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FUNDAMENTAL AND APPLIED RESEARCH IN THE MODERN WORLD

ABSTRACTS OF V INTERNATIONAL SCIENTIFIC AND PRACTICAL CONFERENCE DECEMBER 16-18, 2020

BOSTON
2020

FUNDAMENTAL AND APPLIED RESEARCH IN THE MODERN WORLD

Abstracts of V International Scientific and Practical Conference

Boston, USA

16-18 December 2020

Boston, USA

2020

UDC 001.1

The 5th International scientific and practical conference "Fundamental and applied research in the modern world" (December 16-18, 2020) BoScience Publisher, Boston, USA. 2020. 822 p.

ISBN 978-1-73981-124-2

The recommended citation for this publication is:

Ivanov I. Analysis of the phaunistic composition of Ukraine // Fundamental and applied research in the modern world. Abstracts of the 5th International scientific and practical conference. BoScience Publisher. Boston, USA. 2020. Pp. 21-27. URL: https://sci-conf.com.ua/v-mezhdunarodnaya-nauchno-prakticheskaya-konferentsiya-fundamental-and-applied-research-in-the-modern-world-16-18-dekabrya-2020-goda-boston-ssha-arhiv/.

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UDC 631.374.02

INVESTIGATION OF SMALL OSCILLATIONS OF A TWO-AXLE TRAILER

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Abstract: The conditions of stable movement of a tractor train and the factors influencing the nature of oscillating movement of trailers are analyzed. The location of the cargo on the platform and the speed of the tractor train have a significant impact on the nature of the oscillating motion of trailers. These performance factors cannot be chosen arbitrarily, they must be coordinated with other parameters of the trailer.

Keywords: stability of movement, tractor train, two-axle trailer, drag coefficient.

Introduction. Sugar beet in Ukraine is one of the main crops of agricultural production. The quality of sugar beet harvesting is largely determined by ensuring the synchronicity of the beet harvester and transport unit. When used as a transport unit

of a wheeled tractor with a trailer, the synchronicity of the beet harvesting complex is reduced by different loading of the trailer.

The purpose and statement of the problem. The purpose of research is to define conditions of controllability of the wheeled tractor with the trailer at joint work with the beet harvester.

Solving the research problem. To study small oscillations (swaying) of a two-axle trailer, we use a flat calculation model (Fig. 1), which is developed on the basis of the model of a two-axle trailer proposed in the work.

Assume that the tractor moves at a constant speed ν on a flat horizontal surface, its coupling has a stiffness c and damping with a coefficient of resistance *k*.

On the trailer at oscillations the transverse forces of elasticity sγA and damper-wool $k\dot{\gamma}_A$ in the coupling device of a tractor act; side reactions from the road on the wheels of the front $P_{б1}$ and rear P_{j2} axles; the resistance of the front P_{f1} and rear P_{f2} axles of the trailer; the moment of friction in the turning circle M_T and the moments of resistance to turning the wheels of the front M_{c1} and rear M_{c2} axles of the trailer.

The hitch point A moves in the transverse direction γA, the front of the trailer oscillates relative to the hitch point and deviates from the direction parallel to the longitudinal axis of the tractor, at an angle γ_1. The rear of the trailer oscillates relative to the middle of the front axle and deviates from the longitudinal axis of the front by an angle γ_2. While the rear of the trailer deviates by an angle γ_2, its longitudinal axis forms an angle γ with a direction parallel to the longitudinal axis of the tractor, which is equal to the sum of the angles γ_1 and γ_2, i.e. $\gamma = \gamma_1 + \gamma_2$.

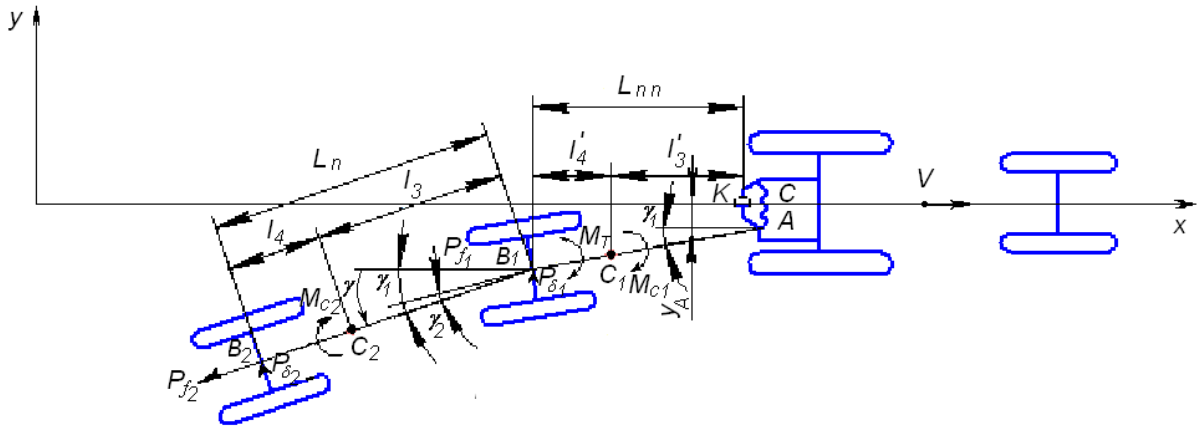

Fig. 1. Scheme for the study of small oscillations of a two-axle trailer

Consider the small oscillations of the trailer. In this case, the sines of the angles γ_1 and γ_2 are equal to their arguments, and the cosines of the same angles are equal to one. The moments of resistance to rotation of the wheels of the front and rear axles of the trailer with small oscillations are insignificant, they can be neglected. The lateral forces acting on the wheels of one axle can be considered the same and replace them with the total force applied in the middle of each axle. To compose the equation of oscillating motion of a two-axle trailer in the form of Lagrange equations of the second kind, we write an expression for the kinetic energy:

$T = 0{,}5(m_1 y_{c1}^2 + m_2 y_{c2}^2 + J_1 \gamma_1^2 + J_2 \gamma^2)$;

potential energy: $E_p = 0{,}5cy^2{}_A$;

scattering functions: $R = 0{,}5ky^2{}_A$;

generalized force on the coordinate in y:

$$Q_y = P_{f1} \sin\gamma_1 + P_{f2} \sin\gamma_1 + P_{б1} \cos\gamma_1 - P_{б2} \cos\gamma_2 \approx$$

$$\approx (P_{f1} + P_{f2})\gamma_1 + P_{f2}\gamma_2 - P_{б1} - \mathrm{P}_{б2};$$

generalized force on the coordinate γ_1:

$$Q_{\gamma 1} = -P_{б1} L_{пп} - P_{б2}(L_п + L_{пп} \cos\gamma_2) + P_{f2} L_{пп} \sin\gamma_2 \approx$$

$$\approx -P_{б1} L_{пп} - P_{б2}(L_п + L_{пп}) + P_{f2} L_{пп} \gamma_2;$$

generalized force on the coordinate γ_2: $Q_{\gamma 2} = -P_{б2} L_п - \mathrm{M}_т sign\, \gamma_2$.

Determine the transverse displacement of the center of mass of the front and rear parts of the trailer with transverse oscillations of the coupling point and angular oscillations of the trailer. Displacement of the centers of mass, respectively, the front and rear of the trailer

$$\mathrm{y}_{c1} = \mathrm{y}_A + l_3' \sin\gamma_1 \approx \mathrm{y}_A + l_3' \gamma;$$

$$\mathrm{y}_{c2} = \mathrm{y}_A + L_{пп} \sin\gamma_1 + l_3 \sin\gamma \approx \mathrm{y}_A + (L_{пп} + l_3)\gamma_1 + l_3\gamma_2.$$

Taking the derivatives of these expressions, we obtain the corresponding rates of transverse shear of the centers of mass of the trailer

$$\dot{\mathrm{y}}_{c1} = \dot{\mathrm{y}}_A + l_3'\gamma_2;$$

$$\dot{y}_{c2} = \dot{y}_A + (L_{пп} + l_3)\dot{\gamma}_1 + l_3\gamma_2.$$

We present the expression for the transverse displacements and velocities of the front and rear parts of the trailer when it oscillates into expressions for the kinetic and potential energy and scattering functions. Taking into account the expressions for the generalized forces at the corresponding coordinates, we take the corresponding derivatives from the expressions for the kinetic and potential energies and scattering functions and obtain a system of equations describing small oscillations of a two-axle trailer.

$$(m_1 + m_2)\ddot{y}_A + [m_1 l_3' + m_2(L_{\text{пп}} + l_3)]\ddot{\gamma}_1 + m_2 l_3 \ddot{\gamma}_2 = -c_A - k\dot{\gamma}_A - P_{\delta 1} - P_{\delta 2} + (P_{f1} + P_{f2})\gamma_1 + P_{\delta 2}\gamma_2;$$

$$[m_1 l_3' + m_2(L_{\text{пп}} + l_3)]\ddot{y}_A + [m_1(l_3')^2 + m_2(L_{\text{пп}} + l_3) + J_1 + J_2]\ddot{\gamma}_1 + [m_2 l_3(L_{\text{пп}} + l_3) + J_2]\ddot{\gamma}_2 = -P_{\delta 1} L_{\text{пп}} - P_{\delta 2}(L_{\text{п}} + l_{\text{пп}}) + P_{f2} L_{\text{пп}} \gamma_2; \quad (1)$$

$$m_2 l_3 \ddot{y}_A + [m_2 l_3(L_{\text{пп}} + l_3) + J_2]\ddot{\gamma}_2 + [m_2(l_3')^2 + J_2]\ddot{\gamma}_2 = -P_{\delta 2} L_{\text{п}} - M_T sign\ \dot{\gamma}_2.$$

The system of equations (1) is indefinite, because in three equations there are 5 unknowns: y_A,γ_1,γ_2,$P_{б1}$,$P_{б2}$. the missing two equations are obtained from the equations of nonholonomic connections for the front and rear axles of the trailer, composed of the condition of no lateral movement of the axles in directions normal to the directions of absolute velocities of the front ν_1 and rear ν_2 axles. The lateral forces acting on the axis of the trailer can be represented as the product of the coefficient of resistance to the diversion of the axis to the angle of diversion.

In the auxiliary coordinate system x_2 B_2 y_2 (Fig. 2) the angle of the rear axle is negative; then

$$\delta_2 = \frac{\dot{y}_A + L_{\text{пп}}\dot{\gamma}_1 + L_{\text{п}}(\dot{\gamma}_1 + \dot{\gamma}_2) + v(\dot{\gamma}_1 + \dot{\gamma}_2)}{v + L_{\text{пп}}\dot{\gamma}_1\gamma_2 - \dot{y}_A(\dot{\gamma}_1 + \dot{\gamma}_2)} \quad (2)$$

The system of equations (1) and (2), which describes the oscillations of a two-axle trailer, is defined because five unknowns correspond to five equations. Solving the system, we determine the parameters that characterize the oscillating motion of a two-axle trailer, the changes in which can be judged on the stability of its movement.

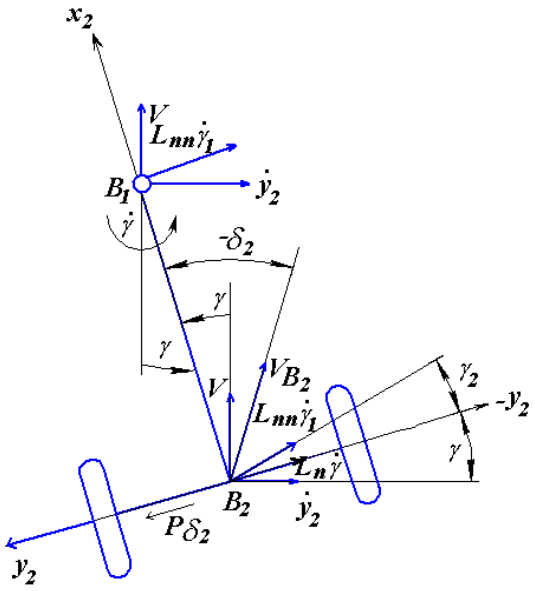

Fig. 2. Diagram for determining the angle of diversion of the rear axle of a two-axle trailer through generalized speeds.

Find the conditions for stable movement of the rear axle of the two-axle trailer relative to the front, moving steadily. The equation of motion of the rear axle of the trailer has the form

$$[m_2 l_3^2 + J_2]\ddot{\gamma} = -P_{б2} L_{п} - M_T.$$

Given $P_{б2}$=$k_{y2}\delta_2$, and in expression (2) with a constant rectilinear motion of the front axle of the trailer$\dot{y}_A = 0$, $\dot{\gamma}_1 = 0$ и $\dot{\gamma}_2 = 0$, the original equation will take the form

$$(m_2 l_3^2 + J_2)\ddot{\gamma} + \frac{k_{y2} L_{п}^2}{v} + \frac{k_{y2} L_{п}^2}{y_2} = -M_T \qquad (3)$$

The natural frequency of the system is found using the characteristic equation

$$(m_2 l_3^2 + J_2)\lambda_2 + \frac{k_{y2}\lambda L_{п}^2}{v} + k_{y2} L_{п}^2 = 0$$

So,

$$\lambda = \frac{-\frac{k_{y2} L_{п}^2}{v} \pm [(\frac{k_{y2} L_{п}^2}{v})^2 - 4k_{y2} L_{п}^2 (m_2 l_3^2 + J_2)]^{-2}}{2(m_2 l_3^2 + J_2)}$$

The solution of equation (3) is stable if the values of λ are real and negative or complex with a negative real part. Since the first term of the numerator is always negative when the tractor train is moving forward (v> 0), the root expression must be

positive to fulfill the specified requirement of stable movement of the rear part of the two-axle trailer:

$$\lambda = \frac{-\frac{k_{y2}L_{\text{п}}^2}{v} \pm [(\frac{k_{y2}L_{\text{п}}^2}{v})^2 - 4k_{y2}L_{\text{п}}^2(m_2 l_3^2 + J_2)]^{-2}}{2(m_2 l_3^2 + J_2)}.$$

The critical speed of the rear of the trailer, which has the following parameters: weight = 5189,5 kg; the moment of inertia of the rear part of the trailer relative to the vertical axis passing through its center of mass $J_2 = 11674\ \text{kg} \cdot m^2$; Thus, the front part of the two-axle trailer moving behind the tractor at a speed of 8.4 m/s will have a stable movement, and the rear part is unstable. , since, and the trailer as a whole will have undamped oscillations (fig. 3) $L_{\text{п}} = 2{,}5\ m\ \ l_3 = 1{,}3\ m$, To keep the two-axle trailer steady, increase the drag on its rear axle to 370 kN/rad by increasing the air pressure in the rear tires, fitting twin wheels on the rear axle or placing the load so that the center of mass of the rear of the trailer is closer to the front. axis.

Thus, l_3 = 0,5 m and the old values of the trailer parameters, the critical speed is $v_{кр} = 5{,}3$ m/s.

The moment of friction in the rotary wheel of the M_T also significantly affects the oscillations of the two-axle trailer. With increasing torque M_T decreases the amplitude of angular oscillations of the front and rear of the trailer. Its rational value for each case can be chosen by solving the system of equations (1).

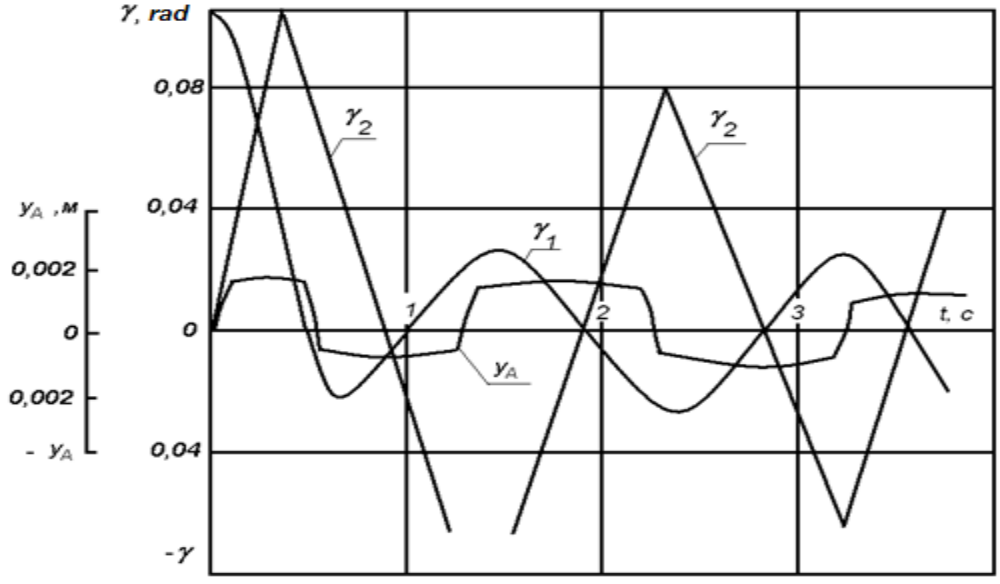

Figure 3– Characteristics of oscillations of a two-axle trailer.

However, at high M_T values, the handling of the two-axle trailer deteriorates.

Conclusion. The stability of the tractor train depends on both the stability of the driven links and the stability of the leading link-tractor. Therefore, considering the movement of the tractor train forward ($v > 0$) at a constant speed, we obtained the conditions for stable movement of the driven links. Analysis of the conditions of stable movement of trailers shows that the location of the cargo on the platform and the speed of the tractor train have a significant impact on the nature of the oscillating movement of trailers. These performance factors cannot be chosen arbitrarily, they must be coordinated with other parameters of the trailer.

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