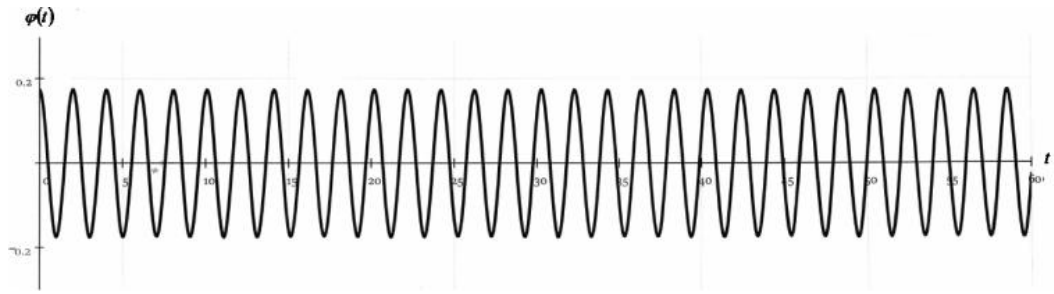

b

Fig. 2. Curves of the angle of rotation $\varphi(t)$

It should be noted that for $l < 0{,}25m,$ the period of oscillation of the rotation angle increases, and for $l > 0{,}25m$ the period decreases.

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LONGITUDINAL OSCILLATION OF THE RAIL DURING RAILWAY COMPOSITION MOVEMENT

Kali Sultan

sultikcray@gmail.com

Eurasian National University named after L.N.Gumilyev

Supervisor - Ibrayev A.G., Doctor of Physical and Mathematical Sciences, Professor, ENU named after L.N. Gumilev

Annotation. The article investigates longitudinal wave processes in the rail under the influence of two mobile loads.

Key words: longitudinal oscillation, railway train, auto- coupling device.

1.Introduction

Most of the well-known works devoted to longitudinal vibrations occurring in a train solve problems mainly of unsteady longitudinal vibrations characteristic of transient conditions and special conditions of train movement and the influence of these vibrations on the realization of the traction force of the traction rolling stock. At the same time, in the process of train movement under the influence of constant or slowly changing forces, the regime of stationary longitudinal vibrations occurring in the train is established. In stationary fluctuations, the forces arising in the shock-traction devices (automatic coupler devices) are determined only by the applied external forces and are independent of the initial conditions. In this work, we study the longitudinal vibrations occurring in the composition and the influence of the longitudinal vibrations of the locomotive on these vibrations. In this case, the force arising between the electric locomotive and the train is external to the composition of the cars.

In this work, a train moving rectilinearly and uniformly with speed V (Figure 1) is presented as a system consisting of the same type of four-axle cars of the same mass and an electric locomotive, interconnected in the longitudinal (along the path) direction by elastic-dissipative bonds with a certain force characteristic. The last carriage joins a part of the infinitely large mass. Each car has one degree of freedom - movement along the path [1].

2. Discussion

A characteristic feature of the considered electric locomotive is the use on it as a longitudinal connection of the bogies with the body of inclined rods (Fig. 1). The design scheme contains a body, trolley frames, wheelsets, traction motors with supporting frame suspension with the corresponding masses and moments of inertia relative to the central horizontal transverse axes of inertia. To achieve this goal, this study takes into account the vibrational movements of the crew, forming longitudinal vibrations of the electric locomotive, which avoids the influence of secondary factors on the results.

Based on this, to simulate crew vibrations in the vertical longitudinal plane that occur when moving along uneven paths $\eta(t)$, the following coordinates are taken as generalized coordinates: jerking $x_к$, bouncing $z_к$, galloping $\phi_к$ of the body; jerking $x_{T,i}$, bouncing $z_{T,i}$, galloping $\phi_{T,i}$ frames of bogies; twitching $x_{кп,j}$, bouncing $z_{кп,j}$, turning the wheelsets $\phi_{кп,j}$; gearbox turns $\phi_{p,j}$; turns $\phi_{я,j}$ of the anchors of electric motors around the axes passing through their centers of mass, where $i=1,...,3$ is the number of the cart; $j=1,...,6$ - the number of the wheelset (Fig. 1). It should be emphasized that, within the framework of the considered design scheme, perturbation from the side of the track acting in the vertical direction is also a cause of longitudinal vibrations and longitudinal forces acting in automatic coupler devices of an electric locomotive and wagons.

A detailed consideration and consideration of the influence of fluctuations in the elements of the locomotive's carriage distinguishes the present work from, for example, [2], and the accounting of a train consisting of cars from, for example, [3].

The expression necessary for determining the dynamic forces T in an inclined link for deformation of an inclined link $\Delta_{нш}$, calculated as the difference between the projections on the longitudinal axis of the inclined link, of the displacements of its attachment points to the trolley frame and the body, for an inclined

the traction located in front of the trolley will be as follows:

$$\Delta_{нш} = (z_к - \phi_к L)\sin\gamma + (x_к + \phi_к H)\cos\gamma - (z_T - \phi_T l)\sin\gamma - (x_T + \phi_T h)\cos\gamma, \qquad (1)$$

where γ is the angle of inclination to the horizontal of the inclined thrust; l, h, L, H - the coordinates along the *x* and *z* axes of the points of attachment of the inclined thrust to the trolley and the body, respectively, in the longitudinal and vertical directions in coordinate systems associated with the trolley frame and the body, respectively, as shown in Figure 1.

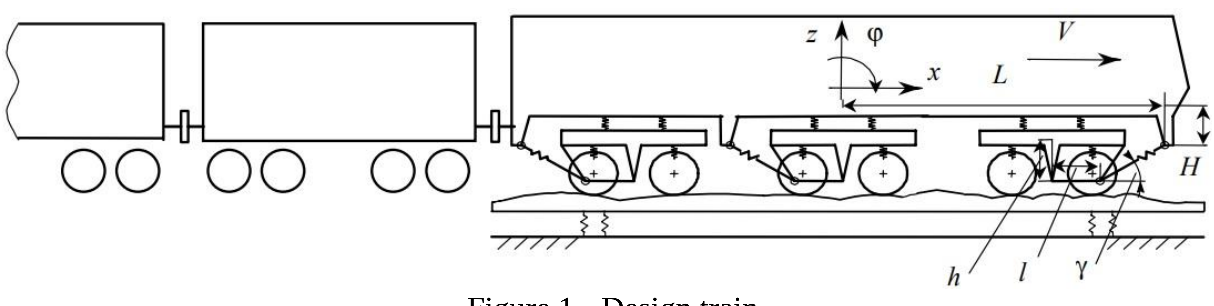

Figure 1 - Design train

Using formula (1), we write the expressions for calculating the quantities that make up the deformation of the elastic block of inclined traction from vibrations:

– bodywork $\Delta_\kappa = x_\kappa \cos\gamma + \phi_\kappa (H\cos\gamma - L\sin\gamma) + z_\kappa \sin\gamma,$ (2)

– trolleys $\Delta_T = -x_T \cos\gamma - \phi_T (h\cos\gamma - l\sin\gamma) - z_T \sin\gamma.$ (3)

The forces in the longitudinal bonds between the moving units in the train were determined by the experimentally obtained power characteristic, which for two series-connected automatic coupler devices (ACD) during loading and unloading is shown in Figure 2. In this case, the stiffness during loading is 13.600 MN / m, during unloading - 4.375 MN / m, structural rigidity (transition from loading to unloading and vice versa) - 100 MN / m. Due to the non-linear characteristics of the AC, the initial position of the cars and the electric locomotive is ambiguously determined. Therefore, in the calculations, for a given traction force of the electric locomotive F_T, the initial position x_T of each moving unit in the train was determined in advance from the following conditions: first, the initial operating point (point O, see Fig. 2) is on the line characterizing the rigidity of the structure, second, the segments Oa and Ob are equal (see Fig. 2). We believe that the resistance to the movement of cars is close to zero and therefore the cars are in the same initial position.

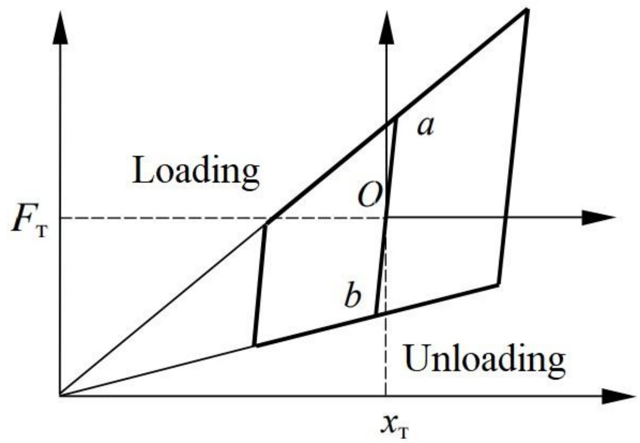

Figure 2

Random perturbation on the path side was set in the form of an equivalent geometric unevenness.

Calculations on a personal computer were carried out with geometric, mass, elastic and dissipative crew parameters close to an electric locomotive of the VL65 type with a traction drive of the second class. The stiffness of the elastic block of inclined rods connecting the bogie with the body is taken to be cnt = 8 MN / m. For each speed, the traction force of one truck was set: 80 km / h - 40 kN, 100 km / h - 30 kN, 120 km / h - 20 kN.

At the first stage, calculations were performed in which only longitudinal vibrations of one (first) bogie, the body of an electric locomotive and wagons were modeled (other vibrations were excluded from consideration by setting the corresponding parameters). The power characteristic of the ACD was assumed linear with a stiffness coefficient c_κ = 100 MN / m. For the crew representing one carriage (the body is stationary), the frequency of its twitching was 2.9 Hz - this is the natural frequency of the longitudinal movements of the carriage. For movable carts and bodies, but excluding wagon vibrations, jerking frequencies were obtained equal to 2.8 and 6.5 Hz. For an electric locomotive and one car, these frequencies were 2.6–2.8 and 4.5 Hz. From calculation to calculation, the number of cars connected to an electric locomotive increased in one to ten. At the same time, the number of ranges of observed frequencies and waveforms also increased. The results began to repeat.

Based on this, we can conclude that when performing calculations in the calculation scheme, the number of cars can be limited to ten [5].

Next, calculations were performed according to the full design schemes (taking into account bouncing, galloping and other vibrations of the elements of the electric locomotive) for two options: the first - the electric locomotive was connected to the train with an infinitely large mass through the AU, i.e. wagons do not commit vibrations; the second is an electric locomotive and a train of ten cars (the last car is connected to an infinitely large train). Based on the fact that a stationary random disturbance is applied to the model input, to ensure the necessary reliability of the results obtained, the level of dynamic processes is estimated by averaging the results over twenty-five realizations with a duration of at least 15 s each, as is customary when conducting full-scale running tests of rolling stock.

Figure 3 shows the spectral densities (SD) of the dynamic forces in an automatic coupler of an electric locomotive for a speed of 100 km / h (subsequent figures also for a speed of 100 km / h). It can be seen that the frequency composition of the processes is almost the same for both options. The intensity of the forces in the automatic coupler for the version without cars is higher than in the version with the train, which is quite understandable by the dispersion of energy in the ACD between the cars. Moreover, for the train variant, the greatest forces are observed in the ACD connecting the electric locomotive and the first car.

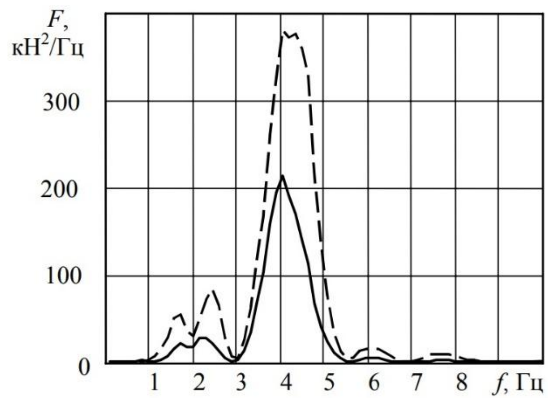

Figure 3 - Spectral densities of dynamic forces of an automatic coupler of an electric locomotive: in a variant with a train of ten wagons;

The spectral densities of the dynamic forces in the inclined rods of the carts of an electric locomotive are almost the same for both versions of the design scheme. That is, the connection of cars did not affect the level of forces in inclined traction.

Numerous works have been devoted to the problem of modeling the interaction of a wheel and a rail during rolling, which is associated with its acute relevance. The longitudinal and transverse creep curves constructed from the experimental data of various authors can significantly differ from each other quantitatively, especially in the area where the dependence of the relative tangential force on the relative slip velocity is non-linear. This is primarily due to the fact that in experiments both longitudinal and transverse creeps are simultaneously manifested, the separation of which is a difficult task. In addition, the differences are explained by the presence of roughness and contamination on the surfaces of the wheel and rail. The properties of pollution can vary significantly during the day, year, and depend on weather, climatic conditions, temperature, implemented in the contact "wheel-rail", and a number of other factors [4].

In existing models of the interaction of the track and rolling stock, the tribological state of the surfaces of the rails and wheels is characterized only by the coefficient of friction of the sliding of the wheel along the rail, which affects the value of the maximum absolute value of the tangential force in the contact.

Conclusion

Thus, when studying the oscillations of an electric locomotive in a longitudinal vertical plane for the parameters of the crew adopted in this work, a scheme can be used in which the electric locomotive in the longitudinal direction is connected with a motionless train of infinitely large mass. To study the processes indicated in this work in a train, it is necessary to consider a more detailed scheme (it is quite enough to take into account the train of ten cars) and, if the parameters of the crew part are changed, control the possible mutual influence of the oscillations of the locomotive and the cars.

In conclusion, we can draw the following conclusion: since dynamic forces in inclined traction are formed mainly by vibrations of bogies, these forces cannot have a noticeable effect on the level of dynamic forces in couplers and, therefore, significantly affect the intensity of longitudinal vibrations of cars.

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ӘОК 532.01

ҚҰЙЫНДЫ ГИДРОЭЛЕВАТОРДЫҢ АРАЛАСУ КАМЕРАСЫН ЕСЕПТЕУ

Қабдір Шалқар, Қыдырсиық Руслан
shalkarabdir@mail.ru
Л.Н.Гумилев атындағы ЕҰУ механика-математика факультетінің 4-курс студенттері,
Нұр-Сұлтан, Қазақстан
Ғылыми жетекшісі – Қасабеков М.И.

Эйлер теоремасы тура ағынды ақпалар есебін қарастырғанда жақсы нәтижелер берді. Ал бұралған ақпалардың сипаттамаларын анықтағанда Эйлердің тұтас орта үшін жазылған қозғалыс мөлшерінің өзгеруі туралы теореманы қолдануға болмайды. Себебі қозғалыс мөлшері материалық жүйенің масса центрі мен бірге ілгерімелі қозғалысын ғана сипаттайтын мәлім.

Сондықтан, төменде кинетикалық энергияның өзгеруі туралы теореманы тұтас орта үшін қолдану ерекшеліктері қарастырылады. Материялық жүйенің кинетикалық энергиясының өзгеруі туралы теореманың шектелген түрін алайық [1,2],

$$T_2 - T_1 = \Sigma A_i^E \tag{1}$$