frequency of 500 Hz), 17 dB (at geometric average frequency of 1000 Hz), 5 dB (with a mean geometric frequency of 2000 Hz).

Also, calculations of noise reduction were carried out when installing a steel bonnet over the electric motor of the tamping and punching machine RTM-02, the MPD-2 motor platform, the railway crane KDE-163 and KDE-253. The results of the calculations turned out to be identical with the above presented calculation of noise reduction of the tamping and punching machine RTMA-4K.

4. Conclusion

According to the results of the calculations, it was found that the steel hood with sound-absorbing material «asbestos felt» reduces noise more efficiently than the hoods with other sound-absorbing materials, therefore, to effectively reduce noise, you should install a steel hood with sound-absorbing material «asbestos felt». It should be noted that the steel hood with sound-absorbing material «asbestos felt» reduces noise more efficiently than other materials by only 5 dB, therefore sound-absorbing materials such as «glass wool», «mineral wool» and «construction felt» are also applicable and effective.
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