THE AMPLITUDE-FREQUENCY CHARACTERISTICS OF ACCELERATION OF THE SUSPENSION OF A RAILWAY VEHICLE

Abstract.
Over the last years in Kazakhstan the problem of passenger transport, concerning the moral depreciation of passenger cars, 40% of which are being used for more than 30 years, has blown up. Therefore, the road administration had to obtain the rolling-stock of light-weight type, such as “Tolgo Pendular” firm (Spain).
Currently, the pilot runs of “Tolgo” designed for high-speed traffic along the normal railway between Almaty and Nur-Sultan, are carried out. At the same lime, the construction of cars of a new type gives rise for a number of questions.

Key words: amplitude-frequency, rigidity, hopping, freight car, difference of track.

Introduction.
It is known that the accelerations of the car body are one of the basic characteristics, by which the smoothness of the car movement is determined as well as its dynamic qualities are assessed. The level of comfort, as well as the maximum permitted speed for passenger cars and electric train cars, and for freight cars, the security of goods transported, are determined by the characteristics of smoothness of the movement, accepted currently as criteria for assessment. In this connection it is extremely important to know how the parameters of the suspension, that is the rigidity and resistance of the damper, influences the module of the amplitude-frequency characteristics of acceleration change.

Materials and Methods.
Using a well-known in the operational calculation dependence /1/ between the second derivative (at zero initial conditions) and the presentation of the function, we may write the following

for the galloping movement

\[
\ddot{O}(S) = S^2 \theta(S)
\]

(1)

for the hopping fluctuations

\[
\ddot{Z}(S) = S^2 Z(S)
\]

(2)"
The transfer functions of acceleration of fluctuations of the suspended masses are the ratio of the transformations of Laplas of the accelerations of the fluctuation process to the transformations of Laplas of the influence of the surface irregularity of the track.

Consequently, to obtain the expression for the transfer functions of acceleration it would be sufficient to divide (1) and (2) to the presentation of the function of influence of the irregularities. In this case we have

\[ W_0(S) = S^2 W_\theta(S) \]  
\[ W_2(S) = S^2 W_Z(S) \]

Setting up the values of \( W_\theta(S) \) and \( W_Z(S) \) we would have:

for the galloping fluctuations

\[ W_0(S) = \frac{\xi s^3 + \kappa s^2}{2 J_y s^2 + b_{21}s + b_{20}} \]  

for the hopping fluctuations

\[ W_2(S) = \frac{v s^3 + \kappa s^2}{2 m_k s^2 + a_{11}s + a_{10}} \]

The expressions for the amplitude-frequency characteristics of acceleration can be found by using the transfer functions by substitution of \( s = i\omega \) into them

\[ W_0(i\omega) = \frac{\xi}{2 J_y} \frac{-(\omega^2 + ik\omega^3)}{(b_{20}-\omega^2)+i\omega b_{21}} \]  
\[ W_2(i\omega) = \frac{v}{2 m_k} \frac{-(\omega^2 + ik\omega^3)}{(a_{10}-\omega^2)+i\omega a_{11}} \]

Since, for the establishing of static characteristics of acceleration of fluctuations it is necessary to know the amplitude-frequency characteristics, these dependencies can be obtained from the equations (7) and (8):

for the galloping fluctuations

\[ |W_0(i\omega)| = \frac{\xi}{2 J_y} \sqrt{\frac{k^2\omega^6 + \kappa^2\omega^4}{(b_{20}-\omega^2)^2 + b_{21}^2\omega^2}} \]  

for the hopping fluctuations

\[ |W_2(i\omega)| = \frac{v}{2 m_k} \sqrt{\frac{k^2\omega^6 + \kappa^2\omega^4}{(a_{10}-\omega^2)^2 + a_{11}^2\omega^2}} \]
Using the equations (9) and (10) we can analyze the influence of such parameters of the car. as the rigidity and resistance of the damper of fluctuations of suspension, moment of inertia of the body, masses of suspended elements of the car, bogie base, car base, to the value of the module of the amplitude-frequency characteristics.

Let us consider how the change of rigidity of the suspension set influences the value of the module of the amplitude frequency characteristics of acceleration of galloping fluctuations at the example of the freight car.

Setting up \( m \) series the values of the frequency \( \omega \), for different values of the rigidity, we shall determine the value of \( |W_0(i\omega)| \) according to the formula (9), setting up beforehand the expression (9) as a product of the factor of non-simultaneous influence of \( \xi \) to the multiplier \( A_0(i\omega) \).

\[
A_0(i\omega) = \frac{1}{2jy} \sqrt{\frac{k^2\omega^6 + \omega^2 u^2}{(b_{20} - \omega^2)^2 + b_{21}^2\omega^2}}
\]

(11)

It is advisable to determine the value of \( \xi \) from the graph, presented on Fig. 1/2.

![Graph](image)

Figure 1 - Dependence of the factor of non-simultaneous influence of the track irregularities to different wheels of the car. from the frequency: 1, 2, 3, 4, 5 - at the speed 10, 20, 30, 40, and 50 km/sec, respectively

**Results and Discussion.**

The received results of calculation show, that with the increase of the rigidity of suspension, the amplitude frequency characteristics of acceleration also increase and have two maximums (peaks): first - when the frequency is approximating the own frequency of fluctuation; second - when the frequency depends on the factor of non-simultaneous influence. This maximum depends on the speed of movement. If the speed increases a shift of the second maximum towards the higher frequencies is taking place.
When the first maximum fits the second maximum (i.e., the values of these maximums become the same) sharp growth of the amplitude-frequency characteristics of acceleration is taking place; in this case the speed, corresponding to this frequency, is called "critical". By the way of analyzing of expression (11) we can trace how the value of resistance of damper influences the module of the amplitude-frequency characteristics of acceleration. To this end let us accept the rigidity of the suspension set at 400 t/m, and the resistance of the fluctuation damper - 1; 2.5; 5 t*m*s⁻¹. The graph 2 presents the character of change of the multiplier $A_0(i\omega)$ of the amplitude frequency characteristics at the different values of the resistance of the fluctuation damper. This graph shows that with the increase of the resistance, the amplitude-frequency characteristics of acceleration in pre-resonance zone does not actually change. In the resonance zone the highest amplitude decreases substantially, while in the post resonance zone it increases noticeably.

In order to follow up how the speed of movement influences the value and character of change of the amplitude frequency characteristics, it is sufficient to multiply the results of the function $A_0(i\omega)$ by the factor $\xi$ which in turn depends on the speed.

As a result, we have that the zone of the amplitude-frequency characteristics of acceleration enlarges, while the maximum of its value shifts to some degree towards a higher frequency.

**Conclusion.**

Taking into account the above stated we can make the following conclusions: 1. The values of amplitude-frequency characteristics of the forced fluctuations of the suspended masses of the car sufficiently depends on the rigidity of the suspension and the degree of damping. 2. With the increase of the rigidity at the same degree of damping the highest value of the amplitude-frequency characteristics increases and shifts towards the zone of higher frequencies. 3. The change of the resistance of dampers with constant rigidity results in the decrease of the maximum value of the
amplitude-frequency characteristics of fluctuations (in resonance zone) and actually does not influence the frequency of the forced fluctuations.

4. By setting up the predetermined values of the amplitude-frequency characteristics one can determine to what degree the value of the resistance of the fluctuation damper should be lesser than that of the flexible suspension compared to more rigid suspension.

5. The amplitude-frequency characteristics of fluctuations at the predetermined values of rigidity and the resistance of the damper reach the highest value at the “critical” speed of movement, at which the coincidences of the frequencies of the maximum factor of non-simultaneous influence of the irregularities of the track to the different wheels and frequencies of the maximum of the amplitude-frequency characteristics of fluctuations are observed.

6. In case of irregularities were observed on a large distance along the track, as well as of the lower frequency of these irregularities within the range of the operational speed of movement, it would be more reasonable to apply the less flexible suspension with higher rigidity.

7. To ensure a certain predetermined level of the amplitude-frequency characteristics of fluctuations of the suspended masses in case of short and long irregularities of the track, it is necessary to have variable characteristics of the suspension parameters.

REFERENCES


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