IOP Conference Series: Materials Science and Engineering

Contemporary principles for solving the problem in noise reduction from railway rolling stock

To cite this article: Yu Zelenko *et al* 2020 *IOP Conf. Ser.: Mater. Sci. Eng.* **985** 012015

Contemporary principles for solving the problem in noise reduction from railway rolling stock

Yu Zelenko[1,2], **D Zelenko**[1] **and L Neduzha**[1,3]

[1]Dnipro National University of Railway Transport named after Academician V. Lazaryan, Lazaryan str., 2, 49010, Dnipro, Ukraine

[2]j.v.zelenko@gmail.com, [3]nlorhen@i.ua

Abstract. The statistical and monitoring data confirm the significant impact of the operational mode on the most important noise and vibration parameters, which is relevant for ensuring the efficiency and quality of the operational process with regard to ergonomic and environmental requirements. The article analyzes the acoustic parameters of rolling stock of the railway, emphasizes the peculiarities of noise emission from various elements of rolling stock and a track. Existing approaches towards solving the problem in the organization of railway noise control are outlined. On the basis of existing modern methods for measurement and analysis of acoustic parameters, the authors propose conceptual approaches toward monitoring the acoustic parameters, predicting noise characteristics and constructing the noise maps of railways. The algorithm of the developed acoustic model for the operational monitoring of noise load and the possibility to compile a case of noise maps for Ukrzaliznytsia is presented. The proposed algorithm allows at given basic design parameters and speed of rolling stock, known sound-absorbing and dissipative characteristics of all elements to carry out a rational selection of noise-protective measures in accordance with the sanitary noise regulations for a specific receptive facility.

1. Introduction

Along with higher safety, railway transport has obvious advantages over other modes of transport in terms of environmental safety, it is characterized by high energy efficiency and lower hazardous substances emissions [1-7].

Simultaneously, one of the current priority directions for the development of transport systems is to ensure the efficiency and quality of the operational process, taking into account ergonomic and environmental requirements [7-18]. Herewith, statistics and monitoring data confirm that the operating mode significantly affects the most important noise parameters arising from the rolling stock movement in curves [7, 12-15, 17, 18], and the basic operational requirements are determined by the infrastructure, in particular, the presence curves and their minimum radii.

2. Evaluation the degree of the railway noise impact

To meet the requirements of sanitary and environmental safety [7, 19, 20, 22-25], it is necessary to calculate the expected noise levels in territories adjacent to the railway lines at the stages of railway design, development and commissioning of rolling stock.

If necessary, one should develop noise reduction measures, for example, through specific technologies for noise reduction in the source or installation of the noise screens along the railway tracks. In this regard, the reliability of methods for calculating noise from railway transport and the correct determination of noise characteristics are important.

As the noise generated by the railway transport has a pronounced non-permanent nature of changes over time, its evaluation for compliance with the permissible levels is carried out simultaneously according to the equivalent and maximum sound levels, which are determined at a distance of 25 m from the axis of the close track at a height of 1.5 m from the ground level.

Unfortunately, there are still no specific technical regulations that require monitoring and control of noise from railway transport at the nationwide level. Table 1 compares data upon noise levels from domestic rolling stock with European standards.

Table 1. Comparative analysis of noise levels of rolling stock compared to European standards.

Train class	Maximum noise level at a distance of 25 m, dB(A)		Exceeding norms, dB
	Ukraine	European standards	
Electric train	87	83	4
High-speed train type ICE	88	85	3
Freight train	89	84	5
Passenger train	93	90	3
Track equipment	95	85	10

As indicated in the data analysis, the recorded noise levels at one of the sections of the Prydniprovska railway line exceed the established European standards by 3 – 10 dBA.

3. Analysis of the acoustic parameters of rolling stock

The main sources of noise on railway transport are classified as follows:

- train locomotive noise (traction noise);
- noise generated by rolling vibrations;
- noise from the impact of car wheels in contact with the rails;
- aerodynamic noise at the train movement, which depends on the speed and a set of cars.

Such factors as traffic intensity, speed and length of trains, etc. [7, 19, 21] affect the noise level from the traffic of railway transport.

To evaluate the noise levels in the surrounding area, calculation techniques based on current regulatory documents are applied. They take into account all of the above-described factors.

In the practice of estimating the transport noise, it is accepted as a model train to consider a linear source of finite length (ℓ) over an acoustically rigid surface, consisting of uniformly distributed incoherent non-directional, inphase- oscillating point sources. The mechanism of noise generation and emission demonstrates the distribution of energy between the main emitting surfaces (Figure 1) and has a clearly expressed frequency character.

The physical mechanism of rolling noise from rolling stock is characterized by the following parameters:

- the propagation of sound waves along the rail causes noise emission in the range up to 1000 Hz;
- the vibration of the wheel arises from 1600 Hz, in this, the main contribution to the noise level of the train occurs at the frequency of 2000 – 4000 Hz and can reach 8000 Hz;
- the frequency range of the noise emitted by the elements of rolling stock is 100 – 500 Hz;
- the noise emission from sleepers occurs in the frequency range up to 400 Hz;
- the surface irregularities of the wheel and rails (roughness) generate vibration upon their contact. The vibration is transmitted through the pad between a rail and a sleeper.

In general, there is a characteristic noise dependence on speed: at speeds up to 50 km/h internal sources: elements of rolling stock (electric motors, compressors) prevail; at a speed of 50 – 300 km/h noise from the "wheel-rail" interaction prevails; more than 300 km/h one can observe that typical aerodynamic processes are manifested [7, 20].

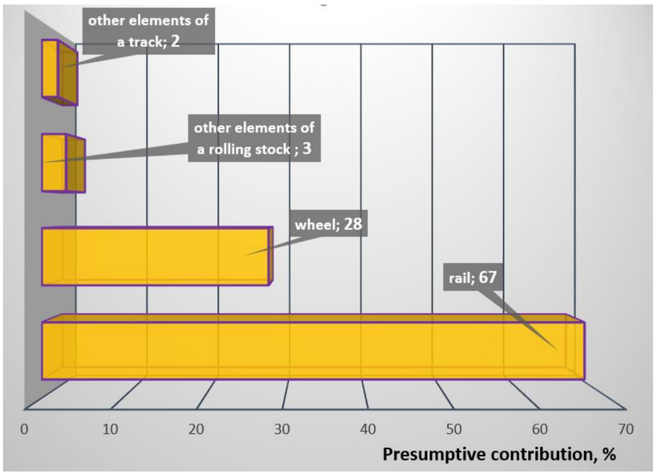

Figure 1. Noise emission characteristics for the high-speed ICE train (at ν =185 km/h).

Today, many analytical and numerical methods are used to solve the task of rolling noise analysis. The most common methods of calculation are based on a refined Remington-Thompson model. In this model, in addition to vibration caused by the interaction of wheel and rail irregularities, the processes of sound emission during their force interaction are taken into account: vibrations from elastic wheel and rail deformation. This allows obtaining detailed vibroacoustic parameters for the recipient accounting point in order to develop specific measures concerning the sound damping in the source [7].

Thus, the analysis of the experimental data (Figure 2) confirms that at small distances the indices of noise emission from the wheel (W) and the rail (R) is approximately the same. At the same time, with increasing distance, they increasingly differ. This is because the wheel emits a spherical sound wave and the rails emit cylindrical one. At distances greater than 50 m this difference can reach 7 – 10 dB.

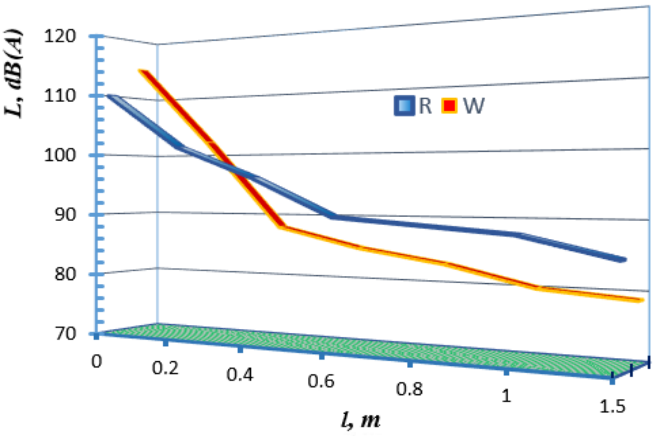

Figure 2. Sound pressure distribution L, dB(A) depending on the distance to the noise source: R is rail noise, W is wheel noise.

Thus, at these distances, the rails are the main source of rolling noise and noise reduction measures should be aimed at eliminating irregularities on the surface of a rail, increasing the impedance of the rail, reducing its noise-emitting ability.

4. Development of measures for monitoring of acoustic parameters on railway transport

The concept of noise monitoring has been introduced as an overall system for monitoring environmental noise, estimating and predicting changes in environmental noise due to technogenic activity [22-25]. This definition allows to provide the noise monitoring using special calculation methods. The inclusion of calculation methods in the noise monitoring system makes it possible to monitor large linear-type and magistral facilities at visible time intervals. This would be practically impossible if monitoring was limited only by long-term noise measurements in a representative number of points necessary for compiling noise maps. At the same time, it is necessary to emphasize the necessity of measurements when checking the calculation results for compiling operational noise maps, developing action plans to reduce noise, as well as evaluating the effectiveness of their implementation.

For many complex projects, such as linear mainline facilities, nodes, bridges, and stations, a noise map is the only possible tool toward reliable monitoring and solving the noise question. Noise maps enable:

- to select recipient points for acoustic monitoring and perform acoustic monitoring;
- to estimate background noise levels at any point of the mainline when designing a new housing estate;
- to justify the evaluation of individual sites for building;
- to evaluate the list of necessary noise-protection measures when designing objects;
- to simulate changes in acoustic impact when changing the characteristics of transport nodes and traffic.

The stringency of domestic environmental requirements for rolling stock, their approximation to European standards also confirms the need to use more extensively the results of numerous foreign studies in estimating the processes of formation, propagation of transport noise, its prediction.

The most comprehensive understanding of the acoustic situation near the railways lines is represented by noise maps, which are developed on the basis of the current regulations and calculation techniques for noise level evaluation. In Europe, the legal basis for compiling the noise maps is represented by European Parliament Directive 2002/49/EC concerning the environmental noise. According to this Directive, the development of noise maps for cities, motorways and railways, as well as the development of action plans for heavy railways passing near residential areas, are envisaged [7, 22-25].

Estimation of existing and comparison of planned noise situations is mainly performed by means of special acoustic programs for the analysis of ambient noise. Software packages can effectively reduce the load and allow performing a more in-depth analysis. Here are some basic requirements for successful selection of the appropriate program:

- functions in processing efficiency of computational models;
- open software interface and modular system;
- configuration capability for types of objects and their attributes;
- support for customizable interface features programmable by the client.

To compile noise maps, the authors apply new approaches and methods that have been developed in the light of the worldwide experience of noise evaluation and monitoring [7]. According to which, the authors created a database filled with information about the geometry of the railways line and the source of traffic noise (it makes it possible to construct an acoustic model and make calculations to determine the noise levels at the recipient point). The construction of the acoustic model is presented in the form of a block-diagram, which is shown in Figure 3. The presence of this algorithm allows with the known basic design parameters and the speed of rolling stock, sound-absorption and dissipative characteristics of all elements by calculation, to carry out their rational selection accordingly to compliance with sanitary noise standards for the receptive facility.

In fact, the name "noise map" means not one single map, but a massif of preassigned digitized cartographic objects, which are applied with colored zones of all noise indices ($L_{full\,day}$, L_{day} and L_{night}), as well as all existing sources of noise that fall into the impact zone on the recipient calculated point (main roads, streets, railway and tram tracks, airport, industrial facilities, etc.).

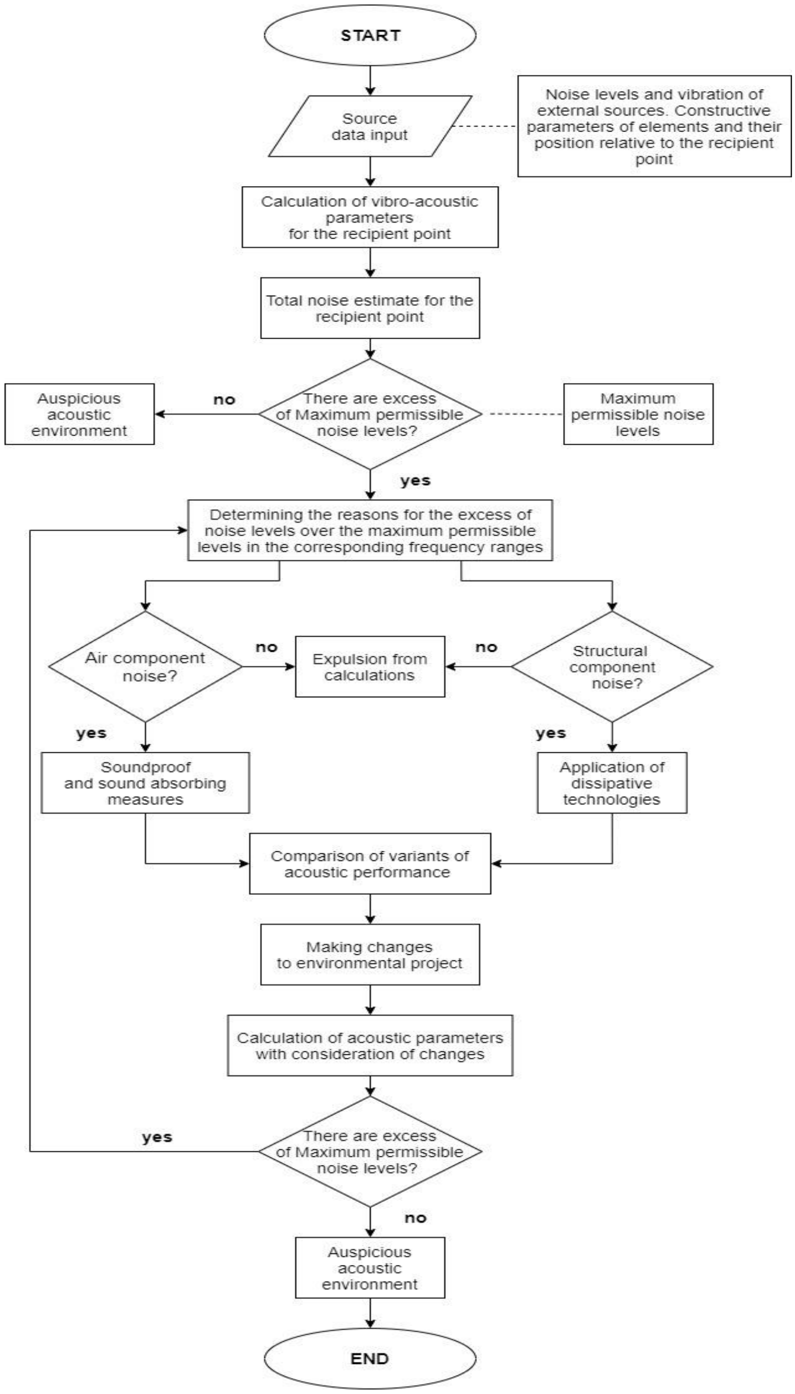

Figure 3. The algorithm of the proposed acoustic model.

Figure 4 shows visualization in the distribution of the indicator value ($L_{full\,day}$) according to the proposed by authors acoustic model for the section of the railway line in the area of the large rail junction at the Regional Branch "Prydniprovska zaliznytsia" – Nyzhnodniprovsk-Vuzol. Analysis of the representative data confirms that at a designated railway facility in the area of Nyzhnodniprovsk-Vuzol sections with above-permitted indices of noise load ≥ 85 dB were identified (A), which marked with red color.

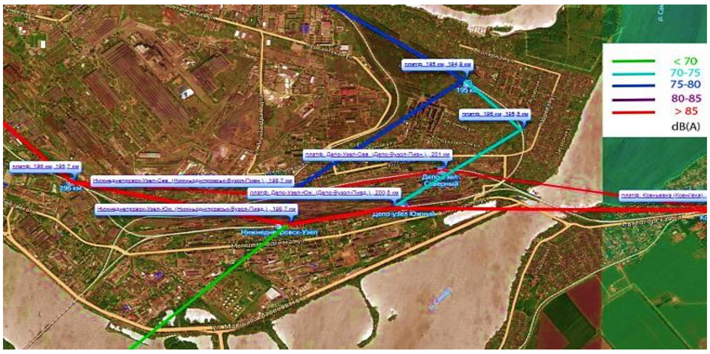

Figure 4. Visualization of the indicator value distribution for the section of the railway line in the area of Nyzhnodniprovsk-Vuzol, L_{day}, dB(A).

Based on the analysis of the representative data obtained, it is proved that determining the dominant type of noise generated is of great importance for improving the effectiveness of measures against the skirr in curves. In addition, the typical characteristics of the track (curve radii, slopes, requirements for adhesive coefficient), rolling stock and operating process must also be clearly defined. It is on the basis of these data that we can determine which measures are most appropriate.

The application of visualization models allows to identify linear and precise objects, in which an excess of permissible norms in noise loads is recorded, to conduct monitoring for specified objects in dynamics, to determine the causes of acoustic loads and to develop priority measures to handle the acoustic situation at the facility.

5. Conclusions

European Directive 2002/49/EC on the evaluation and oversight of noise in the environment emphasizes that EU Member States need to develop a noise reduction plan (the so-called Action Plans), and in the current European integration context, this is already true for Ukraine. In this connection, the authors analyzed static and research data, confirming the availability of a wide range of noise reduction systems and technologies that can be included in the database to select and test specific measures for a specific recipient point.

Since measures to prevent or reduce noise can be applied at different stages in the process of occurrence of the described types of noise, the search and development of contemporary mathematical models that can take into consideration the type of noise, features and phasing of its formation is an important monitoring process. Such models will make it possible to rationalize the choice of the activity or justify applying the range of noise-protective methods, which is a timely and most urgent task of acoustic ecology on transport.

The presence of the algorithm proposed by the authors will allow, at the given basic design parameters and speed of rolling stock, known sound-absorbing and dissipative characteristics of all elements to carry out a rational selection of noise-protective measures in accordance with the sanitary regulations of noise for a specific receptive facility.

6. References

[1] Zelenko Y, Malovanyy M and Tarasova L 2019 Optimization of heat-and-power plants water purification *Chemistry and Chemical Technology* **13** 2 pp 218–223
[2] Bannikov D O 2011 Analysis of the causes of accidents of steel capacitive structures for bulk materials *Metallurgical and Mining Industry* **3** 5 pp 243–249
[3] Kunah O M, Zelenko Y V, Fedushko M P, Babchenko A V, Sirovatko V O and Zhukov O V 2019 The temporal dynamics of readily available soil moisture for plants in the technosols of the Nikopol Manganese Ore *Basin Biosystems Diversity* **27** 2 pp 156–162
[4] Zelenko Y and Bezovska M 2019 Development of an environmentally friendly scheme for the recovery of used engine oils *New stages of development of modern science in Ukraine and EU countries: monograph* 3rd ed (Riga: Baltija Publishing) pp 143–164
[5] Plakhotnyk V M, Yaryshkina L A, Boychenko A M 2005 Environmental aspects of transport accidents with dangerous freights *Czasopismo Techniczne. Mechanika* **10** pp 33–38

[6] Zelenko Yu, Lunys O, Neduzha L and Steišūnas S 2019 The assessment of negative impact of oil products on railroad track and rolling stock constructions *Proc. of the 23rd Intern. Sci. Conf. Transport Means 2019* pt III (Palanga, Lithuania: Kaunas Univ. of Techn.) pp 1300–1306
[7] Myamlin S V 2014 *Parametric environment in railway transport. Principles, assessment, monitoring, security: monograph* (Dnipropetrovsk: Lithographer Publ) p 203
[8] Burdzik R and Słowiński P 2020 Images of Vibrations of a Passing Railway Vehicle *Proc. of the: Transportation Science and Technology. Lecture Notes in Intelligent Transportation and Infrastructure* (Vilnius: Springer, Cham) pp 47–56
[9] Kardas-Cinal E and Gągorowski A 2019 Application of Statistical Analysis to Investigate the Relation Between Road Roughness and Vehicle Vibrations *Proc. of the 23rd Int. Sci. Conf. Transport Means 2019* pt I (Palanga, Lithuania: Kaunas Univ. of Technology) pp 285–289
[10] Klimenko I, Černiauskaite L, Neduzha L and Ochkasov O 2018. Mathematical Simulation of Spatial Oscillations of the "Underframe-Track" System Interaction *Proc. of 12th Int. Conf. ITELMS'2018* (Panevėžysm, Lithuania: Kaunas Univ. of Techn.) pp 105–114
[11] Myamlin S, Neduzha L and Urbutis Ž 2016 Research of Innovations of Diesel Locomotives and Bogies *Proc. Eng.* **134** (Vilnius, Lithuania: Vilnius Gediminas Techn. Univ.) pp 469–474
[12] Klimenko I, Kalivoda J and Neduzha L 2018 Parameter optimization of the locomotive running gear *Proc. of 22nd Int. Sci. Conf. Transport Means 2018* pt III (Trakai, Lithuania: Kaunas Univ. of Techn.) pp 1095–1098
[13] Lunys O, Neduzha L and Tatarinova V 2019 Stability research of the main-line locomotive movement *Proc. of the 23rd Int. Sci. Conf. Transport Means 2019* pt III (Palanga, Lithuania: Kaunas Univ. of Techn.) pp 1341–1345
[14] Kostritsa S A, Sobolevska Y H, Kuzyshyn A Y and Batih A V 2018 Mathematical model of DPKR-2 dyzel train car *Science and Transport Progress* **1** 73 pp 56–65
[15] Raksha S V, Anofriev P G, Bohomaz V M and Kuropiatnyk O S 2019 Mathematical and S-models of cargo oscillations during movement of bridge crane *Naukovyi Visnyk Natsionalnoho Hirnychoho Universytetu* **2** pp 108–115
[16] Shashenko O, Shapoval V, Khalymendyk O, Andrieiev V, Arbuzov M, Hubar O and Markul R 2019 Features of the nonlinear calculation of the stress-strain state of the "rock massif-excavation support" system taking into account destruction *Proc. of the 23rd Int. Sci. Conf. Transport Means 2019* pt III (Palanga, Lithuania: Kaunas Univ. of Techn.) pp 1356–1363
[17] Bondarenko I, Lunys O, Neduzha L and Keršys R 2019 Dynamic track irregularities modeling when studying rolling stock dynamics *Proc. of the 23rd Intern. Sci. Conf. Transport Means 2019* pt II (Palanga, Lithuania: Kaunas Univ. of Techn.) pp 1014–1019
[18] Ignatenko D, Tiutkin O, Petrenko V and Alkhdour A 2019 Application of centrifugal modeling for the study of landscape structure stability *International Journal of Civil Engineering and Technology (IJCIET)* **10** 01 pp 2179–2187
[19] Gerlici1 J, Gorbunov M, Kravchenko K and Lack T 2018 Noise and temperature reduction in the contact of tribological elements during braking *MATEC Web of Conf.* **157** 4: 02010
[20] Matsiuk V, Myronenko V, Horoshko V, Prokhorchenko A, Hrushevska T, Shcherbyna R, Matsiuk N, Khokhlacheva J, Biziuk I and Tymchenko N 2019 Improvement of efficiency in the organization of transfer trains at developed railway nodes by implementing a "flexible model" *Eastern-European Journal of Enterprise Technologies* **2** 3-98 pp 32–39
[21] Bodnar B, Kapitsa M, Bobyr D and Kyslyi D 2019 Defining the Limits of Application and the Values of Integration Variables for the Equations of Train Movement *Naukovyi Visnyk Natsionalnoho Hirnychoho Universytetu* **6** pp 59–65
[22] ISO 2631-1. 1985, 1997 Mechanical vibration and shock. evaluation of human exposure to whole-body vibration. Part 1: International Organization for Standardization
[23] ISO 8608:1995 Mechanical vibration – road surface profiles – reporting of measured data
[24] SSR 3.3.6.037-99 "Sanitary regulations for industrial noise, ultrasound and infrasound"
[25] Directive 2002/49/EC of the European Parliament and of the Council of 25 June 2002 Relating to the Assessment and Management of Environmental Noise