Evaluation of the effectiveness of using an electromechanical shock absorber in a subway car

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Highlights

- Study of vertical oscillations of a subway car due to random track irregularities.

- Indicators of dynamic quality of the metro car with electromechanical shock-absorbers.

- Advantage of electromechanical shock absorbers over central spring suspension.

- Recommendation of using electric shock absorbers in the design of a subway car.

Abstract

The paper evaluates the effectiveness of the electromechanical shock absorber for a subway car based on dynamic quality indicators. To determine them, a method of synthesis of random forced vertical oscillations of a dynamic model of a subway car was developed, which is based on the method of sliding summation taking into account the spectral density obtained when processing the test results of a subway car. Also in the work the technique on definition of indicators of dynamic quality of the metrocar with electromechanical shock-absorbers which is based on modeling of processes of movement of the subway car on a site of a way with casual roughness and definition, by results of modeling, indicators of dynamic quality is created. The study of forced random oscillations of the dynamic model of a subway car showed that the spring suspension based on electromechanical shock absorbers has a significant advantage over the central spring suspension for all quality indicators in the entire range of speeds. The dependence of the average power generated by the shock absorber is established.

Keywords

electromechanical shock absorber, subway car, indicators of dynamic quality, spring suspension, running gear.

1. Introduction

Investigation of rail vehicles dynamics is one of the main elements in developing new vehicle designs, approval process and shaping and monitoring the railway track geometry [2,10]. A key factor in such investigations is random track irregularities which arise due to repetitive load from running vehicles [11]. These irregularities disturb the railway vehicle motion and result in vehicle vibrations which affect the ride comfort of travelling passengers [6] and the safety of the freight transportation [4,24].

The comfort of subway passengers is directly related to the smooth movement of subway cars. To ensure it, it is necessary to have an effective system for damping vehicle vibrations [15]. The system of damping oscillations on most subway cars usually has two, different parameters of the degree of spring suspension. Conversion of energy of oscillations of a body and elements of car into other types of energy is provided by existence in a running gear of dampers of oscillations - shock-absorbers.

Characteristics of vibration dampers determine the nature of oscillations of the running gear of the rolling stock and directly affect traffic safety and its speed.

Shock absorber performance is determined by the type and design of the shock absorber. As noted in [20] on the smoothness of the best performance inherent in pneumatic shock absorbers, their use requires an additional system of pneumatic power - compressors that reduce the overall energy efficiency of electric rolling stock [14]. To increase the energy efficiency of electric rolling stock, the authors [13] proposed the use of electromechanical shock absorbers. Shock absorbers

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of this type do not consume additional energy, instead they are able to partially recover the energy of the oscillations. The generating capabilities of electromechanical shock absorbers make it possible to increase the energy efficiency of rolling stock in general and the chassis in particular [13].

2. Analysis of literature data and problem statement

A comprehensive analysis conducted in [19] showed that in world practice the most common is the spring suspension of trolleys. The suspension consists of an axle box and a central part. A similar system is used on subway cars in Ukraine. The purpose of the spring suspension is to reduce the impact of track irregularities and curved road sections that occur during the movement of the metro car. The most common vibration damping systems that occur in the central suspension of trolleys are hydraulic shock absorbers [19]. In [16] it is noted that a common technical solution is friction vibration dampers, supplemented by hydraulic dampers. Such combined systems are installed in the second stage of the spring suspension. To increase the comfort of passengers and increase the smoothness of the metro car series E-KM [9] at PJSC "Kryukiv Carriage Plant" (Kremenchuk, Ukraine) have new carts model 68-7054 with central pneumatic spring suspension, which is supplemented by the shock absorbers. However, the use of pneumatic springs requires additional energy losses and power of the pneumatic system [14].

An alternative way to increase the smoothness of movement is the use of electromechanical energy absorber in the second stage of the spring suspension of metro cars [12, 20].

Electromechanical shock absorbers are most common in road transport. Structurally, such shock absorbers are integrated into the suspension type McPherson [21] together with the spring. The process of recovery of vibration energy from the electromechanical shock absorber and its connection to the onboard network of the vehicle is described in [3]. Estimation of energy efficiency of systems of recovery of energy of mechanical fluctuations for cars KRAZ-65055 (Russia), KAMAZ-45143 (Russia), Gazelle-3302 (Russia), VAZ 2101 (Russia), Reno Megane (France), Toyota Camry (Japan) on the basis Previous results of mathematical modeling of such systems are given in [25]. As noted in [25], the use of electromechanical shock absorbers has provided opportunities to increase the efficiency of vehicles.

To analyze the oscillations of the rail transport body, it is necessary to create a generalized mathematical model of the main approaches to its creation proposed in [23]. The authors of [23] also analyzed the complex processes of oscillations in the mechanical system of the chassis of vehicles.

For an electromechanical shock absorber, the design of which is proposed in [16] and shown in Fig. 1 the authors of [12] developed a mathematical model of a subway car on two two-axle carts with an axial characteristic of 2_0-2_0, in the central stage of the spring suspension which used springs and electromechanical dampers.

The model is developed on the basis of the spatial kinematic scheme of the model of the subway car shown in Fig. 2 and 3.

The peculiarity of the model is that it contains the following components: 17 differential equations of the second order, which describe the operation of the mechanical part of the car-rail track; 8 first-order differential equations that describe the operation of 4 electromechanical shock absorbers. The model is supple-
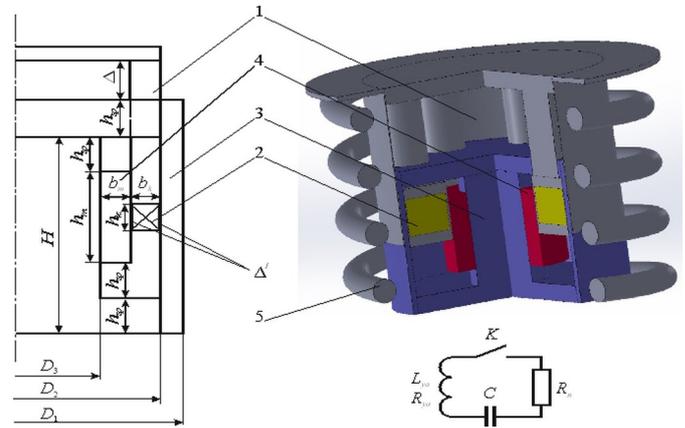

Fig. 1. Electromechanical shock-absorber of a direct current: 1 - an anchor; 2 – armature winding; 3 - bed; 4 - permanent magnet; 5 - spring
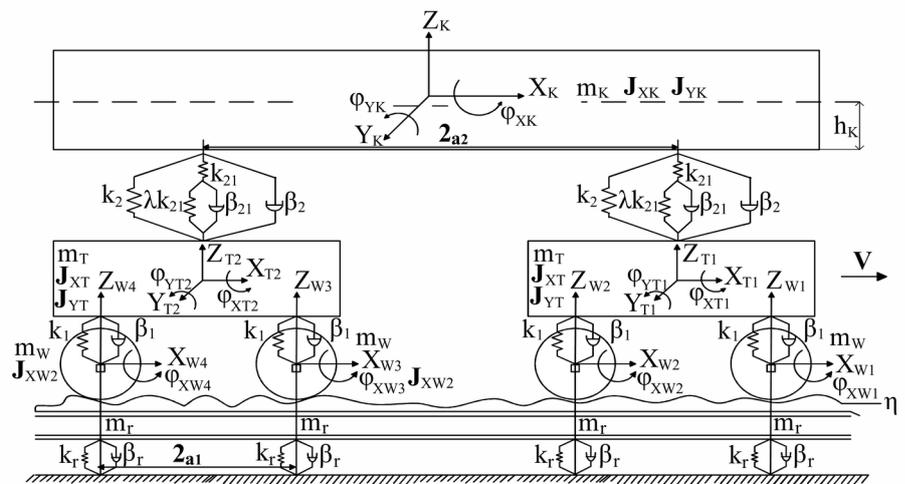

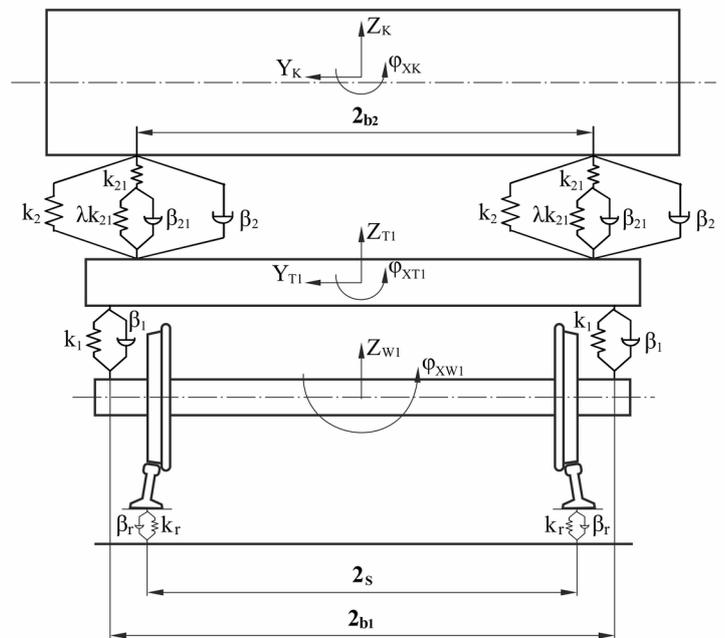Fig. 2. Spatial kinematic scheme of the subway car model (side view)

Fig. 3. Spatial kinematic scheme of the subway car model (front view)

mented by three polynomials of 32 and 63 orders, which describe the state of the magnetic field of electromechanical shock absorbers and

their electromagnetic force, as well as 4 algebraic coupling equations obtained on the basis of the provisions given in [14].

To assess the effectiveness of the spring suspension, as described in [20], it is necessary to determine for the studied model of the subway car the dependence of the values of their dynamic qualities on the speed of movement. The obtained values of quality indicators must be compared with the permissible values, which are regulated by current regulations [22]. The allowable speed [v] is determined and checked taking into account the unevenness of the track $[v] > v_k$.

Permissible values of indicators of dynamic qualities for subway cars intended for transportation of passengers are accepted according to [22] and are included in table 1.

Table 1. Permissible values of indicators of dynamic qualities of subway cars

Type of dynamic quality indicator	Valid value
Smoothness coefficient, C	3,25
Maximum vertical acceleration, $\ddot{z}_k$	0,35g
Coefficient of dynamics in the central suspension, κ_{dc}	0,2
Coefficient of dynamics in axle box suspension, κ_{db}	0,35

An important indicator of the energy efficiency of the electromechanical shock absorber is the average power generated by random excitation of track irregularities, which is determined by the expression:

$$P = \sum_{k=1}^{4} \int_{0}^{t_{end}} R_n i_k^2 \, dt \qquad (1)$$

where t_{end} – time of movement on a track with random irregularities,

i_k – electric current generated in k-th shock absorber (k=1,2,3,4),

R_n – load resistance.

Given the above, it is also possible to note the quality indicator as the maximum movement of the places of installation of auto-coupling on the body, which is important for subway cars moving in the tunnel. Traffic in the tunnel imposes additional restrictions on the amplitude of oscillations of the subway car body.

Determination of dynamic quality indicators is carried out by determining the coefficients.

The coefficient of smoothness of motion C for the implementation of a random process of acceleration of the body duration t_r in the work was calculated according to the expression recommended in [18]:

$$C = \alpha \cdot 6{,}67 \sqrt{\sum_{j=1}^{n} \frac{t_j}{t} \left(2 \int_{f_n}^{f_v} q_n^2(f) G_{\ddot{z}kj}(f) df \right)} \qquad (2)$$

where α – coefficient of proportionality, $\alpha = 4{,}346$;

t_j – duration of the j-th implementation, $t_p = \sum_{j=1}^{n} t_j$;

f_n, f_v – respectively the lower and upper limits of the frequency range of the measured accelerations;

$G_{\ddot{z}kj}(f)$ – spectral density of the j-th implementation of the process of body acceleration;

$q_n(f)$ – normalized amplitude-frequency characteristic of the correcting filter (approximation of physiological coefficient)

$$q_n(f) = 1{,}15 \sqrt{\frac{1 + 0{,}1f^2}{\left(1 + 4{,}04f^2\right)\left[\left(1 - 0{,}0364f^2\right) + 0{,}045f^2\right]}} . \qquad (3)$$

The coefficient of vertical dynamics of the car body is determined [17]:

$$k_{dv} = \frac{P_{dv} - P_{cm}}{P_{cm}} \qquad (4)$$

where P_{dv} – dynamic vertical force transmitted from the body to the chassis in the central or axle suspension;

P_{cm} – static load transmitted from the body to the chassis.

In [18] a comparative analysis of spring suspension and suspension based on pneumatic springs was performed. A similar approach is rationally used in assessing the quality of use of electromechanical shock absorbers.

As follows from the analysis [3, 9, 12-14, 16, 18-23, 25] of the current state of the problem, the problem is partially solved, because only the following results were obtained. The design and mathematical model of the electromechanical shock absorber for the metrocar have been developed. The model allows to model the processes of metrocar movement during the passage of the track with different types of track irregularities. The authors of the work [3, 9, 12-14, 16, 18-23, 25] developed approaches to determining the indicators of dynamic qualities of subway cars. However, the developed models do not allow to determine these indicators for subway cars equipped with electromechanical shock absorbers. Also the problem of the comparative analysis of efficiency of application of electromechanical shock-absorbers in comparison with traditional designs is not solved.

3. The purpose and objectives of the study

The purpose of the study is to conduct a comparative evaluation of the effectiveness of the electromechanical shock absorber for a subway car on the only indicators of the dynamic qualities of subway cars.

To achieve this goal, the following tasks were set:
– to develop a method for determining random forced vertical oscillations of the dynamic model of a subway car;
– to develop a method for determining the indicators of dynamic quality of a metrocar with electromechanical shock absorbers;
– to conduct a comparative analysis of the results of research on the spring suspension of subway cars with an electromechanical shock absorber.

4. Comparative evaluation of the effectiveness of the electromechanical shock absorber for the subway car

4.1. Random forced vertical oscillations of the dynamic model of a subway car

The coefficient of smoothness is determined by the results of modeling the movement of the metro car. Mathematical model and modeling technique are given in [18]. However, since it is important to determine the coefficient of smoothness according to [18] it is necessary to conduct modeling when driving on a section of track with random unevenness of the rails.

For the synthesis of track irregularities according to [18], it is necessary to determine the spectral power density. The paper applies the

spectral density obtained by processing the test results of the subway car model 81.717. The power spectral density is approximated by a dependence that corresponds to a random process and is differentiated according to the recommendations [18]:

$$G_\eta(\omega, v) = \frac{S_\eta^2}{2\sqrt{\pi}} \sum_{j=1}^{n} \frac{a_j}{\alpha_j \cdot v} \left\{ \exp\left[-\frac{(\omega + \omega_j v)^2}{4\alpha_j^2 v^2} \right] + \exp\left[-\frac{(\omega - \omega_j v)^2}{4\alpha_j^2 v^2} \right] \right\}$$

(5)

where S_η^2 – variance of equivalent geometric irregularity (according to the test results value $S_\eta^2 = 13,01$ m^2 [20] was obtained,

ω – current value of frequency, rad/s,

ω_j – the frequency of the j-th maximum of the spectral density,

a_j – the proportion of variance at the j-th maximum of the spectral density,

α_j – half the width of the j-th maximum of the spectral density at half its height.

For the generation of the track irregularity the method of sliding summation is used. This method is described in [1, 8, 20] and has previously been used both for generating random track irregularities in studies of the railway vehicle dynamics [5, 7] as well as road profiles [1]. The method is equaivalent to the the spectral representation method, where the generated process is modeled as the sum of harmonic signals of fixed amplitudes and random phases.

When applying the sliding summation method at each step of modeling the equivalent geometric irregularity, new values of the generated random numbers are used. As the initial data for modeling, the mean value of the irregularity $\bar{\eta}$ and its power spectral density $G_\eta(\omega)$ are acquired.

Discrete values of the simulated process are obtained with the expression in the form of the sliding summation (moving average):

$$\eta_i = \bar{\eta} + \sum_{j=-M}^{M} c_j \cdot \varepsilon_{i-j}$$

(6)

where c_j – weights,

ε_j – independent random variables distributed according to Gauss's law, obtained by [20] from the values of the initial stationary discrete white noise distributed according to the uniform law,

$2M$ – number of weights.

To obtain a process whose power spectral density will fully coincide with the assumed spectral density, it is necessary that $2M \rightarrow \infty$. Thus, to reproduce this spectral density at satisfactory level the number of weigths $2M+1$ must be sufficiently large. According to recommendations given in [17] it was assumed $2M = 9600$.

The value of the weights was determined with the formula:

$$c_j = \frac{1}{\omega_c} \int_0^{\omega_c} \left[\omega_c G_\eta(\omega) \right]^{0,5} \cdot \cos\frac{j\pi\omega}{\omega_c} d\omega$$

(7)

where ω_c – the sampling frequency of the random process $\eta(t)$:

$$\omega_c = \frac{\pi}{\Delta t},$$

Δt – sampling step.

When modeling $\eta(t)$ by the method of sliding summation, the equivalent geometric irregularity for the speed of motion is modeled, and then in the process of solving the problem "move" on this irregularity with the required speed. This approach is the main one for studying the oscillations of dynamic models of rolling stock during their movement on the simulated section of the track with variable speed according to the operating schedule.

Thus, the functions of the irregularities η of left and right rail for the speeds v = 40, 50, 60, 70, 80, 90 and 100 km/h were synthesized. The speed range was chosen taking into account the excess of the design speed (v_k = 90 km/).

When modeling the parameters of the analytical expression of the spectral density of expression (5) were determined by α_j, ω_j and a_j (Table 2).

Table 2. Parameters of the analytical expression of spectral density

The number of the component of the spectrum	α_j, (rad/s)/(m/s)	ω_j, (rad/s)/(m/s)	a_j
1	1,0	0	0,697
2	0,0018	0,20096	0,12
3	0,002	0,25749	0,109
4	0,01	0,314	0,074

The duration of the synthesized process according to the recommendations [18, 20] is t_p = 32,768 s. This roughly corresponds to the implementation length, which is usually accepted in tests of 30 s. The duration of the process in this case corresponds to the number of points of implementation of the reaction of the dynamic system „car - rail track" is N = 32768, which corresponds to 2^{15}. However it meets the requirements for spectral analysis using fast Fourier transform.

4.2. Determination of indicators of dynamic quality of a metrocar with electromechanical shock absorbers

The dynamic quality indicators determined by the results of numerical simulation must correspond to the permissible values regulated by the current norms [22], while determining the permissible speed [v], which corresponds to the conditions of inequality [v] ≥ v_k.

The paper adopted the following indicators of the dynamic qualities of the subway car [20, 22]:

1. Coefficients of smoothness of the course C_1 and C_2 over the first and second along the movement of pivot points on the floor of the body.

2. The maximum values of accelerations $\ddot{z}_{k1}$ and $\ddot{z}_{k2}$ respectively at the same points as the coefficients of smoothness.

3. Coefficients of dynamics in the relationship between the body and the frame of the trolley, as well as the frame of the trolley and wheelsets: k_{dc1}, k_{dc2}, k_{dc3} and k_{dc4} - coefficients of dynamics in the elements of the central degree of the spring suspension of the first (k_{dc1}, k_{dc2}) and the second (k_{dc3}, k_{dc4}) along the movement of carts; k_{db1}, k_{db2}, k_{db3}, k_{db4}, k_{db5}, k_{db6}, k_{db7} and k_{db8} - dynamics coefficients in the axle stage of the spring suspension of the first (k_{db1}, k_{db2}, k_{db3} and k_{db4}) and the second (k_{db5}, k_{db6}, k_{db7} and k_{db8}) in the course of movement of carts, respectively for the left and right wheels of one wheel pair.

The coefficients of dynamics were defined as the ratio:

$$k_d = \frac{F_{din}^{max}}{F_{stat}}$$

(8)

where $F_{\text{din}}^{\max}$ – maximum dynamic force in the above elements of the spring suspension, F_{stat} – the static value of the force in the above elements of the spring suspension.

Statistical characteristics of the distribution of absolute maxima of H processes are determined by [18, 20]:

$$\bar{H} = \int_0^\infty H f(H) dH \qquad (9)$$

where $f(H)$ is the distribution density of the absolute maxima of the random process $q(t)$.

Using the expression for a stationary Gaussian process we find:

$$f(H) = \frac{d}{dH} \exp\left\{ -f_e t_p \exp\left[-\frac{(H - \bar{H})^2}{S_q^2} \right] \right\} \qquad (10)$$

where f_e – is the effective frequency of the random process $q(t)$;
t_p – time of implementation of a random process [20].

Taking into account the assumptions considered in [17], the values of the average values of the absolute maxima H for the implementations $q(t)$ are determined by the approximate expression:

$$\bar{H}_q \cong S_q\left(\sqrt{2 \ln f_e t_p} + \frac{1}{\sqrt{2 \ln f_e t_p}} \right) \qquad (11)$$

where S_q is the standard deviation of the random process $q(t)$.

The value of f_e is determined directly by the implementation of reactions $q(t)$:

$$f_e = \frac{n_0}{2 t_p} \qquad (12)$$

where n_0 is the number of zeros of the random process $q(t)$.

The standard deviation S_q was determined by the dependence on $q(t)$ by the formula:

$$S_q = \sqrt{\frac{1}{N} \sum_{i=1}^{M} (q_i - \bar{q})^2} \ . \qquad (13)$$

The coefficient of smoothness of stroke C on the realizations of the random process of accelerations of the body duration t_p was calculated according to expression (2) [18].

To facilitate the analysis of mathematical models and the obtained results, the natural frequencies of oscillations of subway cars with spring suspension and electromechanical shock absorber were determined.

Eigenfrequency calculations are performed for the frequency of partial oscillations. The results of the calculation are given in table 3.

As can be seen from table 3 the partial frequencies of oscillations of the body and carts are different in the subway cars under study, because the stiffness of the base spring and the spring of the electromechanical shock absorber differ by 40% (Zw_2=2174,2 kN/m, Zw_{21}=1311,2 kN/m).

Resonant velocities corresponding to the j-th maximum of the spectral density of the equivalent geometric irregularity can be determined by the formula [20]:

$$V_p = \frac{f_{ci}}{\omega_j} 3,6 \quad \text{km/h}, \qquad (14)$$

where f_{ci} - the frequency of natural oscillations of the body of the model of the subway car on i-th generalized coordinate; ω_j is the frequency of the j-th maximum of the spectral density.

According to the results of calculations, it was found that the resonant velocities even in the body oscillations are outside the studied speed range v = 40-100 km/h. For spring-loaded central suspension, they are in the range of 115-207 km/h [20], and for suspension with electromechanical shock absorbers in the range of 110-196 km/h.

On the other hand, in the results of calculations of the dependences of dynamic quality indicators on the velocity of motion, the first maximum of spectral density approximation with frequency ω_1=0, which accounts for 69.7% of the variance of the equivalent geometric irregularity, should manifest itself.

4.3. Comparative analysis of the results of studies of spring suspension of subway cars with electromechanical shock absorbers

The analysis was performed between the parameters of elastic spring suspension and spring suspension using an electromechanical shock absorber.

The dependences of dynamic quality indicators on the speed of movement for the studied model of the subway car are calculated. The obtained values of quality indicators were compared with the permissible values, which are regulated by current regulations (Table 1) and are limited by the movement of the train in the tunnel, as well as among themselves.

Table 3. Values of partial oscillation frequencies

№	Model element	Type of oscillations	The value of the partial frequency, Hz	
			Model with spring spring suspension [1]	Model with electro-mechanical shock absorber
1	Body	bouncing	2,32	1,89
		galloping	2,49	1,98
		lateral sway	2,21	1,82
2	Cart	bouncing	8,09	7,93
		galloping	5,79	5,78
		lateral sway	8,08	8,07
3	Wheelset	bouncing	45,36	45,35
		lateral sway	45,92	45,92

An additional restriction was introduced due to the existing possibility of self-disengagement of metro cars and is not to exceed the difference of the longitudinal axes of auto-couplings, which is allowed, and has the form:

$$z_k \leq \frac{h_{\text{àñ}}}{2} = [z_k] = 0.055 \text{ m.} \tag{15}$$

The results of the research in the form of graphs of the dependence of the indicators of dynamic quality on the speed v are shown in Figures 4-8.
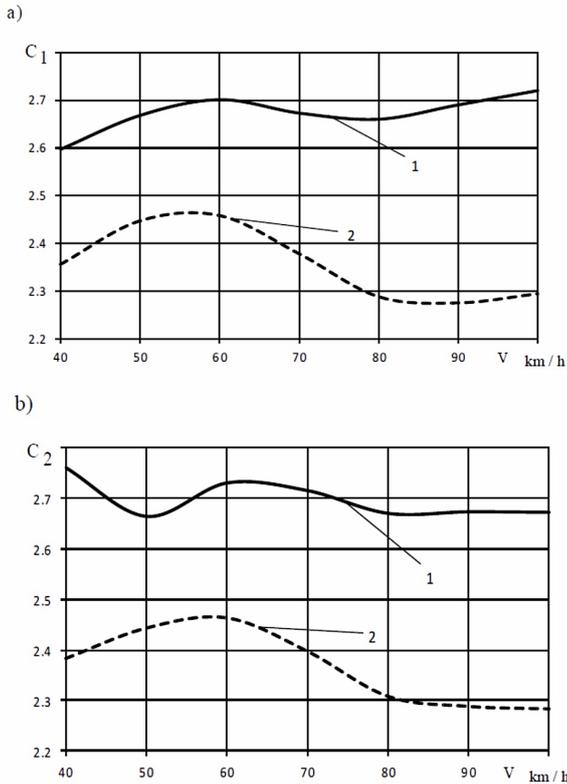
a)

b)

Fig.4. Dependence of the coefficient of smoothness over the first (a) and second (b) pivot points of the body on the speed, 1 - spring central spring suspension; 2 - spring suspension with electromechanical shock absorber

5. Discussion of the results of evaluation of indicators of dynamic quality of subway cars equipped with electromechanical shock absorbers

Comparative analysis of graphs shows that the indicators of the dynamic quality of the model of the subway car with both spring and pneumatic spring suspension do not exceed their allowable values up to the speed $v = 100$ km/h.

According to the obtained dependences, it is possible to note that this maximum was especially manifested in the speed range $v = 60\text{-}70$ km/h on the dependences $C_{1,2}(v)$, $\ddot{z}_{k2}(v)$ and $K_{dc3,4}(v)$.

In Fig. 4-8 we see that the model with spring suspension with electromechanical shock absorber has better performance compared to spring suspension. For example, the plots in Fig. 4 show that this is the case for such an indicator as the coefficient of smoothness C_1 for suspension with electromechanical shock absorber (curve 2) in the entire speed range $v = 40\text{-}100$ km/h, the value of this coefficient is 9.2-15.6% less than for spring suspension (curve 1), and for C_2 - at 13.3-14.5%.

According to the value of the maximum acceleration (Fig. 5) on the floor of the body above the first pivot point, the difference between
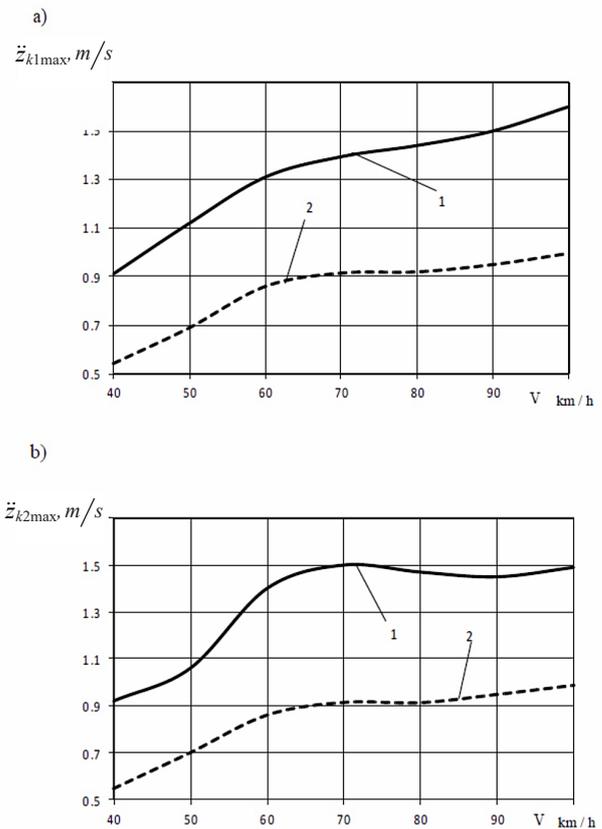
a)

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Fig. 5. Dependence of the maximum acceleration over the first (a) and second (b) pivot points of the body on the speed of movement. 1 - spring central suspension; 2 - spring suspension with electromechanical shock absorber
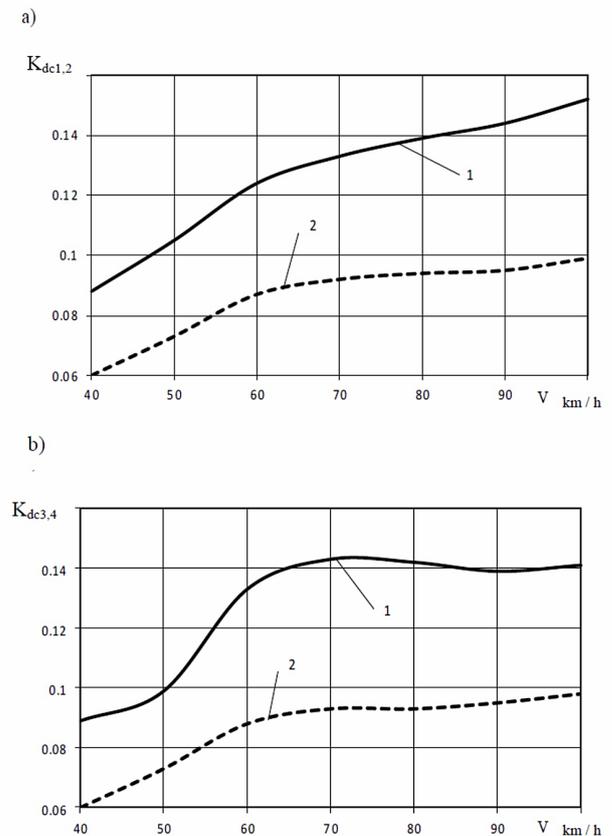
a)

b)

Fig. 6. Dependence of coefficients speakers in the central stage of suspension on the first (a) and the second (b) carts from the speed of movement. 1 - spring central suspension; 2 - spring suspension with electromechanical shock absorber
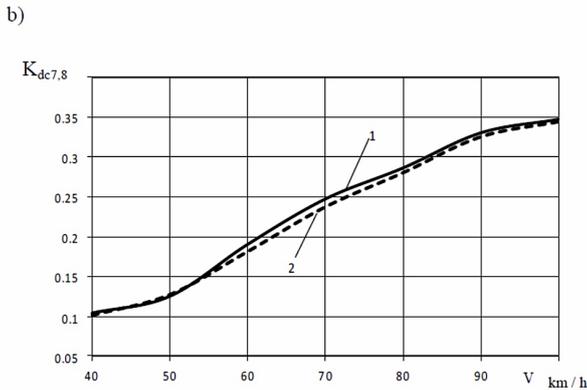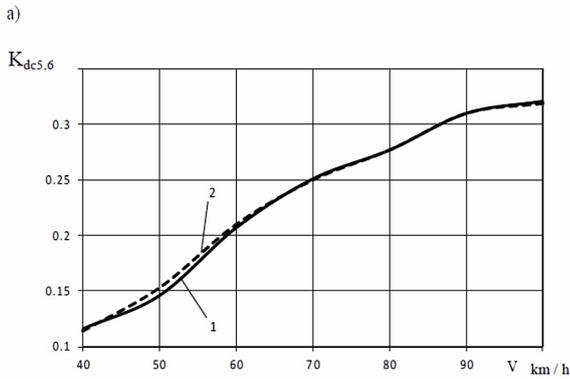
a)

b)

Fig. 7. Dependence of the coefficients of dynamics in the axle stage of suspension of the first wheel pair (a) and the second wheel pair (b) of the first wheelchair from the speed of movement. 1 - spring central suspension; 2 - spring suspension with electromechanical shock absorber
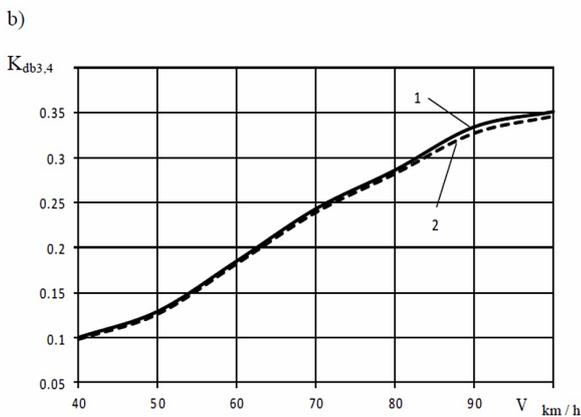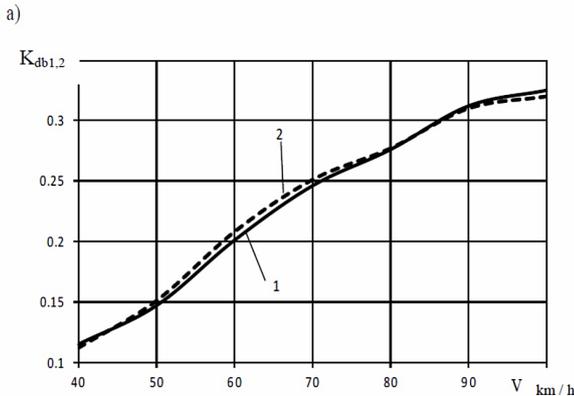
a)

b)

Fig. 8. Dependence of coefficients dynamics in the axle stage of suspension of the first wheel pair (a) and the second wheel pair (b) of the second trolley from the speed of movement. 1 - spring central suspension; 2 - spring suspension with electromechanical shock absorber

the spring and electromechanical suspension shock absorber is in the whole range of speeds 40.4-37.7%, and for - 40.5-33.8%.

The value of the coefficients of dynamics in the central stage with air suspension $K_{dc1,2}$ (Fig. 4) is less by 31.8-34.9% compared to the spring suspension, and for the coefficient of dynamics $K_{dc3,4}$ - by 32.6-30.5% .

The coefficients of dynamics in the axle box stage of spring suspension K_{db1-8} (Fig. 7, Fig. 8) with the same designs of this stage for carts with spring spring suspension and spring suspension with electromechanical shock absorber in this speed range, differ little and, as can be seen from the graphs, do not exceed the permissible value $[K_{db}]$ = 0.35 (except $K_{db3.4}$ for spring central suspension).

According to the results of modeling the operation of the spring suspension with an electromechanical shock absorber, the average power generated by the shock absorber depending on the speed for random irregularity is determined (Fig. 9).

The average power of an electromechanical shock absorber when excited by a random roughness is much greater than with a sinusoidal roughness given in [12], which is due to the higher values of random accelerations and velocities that it dampens. Yes, the average power at speed 100 km/h is 189 watts, and at 60 km/h - 46 watts.

The results were obtained when the value of the variance of the equivalent geometric-irregularity of the rail path of the subway tunnel is 13.01 mm².

Thus, the results of the calculations should be used for subway cars with spring suspension based on electromechanical shock absorbers.

The method of determining the maximum values of dynamic forces in the elements of the spring suspension, displacements and accelerations of the pivot points of the body on the average value of their absolute maximum is more correct than estimating the value of $3S_q$. This is due to the fact that the value depends on such important characteristics of the random process $q(t)$ as t_p and f_e, and the values of the three standard deviations are clearly not affected by these characteristics.
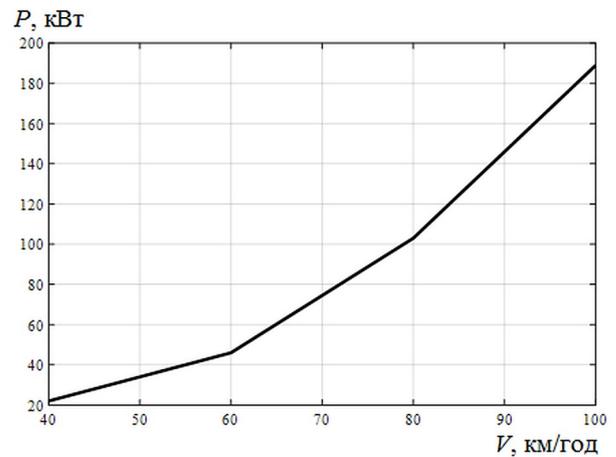

Fig. 9. Graphs of the dependences of the average generated power on the speed of motion at a random excitation irregularity

The presented methods and results of calculation of indicators of dynamic quality of spring suspension of a running gear of the subway car with electromechanical shock-absorbers allow to receive criteria of efficiency of work of shock-absorbers at various modes.

6. Conclusions

1. A method for the synthesis of random forced vertical oscillations of a dynamic model of a subway car, based on sliding summation and taking into account the power spectral density obtained by processing the test results of a subway car model 81.717, is adapted and applied.
2. The technique on definition of indicators of dynamic quality of the metro car with electromechanical shock-absorbers which

is based on modeling of processes of movement of the subway car on a section of a way with casual roughness and definition, by results of modeling, indicators of dynamic quality is created.

3. The study of forced random oscillations of the dynamic model of the subway car showed that the spring suspension based on electromechanical shock absorbers has a significant advantage over the central spring suspension for all quality indicators in the entire range of speeds. It is proposed to conduct a comparative analysis in the range of speeds from 40 to 100 km/h.

4. The dependence of the average power generated by the electromechanical shock absorber at different speeds is established. It is noted that, unlike air suspension, the electromechanical shock absorber not only does not require additional losses for the operation of the compressor, but also generates electricity. Therefore, analyzing the results of the calculations, it is recommended to use them for the design of a subway car with spring suspension based on electromechanical shock absorbers.

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