ELECTRIC LOCOMOTIVE CLUSTER IN A BIG CITY: PROBLEMS OF ENVIRONMENTAL COMPATIBILITY

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ABSTRACT

The author creates a cluster approach to engineering and environmental analysis of traffic problems in a big city (Moscow is taken for prototype). In the center of attention is the impact of electric railways on the environment of a metropolitan city with reference to the totality of harmful effects: acoustic noise, vibrational shock loads, electrostatic and electromagnetic fields. It is shown that a problem of environmental safety can be solved in the interests of population, primarily with compatibility of development purposes of local transport networks and urban areas, as well as the organization of complex research of operation consequences of electric traction on the inner rail lines in residential areas and commuter communication.

ENGLISH SUMMARY

Background. *If we evaluate an integrated transport system (hereinafter- ITS) of the country [1] in terms of criteria adopted in environmental engineering [2], railways should be considered as the most preferred mode of transportation of goods and passengers. But this estimate is classified as generalized criteria; it is true, for example, when comparing rail and automotive transport. However, it should be noted, that a determining factor in the distribution of transport operations are not environmental, but engineering-economic evaluation [3], when a combination of prime cost and complex of facilities (comfort) for passengers or consignees steps forward.*

In these circumstances, the task of engineering and environmental analysis is localized with respect to individual units (clusters) of a transportation process, or to interaction with other areas of the economy and livelihoods. The most significant of these tasks is engineering and environmental assessment of compatibility of rail transport with the activity of the largest cities of the country, with a large area, high population density and tight control of environmental conditions.

For example, in Moscow within Moscow Ring Road 650 km of railway lines with heavy traffic of motor-car of electric commuter trains as well as passenger and freight trains with electric locomotive traction are operated. In addition, a significant number of shunting locomotives work at stations, but their share in the environmental pollution by exhaust gases is insignificant – less than 1% of the proportion of automotive transport. Therefore, attention should be focused on railway lines with electric traction, which carry out the bulk of transportation [4]. And they are extremely loaded, though they often have 3–4 tracks.

Given this situation, an integral assessment of man-made environment in such a large city should consider the impact of rail transport as a meaningful cluster in the local transport system. The relevance of a theme for the capital is becoming more meaningful for the following reasons:

– a constant growth in passenger flows in commuter communication;

– an organization of intercity passenger transportation in the Small Ring of Moscow Railway (length 54 km);

– an expansion of the urban area, growth in size and mobility of the population;

– an approximation of urban development and, accordingly, people, who reside there, to rail lines.

According to obvious reasons it is advisable to analyze the environmental situation in this cluster «railway- city» separately for each of the hazards. Table 1, respectively, indicates: at the top- main types of harmful effects according to classification adopted in environmental engineering [2], at the bottom – directions and receivers of these effects. A further analysis, in fact, is carried out by the designated scheme.

Objective. *The objective of the author is to investigate different aspects of impact of electric railways on the environment of a large city.*

Methods. *The author uses analysis, comparison and descriptive method.*

Results.

1. <u>Acoustic noise</u> from rolling stock is clearly limited to regulations that are taken into account during designing of locomotives and cars and are checked during acceptance testing. The main sources of noise are contact zones «wheel-rail». Its level greatly depends on the design of the running gear of rolling stock and a track, train speed [5]. Noise intensity under identical conditions of its generation for the freight trains is 1,8–3,1 times higher than that of a passenger, as determined by the design of the elastic suspension. Since a maximum speed of all trains within Moscow Ring Road is restricted at the level of 45–60 km / h, it automatically solves the problem of noise limitation. The main reason for the speed limit is safety in high traffic density and frequency of placement of stop points of commuter trains.

The given considerations refer mainly to the effects of noise on the environment. With regard to passengers of commuter and long-distance trains, the design of modern all-metal cars provides sufficient sound insulation throughout the speed range. It is especially characteristic of long-distance cars with air conditioning, where a good body sealing is provided. A similar solution is laid down in the specifications for new electric commuter trains, but its implementation is difficult because of the unprofitabliness of commuter transportations. The trend towards the development of market relations prevails in relation to progressive technological solutions and is in contradiction with them.

<u>2. Vibrational shock loads</u> on a track infrastructure and environment, primarily on the foundations of buildings in urban areas, are determined by the dynamics of interaction of a rolling stock and a track [6]. The result is periodic shaking of the ground and car bodies. The latter are estimated by coefficient smoothness of movement, and there are several methods for calculating, for example, by the empirical formula:

$$W = 2{,}7 \cdot \sum_{i=1}^{\infty} \sqrt[10]{A_i^3 \cdot f_i^5}, \qquad (1)$$

where $A_i,\ f_i$ *– amplitude and frequency of vibrations for the –th harmonic.*

A man is more sensitive to fluctuations in the range f=5–8 Hz, so that the calculations according to the

Table 1

Impact of electric railway on the environment in a big city

1. Acoustic noise			2. Vibrational shock loads		3. Electric fields, generated by a contact network			4. Wear products of a mechanical part	
Directions of impact									
Environment	Passengers	Train personnel	Building constructions	Passengers and personnel	Electrostatic field	Magnetic field	Galvanic effect	Pollution of a track structure	Relocation to environment

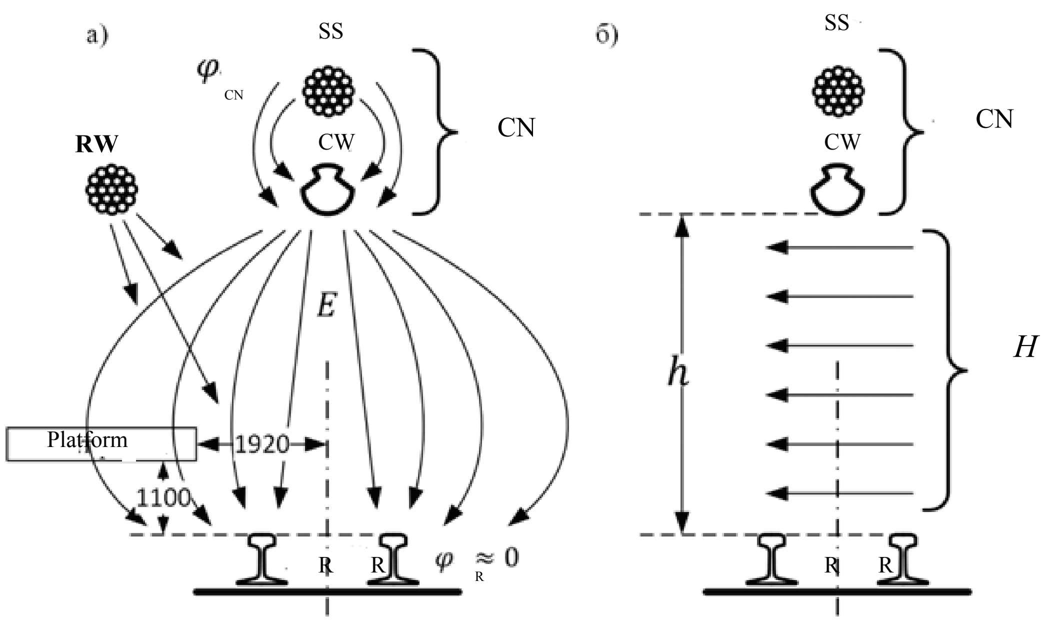
formula (1) can be limited to these frequency values. Comfort is ensured if W=0,85–0,9.

Modern methods of vibration insulation of body of cars and locomotives enable to virtually eliminate the effects of vibration on people; remains a potential danger of the influence of low-frequency oscillations on various city buildings near a railway track. But in reality it is not dangerous for the following reasons: the amplitude of the ground vibrations decays in proportion to the distance power 1,8–2,6; train speed is limited; mainly passenger rolling stock is in operation, having a small load from the axis on the rails. In general, rail rolling stock on vibrational shock loads, according to experts, does not contain threats to urban infrastructure. According to available data, the risk is even weaker than that of the light rail and metro.

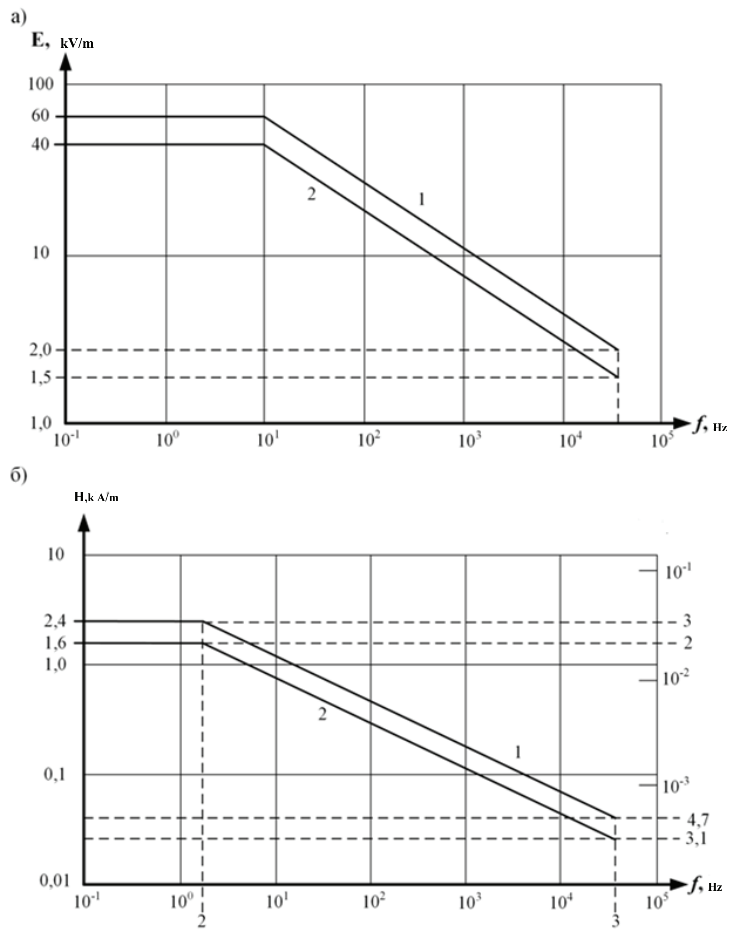
3. Electric fields [7,8] deserve a special attention due to the fact that they always appear on the railways with electric traction, and their effect on a human body has been insufficiently studied, although formally the regulatory documents are available. In particular, the regulations do not take into account the duration of the field impact on a person and a cumulative effect of changes in his body.

Specificity of electric traction is manifested in two ways – in the generation of electric fields by a contact network and the fact that in the area of action of these fields there is a huge number of people – in trains and passenger platforms. The risk is also connected with the fact that a person does not feel the impact of an «invisible enemy» in contrast to the acoustic or vibration exposure.

There is a misconception about the negligible danger of electric fields of a contact network of railways because of the relatively low voltage (3 kV DC and 25 kV AC). An argument here is the fact that trunk transmission lines imply voltage of 500 or 750 kV, and lines are designed for 1500 kV. But in these lines 3-phase alternating current is used and with a full symmetry of currents and voltages the electric fields generated in the system cancel out. A strong uncompensated field is only in the vicinity of each of the wires, and at the ground level the residual field parameters for each line are at least one order lower than a maximum standard.



Pic. 1. The electric field in the area of a contact network (a – an electrostatic field, b – an electromagnetic field).



Pic. 2. Maximum permissible values of the intensity of an electrostatic field E (a) and the parameters H and B of a magnetic field (b) according to international standards: 1 – peak values; 2 – effective values.

A similar situation is in the subway, where the current flowing in a contact rail and rolling rails, reaches 4–5 kA. But the distance between them is insignificant and the electric field is concentrated in this area, essentially without going out above a passenger platform level.

A completely different situation occurs on a railway, where a contact wire is suspended at a height of $h_{cw} = 5m$ over the heads of the rails and the electric field is concentrated in this interval. In the area of concentration a thickening of the lines of force occurs, and there is a mass gathering of passengers in cars and on platforms.

Harmful effects are usually considered separately for electrostatic and electromagnetic field. In the first case (see Pic. 1a), the field intensity E is determined by the potential difference of a contact network φ_{CN} and rails φ_R, i. e.

$$E = (\varphi_{CN} - \varphi_R) / h_{CW}, \qquad (2)$$

where $\varphi_R \approx 0$, so that

$$E = U_{CN} / h_{CW}, \qquad (3)$$

where $U_{CN} \approx \varphi_{CN}$ – is a maximum permissible voltage of a contact network, equal to 4 kV at DC and 32 kV at AC.

The electric field lines of force are directed from one pole of a system to another (see Pic. 1a). In DC system pole «plus' – wires of a contact network CW and SS, «minus' – rails R. Intensity of an electrostatic field is maximum in the zone of a track panel, and here its value is equal to

$$E_{max} = \frac{U_{max}}{h_{min}}, \qquad (4)$$

where U_{max} – maximum voltage in a contact network (4 kV at DC or 32 kV at AC);

h_{min} – minimum height of a overhead catenary suspension (h = 5,5–5,75 m).

According to the formula (4) we get E_{max} = 0,8 kV/m at DC and 6,4 – at AC.

This complies with standards for an electrostatic field (see Pic. 2a), but here it is necessary to take into account a number of additional factors. Firstly, an electrostatic field is always present when there is voltage regardless of the current in wires of a contact network and rails. Secondly, mass gatherings are impossible directly on a track, but they always occur on passenger platforms. If we consider an electrostatic field of only one track, in the area of platform intensity will be 1,4 times less than E_{max}. But in the real situation it is necessary to consider other factors: the impact of the force lines of the electrostatic field from a reinforcing wire (RW) and wires of a nearby track. As a result, the net effect of these electrostatic fields on a person on a platform is characterized by a value of approximately 1,6–1,9 times higher than E_{max}.

For comparison, it is advisable to consider an electrostatic field of urban electric transport. In the subway when the voltage on a conduct rail is 825 V a field is more concentrated, since a contact rail and rolling rails are at a small distance from each other, but at the level of a passenger platform an actual value of intensity is 20–25 times less. In a tram at 600 V in a contact wire intensity does not exceed 0,2 kV / m, which is significantly lower than a standard. In catenary of a trolley both wires +400 V and –400 V create intensity in the space between them to 1 kV / m, while on the ground level, this figure is 30–35 times lower.

In short, the only sources of electrostatic effects on human beings in a large city are railways with electric traction. Despite the constant presence of this field, a passenger is exposed to it for a short time- only when he stays near a track, for example, waiting for a train. A car body has a screening effect, and even when there are window apertures in a steel body an electric field is absent. However, the impact of an electrostatic field on a human body requires additional research.

Similarly, an electromagnetic field is evaluated lower (see Pic. 1b) occurring in the space between wires of a contact network CW + SS and rails R. They form a single turn contour W=1, in which acts a magnetic field with lines of force H. The lines are perpendicular to the plane of a contour with the electric current I and characterize intensity in that contour, which is equal to

$$H = \frac{W \bullet I}{\pi \bullet h}, \qquad (5)$$

where I – current intensity; $\pi = 3{,}14$.

The maximum current in a contact network and, accordingly, reverse current in the rails can reach 5–6 kA – in DC system and 1–1,5 kA in AC system. Therefore, the field intensity in this space will be respectively 1,1 kA / m or 0,3 kA / m, which is applicable to regulatory restrictions (see Pic. 2b). Since the vector of intensity H is directed across the axis of a railway track, and in the area of a passenger platform vectors of both tracks are summed, then there is a contour W=2. That is, previously given intensity values must be doubled, and on multitrack lines – multiplied by 3–4. But even then, the resulting values will be below regulatory limits. It should be noted that a human body is less sensitive to a magnetic field than to an electrostatic one because it is always in Earth's magnetic field, and a source of an electrostatic field in the city can only be a contact network.

Galvanic effect of electric current on the environment is associated with the fact that the reverse current of electric rolling stock, normally flowing through the rails, derives into the ground. And it can derive along an entire track to a traction substation up to 30% of the reverse current. Since a contour of its occurrence in the ground is uncertain, it is called ground current. It causes galvanic corrosion of underground structures in the ground, and this negative effect is sufficiently described in detail in the special literature [9]; methods for protection against it are developed. Obviously, there are other negative effects of ground currents, but there is no serious research in this respect.

4. Wear products of a mechanical part of a rolling stock and rails are dust-like particles produced by galling of wheels, brake pads, rail heads. Their chemical formulas: Fe_2O_3 or Fe_3O_4, and the harmful effects are limited to pollution of a track superstructure. In part, they can be transferred to the environment – with a strong wind or storm drains. Only the effect of track pollution is considered essential, which has its own treatment technology.

Conclusion. Thus, the ecological problem of a rail transport in a big city is multifaceted and requires a comprehensive research, especially in regard to the impact of an electric field on a person.

Keywords: metropolitan city, railway, electric traction, harmful effects, engineering and environmental analysis, cluster «railway-city», environmental compatibility.

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