UDC 693,546

OPTIMIZATION BOUNDARY CONDITIONS RYVKOVOHO MODE REVERSING ROLLER MOLDING INSTALLATION

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The design roller molding installation with cam drive mechanism and built the cam profile for the combined treatment reciprocating forming trolley with ryvkovym reversing edge under optimal conditions.

Roller forming unit, mode of motion, reverse, boundary conditions, cam, drive.

Formulation of the problem. In installations roller forming concrete products during their work there are significant dynamic loads in elements of the drive mechanism and the elements forming carts[1-6]. Despite the rather extensive study of the process of forming concrete products bezvibratsiynym roller method [13]So far not been investigated dynamics of forming the trolley and its impact on the development. Few paid attention to driving mode and molding cart efforts arising in the elements of the drive mechanism.

Analysis of recent research. The existing theoretical and experimental research machines roller forming concrete products proved their design parameters and performance [1-3]. However, not enough attention is paid to study acting dynamic loads and modes movement, which largely affects the operation of the installation and the quality of the finished product. During the regular puskohalmivnyh modes of movement there are significant dynamic loads in elements of the drive mechanism and the elements forming the trolley, which can lead to premature failure of the installation[1-6]. So important is the task of improving the drive mechanism roller molding installation to ensure this mode of movement forming a trolley in which decreased to dynamic loads in elements of installation and increased durability.

The purpose of research is improving the design of the drive mechanism roller molding installation to improve its reliability and durability by optimizing the boundary conditions reversing the process of forming the cart.

Results. For roller molding installation with earthen advisable to have constant speed reciprocating forming carts throughout the area that would have a positive impact on the quality of the finished product. However, in practice such a regime can not make a motion because it lacks plot acceleration and braking, without which there can be cyclical movement. It is therefore proposed to implement a regime of movement during its formative carts move, which would reverse land with minimal dynamic loads and site traffic at a constant speed. To smooth the process of reversing the molding cart invited to perform at its optimal mode of movement ryvkovym [7]. The rate of acceleration and mold carts vary smoothly without creating significant dynamic loads in the installation, which in turn positively affect its longevity.

Criteria mode motion machines and mechanisms can be uneven rates of movement and dynamism. [7] In this paper as a criterion motion mode used by criteria act which is an integral time of the integrand that expresses the extent of movement or action system.

For ryvkovoho regime optimality criterion reversing motion will have the form:

$$I_W = \int_0^{t_p} W\,dt \to \min \quad (1)$$

where: t - Time; t_p - The duration reversal; W - Energy falls:

$$W = \frac{1}{2}\cdot m\cdot \dddot{x}^2, \quad (2)$$

where: m - Mass forming the trolley; $\dddot{x}$ - Jerk.

The condition of a minimum criterion (1) is a Poisson equation:

$$\frac{\partial W}{\partial x} - \frac{d}{dt}\frac{\partial W}{\partial \dot{x}} + \frac{d^2}{dt^2}\frac{\partial W}{\partial \ddot{x}} - \frac{d^3}{dt^3}\frac{\partial W}{\partial \dddot{x}} = 0 \text{ And } (3)$$

where: x, $\dot{x}$, $\ddot{x}$ - Coordinate displacement, velocity and acceleration of the cart.

From the expression (3) can be written:

$$\frac{\partial W}{\partial x} = \frac{\partial W}{\partial \dot{x}} = \frac{\partial W}{\partial \ddot{x}} = 0;\ \frac{\partial W}{\partial \dddot{x}} = m\cdot \dddot{x};\ \frac{d^3}{dt^3}\frac{\partial W}{\partial \dddot{x}} = m\cdot \overset{VI}{x} = 0. \quad (4)$$

From the last equation (4) we obtain the differential equation and its solutions:

$$\overset{VI}{x} = 0;\quad \overset{V}{x} = C_1;\quad \overset{IV}{x} = C_1\cdot t + C_2;\quad \dddot{x} = \frac{1}{2}\cdot C_1\cdot t^2 + C_2\cdot t + C_3;$$

$$\ddot{x} = \frac{1}{6}\cdot C_1\cdot t^3 + \frac{1}{2}\cdot C_2\cdot t^2 + C_3\cdot t + C_4;\quad \dot{x} = \frac{1}{24}\cdot C_1\cdot t^4 + \frac{1}{6}\cdot C_2\cdot t^3 + \frac{1}{2}\cdot C_3\cdot t^2 + C_4\cdot t + C_5; \quad (5)$$

$$x = \frac{1}{120}\cdot C_1\cdot t^5 + \frac{1}{24}\cdot C_2\cdot t^4 + \frac{1}{6}\cdot C_3\cdot t^3 + \frac{1}{2}\cdot C_4\cdot t^2 + C_5\cdot t + C_6,$$

where: $C_1, C_2, C_3, C_4, C_5, C_6$ - Integration constant, determined from the boundary conditions.

Divide reversing the process into two stages: starting and braking. When braking initial conditions are: $t = 0: x = -x_1; \dot{x} = \dot{x}_y; \ddot{x} = 0$. The final terms of braking: $t = t_г : x = 0\,; \dot{x} = 0\,; \ddot{x} = a$. Here x_1 - Coordinate the start of the braking process; $\dot{x}_y$ - Speed of the trolley to steady state before the braking; a - Speed up the trolley at the end of braking phase. We accept that the movement of the trolley x_1 the two phases are the same, and the acceleration of the trolley at the end of braking phase is accelerating its early start. Then the initial conditions at launch are: $t = 0 : x = 0\,; \dot{x} = 0\,; \ddot{x} = a$. The final conditions at start-up: $t = t_n : x = -x_1\,; \dot{x} = -\dot{x}_y\,; \ddot{x} = 0$. Consider the process of braking. Substituting the boundary conditions Braking in equation (5), we get:

$$t = 0: \quad C_6 = -x_1; \quad C_5 = \dot{x}_y; \quad C_4 = 0; \tag{6}$$

$$t = t_г: \quad \begin{cases} \dfrac{1}{120} \cdot C_1 \cdot t_г^5 + \dfrac{1}{24} \cdot C_2 \cdot t_г^4 + \dfrac{1}{6} \cdot C_3 \cdot t_г^3 + \dot{x}_y \cdot t_г - x_1 = 0; \\ \dfrac{1}{24} \cdot C_1 \cdot t_г^4 + \dfrac{1}{6} \cdot C_2 \cdot t_г^3 + \dfrac{1}{2} \cdot C_3 \cdot t_г^2 + \dot{x}_y = 0; \\ \dfrac{1}{6} \cdot C_1 \cdot t_г^3 + \dfrac{1}{2} \cdot C_2 \cdot t_г^2 + C_3 \cdot t_г = a. \end{cases} \tag{7}$$

Solving the system of equations (7), we get constant integration C_1, C_2 and C_3:

$$C_1 = \frac{60 \cdot \left(12 \cdot \dfrac{x_1}{t_г^2} - 6 \cdot \dfrac{\dot{x}_y}{t_г} + a\right)}{t_г^3}, C_2 = \frac{24 \cdot \left(8 \cdot \dfrac{\dot{x}_y}{t_г} - a - 15 \cdot \dfrac{x_1}{t_г^2}\right)}{t_г^2}, C_3 = \frac{3 \cdot \left(20 \cdot \dfrac{x_1}{t_г^2} - 12 \cdot \dfrac{\dot{x}_y}{t_г} + a\right)}{t_г}. \tag{8}$$

After substituting defined constant of integration (6) and (8) the system (5) we obtain the function changes spurt molding cart in the inhibition of established speed $\dot{x}_y$ to a full stop:

$$\dddot{x} = 30 \cdot \left(12 \cdot \frac{x_1}{t_г^2} - 6 \cdot \frac{\dot{x}_y}{t_г} + a\right) \cdot \frac{t^2}{t_г^3} + 24 \cdot \left(8 \cdot \frac{\dot{x}_y}{t_г} - a - 15 \cdot \frac{x_1}{t_г^2}\right) \cdot \frac{t}{t_г^2} + 3 \cdot \left(20 \cdot \frac{x_1}{t_г^2} - 12 \cdot \frac{\dot{x}_y}{t_г} + a\right) \cdot \frac{1}{t_г}, \tag{9}$$

or

$$\dddot{x} = \frac{3}{t_г} \cdot \left[10 \cdot \left(12 \cdot \frac{x_1}{t_г^2} - 6 \cdot \frac{\dot{x}_y}{t_г} + a\right) \cdot \frac{t^2}{t_г^2} + 8 \cdot \left(8 \cdot \frac{\dot{x}_y}{t_г} - a - 15 \cdot \frac{x_1}{t_г^2}\right) \cdot \frac{t}{t_г} + \left(20 \cdot \frac{x_1}{t_г^2} - 12 \cdot \frac{\dot{x}_y}{t_г} + a\right)\right]. \tag{10}$$

Then optimality criterion movement during braking considering expressions (2) and (10) will be as follows:

$$I_{W\text{г}}=\frac{m}{2}\cdot\int_0^{t_\text{г}}\ddot{x}^2\,dt=\frac{9\cdot m}{2\cdot t_\text{г}^2}\cdot\int_0^{t_\text{г}}\left[\begin{array}{l}10\cdot\left(12\cdot\frac{x_1}{t_\text{г}^2}-6\cdot\frac{\dot{x}_y}{t_\text{г}}+a\right)\cdot\frac{t^2}{t_\text{г}^2}+8\cdot\left(8\cdot\frac{\dot{x}_y}{t_\text{г}}-a-15\cdot\frac{x_1}{t_\text{г}^2}\right)\cdot\frac{t}{t_\text{г}}+\\+\left(20\cdot\frac{x_1}{t_\text{г}^2}-12\cdot\frac{\dot{x}_y}{t_\text{г}}+a\right)\end{array}\right]^2 dt=$$

$$=\frac{9\cdot m}{2\cdot t_\text{г}^2}\cdot\int_0^{t_\text{г}}\left[\begin{array}{l}100\cdot\left(12\cdot\frac{x_1}{t_\text{г}^2}-6\cdot\frac{\dot{x}_y}{t_\text{г}}+a\right)^2\cdot\frac{t^4}{t_\text{г}^4}+64\cdot\left(8\cdot\frac{\dot{x}_y}{t_\text{г}}-a-15\cdot\frac{x_1}{t_\text{г}^2}\right)^2\cdot\frac{t^2}{t_\text{г}^2}+\\+\left(20\cdot\frac{x_1}{t_\text{г}^2}-12\cdot\frac{\dot{x}_y}{t_\text{г}}+a\right)^2+160\cdot\left(12\cdot\frac{x_1}{t_\text{г}^2}-6\cdot\frac{\dot{x}_y}{t_\text{г}}+a\right)\cdot\left(8\cdot\frac{\dot{x}_y}{t_\text{г}}-a-15\cdot\frac{x_1}{t_\text{г}^2}\right)\cdot\frac{t^3}{t_\text{г}^3}+\\+20\cdot\left(12\cdot\frac{x_1}{t_\text{г}^2}-6\cdot\frac{\dot{x}_y}{t_\text{г}}+a\right)\cdot\left(20\cdot\frac{x_1}{t_\text{г}^2}-12\cdot\frac{\dot{x}_y}{t_\text{г}}+a\right)\cdot\frac{t^2}{t_\text{г}^2}+\\+16\cdot\left(8\cdot\frac{\dot{x}_y}{t_\text{г}}-a-15\cdot\frac{x_1}{t_\text{г}^2}\right)\cdot\left(20\cdot\frac{x_1}{t_\text{г}^2}-12\cdot\frac{\dot{x}_y}{t_\text{г}}+a\right)\cdot\frac{t}{t_\text{г}}\end{array}\right]dt=$$

$$=\frac{9\cdot m}{2\cdot t_\text{г}}\cdot\left[\begin{array}{l}20\cdot\left(12\cdot\frac{x_1}{t_\text{г}^2}-6\cdot\frac{\dot{x}_y}{t_\text{г}}+a\right)^2+\frac{64}{3}\cdot\left(8\cdot\frac{\dot{x}_y}{t_\text{г}}-a-15\cdot\frac{x_1}{t_\text{г}^2}\right)^2+\left(20\cdot\frac{x_1}{t_\text{г}^2}-12\cdot\frac{\dot{x}_y}{t_\text{г}}+a\right)^2+\\+40\cdot\left(186\cdot\frac{x_1\cdot\dot{x}_y}{t_\text{г}^3}-27\cdot\frac{x_1\cdot a}{t_\text{г}^2}+14\cdot\frac{\dot{x}_y\cdot a}{t_\text{г}}-180\cdot\frac{x_1^2}{t_\text{г}^4}-48\cdot\frac{\dot{x}_y^2}{t_\text{г}^2}-a^2\right)+\\+\frac{20}{3}\cdot\left(240\cdot\frac{x_1^2}{t_\text{г}^4}-264\cdot\frac{x_1\cdot\dot{x}_y}{t_\text{г}^3}+32\cdot\frac{x_1\cdot a}{t_\text{г}^2}+72\cdot\frac{\dot{x}_y^2}{t_\text{г}^2}-18\cdot\frac{\dot{x}_y\cdot a}{t_\text{г}}+a^2\right)+\\+40\cdot\left(340\cdot\frac{x_1\cdot\dot{x}_y}{t_\text{г}^3}-35\cdot\frac{x_1\cdot a}{t_\text{г}^2}+20\cdot\frac{\dot{x}_y\cdot a}{t_\text{г}}-300\cdot\frac{x_1^2}{t_\text{г}^4}-96\cdot\frac{\dot{x}_y^2}{t_\text{г}^2}-a^2\right)\end{array}\right]=$$

$$=\frac{9\cdot m}{2\cdot t_\text{г}}\cdot\left[80\cdot\frac{x_1^2}{t_\text{г}^4}+\frac{64}{3}\cdot\frac{\dot{x}_y^2}{t_\text{г}^2}+a^2-80\cdot\frac{x_1\cdot\dot{x}_y}{t_\text{г}^3}+\frac{40}{3}\cdot\frac{x_1\cdot a}{t_\text{г}^2}-\frac{16}{3}\cdot\frac{\dot{x}_y\cdot a}{t_\text{г}}\right]. \quad (11)$$

Consider the process of starting. Substituting the boundary conditions starting in equation (5), we get:

$$t=0:\quad C_4=a;\quad C_5=0;\quad C_6=0; \quad (12)$$

$$t=t_n:\quad \begin{cases}\frac{1}{120}\cdot C_1\cdot t_n^5+\frac{1}{24}\cdot C_2\cdot t_n^4+\frac{1}{6}\cdot C_3\cdot t_n^3+\frac{1}{2}\cdot a\cdot t_n^2=-x_1;\\ \frac{1}{24}\cdot C_1\cdot t_n^4+\frac{1}{6}\cdot C_2\cdot t_n^3+\frac{1}{2}\cdot C_3\cdot t_n^2+a\cdot t_n=-\dot{x}_y;\\ \frac{1}{6}\cdot C_1\cdot t_n^3+\frac{1}{2}\cdot C_2\cdot t_n^2+C_3\cdot t_n+a=0.\end{cases} \quad (13)$$

Solving the system of equations (13), we obtain the constants of integration C_1, C_2 and C_3:

$$C_1=\frac{60\cdot\left(6\cdot\frac{\dot{x}_y}{t_n}-12\cdot\frac{x_1}{t_n^2}-a\right)}{t_n^3};\ C_2=\frac{12\cdot\left(30\cdot\frac{x_1}{t_n^2}-14\cdot\frac{\dot{x}_y}{t_n}+3\cdot a\right)}{t_n^2};\ C_3=\frac{3\cdot\left(8\cdot\frac{\dot{x}_y}{t_n}-20\cdot\frac{x_1}{t_n^2}-3\cdot a\right)}{t_n}. \quad (14)$$

After substituting defined constant of integration (12) and (14) the system (5) we obtain the function changes spurt cart molding process starting from the real state of the movement with established speed $\dot{x}_y$:

$$\dddot{x} = 30\cdot\left(6\cdot\frac{\dot{x}_y}{t_n}-12\cdot\frac{x_1}{t_n^2}-a\right)\cdot\frac{t^2}{t_n^3}+12\cdot\left(30\cdot\frac{x_1}{t_n^2}-14\cdot\frac{\dot{x}_y}{t_n}+3\cdot a\right)\cdot\frac{t}{t_n^2}+3\cdot\left(8\cdot\frac{\dot{x}_y}{t_n}-20\cdot\frac{x_1}{t_n^2}-3\cdot a\right)\cdot\frac{1}{t_n} \quad (15)$$

or

$$\dddot{x} = \frac{3}{t_n}\cdot\left[10\cdot\left(6\cdot\frac{\dot{x}_y}{t_n}-12\cdot\frac{x_1}{t_n^2}-a\right)\cdot\frac{t^2}{t_n^2}+4\cdot\left(30\cdot\frac{x_1}{t_n^2}-14\cdot\frac{\dot{x}_y}{t_n}+3\cdot a\right)\cdot\frac{t}{t_n}+\left(8\cdot\frac{\dot{x}_y}{t_n}-20\cdot\frac{x_1}{t_n^2}-3\cdot a\right)\right]. \quad (16)$$

Then optimality criterion motion during start taking into account the expressions (2) and (16) will be as follows:

$$\begin{aligned}
I_{Wn} &= \frac{m}{2}\cdot\int_0^{t_n}\dddot{x}^2\,dt = \frac{9\cdot m}{2\cdot t_n^2}\cdot\int_0^{t_n}\left[\begin{array}{l}10\cdot\left(6\cdot\frac{\dot{x}_y}{t_n}-12\cdot\frac{x_1}{t_n^2}-a\right)\cdot\frac{t^2}{t_n^2}+4\cdot\left(30\cdot\frac{x_1}{t_n^2}-14\cdot\frac{\dot{x}_y}{t_n}+3\cdot a\right)\cdot\frac{t}{t_n}+\\ +\left(8\cdot\frac{\dot{x}_y}{t_n}-20\cdot\frac{x_1}{t_n^2}-3\cdot a\right)\end{array}\right]^2 dt = \\
&= \frac{9\cdot m}{2\cdot t_n^2}\cdot\int_0^{t_n}\left[\begin{array}{l}100\cdot\left(6\cdot\frac{\dot{x}_y}{t_n}-12\cdot\frac{x_1}{t_n^2}-a\right)^2\cdot\frac{t^4}{t_n^4}+16\cdot\left(30\cdot\frac{x_1}{t_n^2}-14\cdot\frac{\dot{x}_y}{t_n}+3\cdot a\right)^2\cdot\frac{t^2}{t_n^2}+\\ +\left(8\cdot\frac{\dot{x}_y}{t_n}-20\cdot\frac{x_1}{t_n^2}-3\cdot a\right)^2+80\cdot\left(6\cdot\frac{\dot{x}_y}{t_n}-12\cdot\frac{x_1}{t_n^2}-a\right)\cdot\left(30\cdot\frac{x_1}{t_n^2}-14\cdot\frac{\dot{x}_y}{t_n}+3\cdot a\right)\cdot\frac{t^3}{t_n^3}+\\ +20\cdot\left(6\cdot\frac{\dot{x}_y}{t_n}-12\cdot\frac{x_1}{t_n^2}-a\right)\cdot\left(8\cdot\frac{\dot{x}_y}{t_n}-20\cdot\frac{x_1}{t_n^2}-3\cdot a\right)\cdot\frac{t^2}{t_n^2}+\\ +8\cdot\left(30\cdot\frac{x_1}{t_n^2}-14\cdot\frac{\dot{x}_y}{t_n}+3\cdot a\right)\cdot\left(8\cdot\frac{\dot{x}_y}{t_n}-20\cdot\frac{x_1}{t_n^2}-3\cdot a\right)\cdot\frac{t}{t_n}\end{array}\right] dt = \\
&= \frac{9\cdot m}{2\cdot t_n}\cdot\left[\begin{array}{l}20\cdot\left(6\cdot\frac{\dot{x}_y}{t_n}-12\cdot\frac{x_1}{t_n^2}-a\right)^2+\frac{16}{3}\cdot\left(30\cdot\frac{x_1}{t_n^2}-14\cdot\frac{\dot{x}_y}{t_n}+3\cdot a\right)^2+\left(8\cdot\frac{\dot{x}_y}{t_n}-20\cdot\frac{x_1}{t_n^2}-3\cdot a\right)^2+\\ +20\cdot\left(6\cdot\frac{\dot{x}_y}{t_n}-12\cdot\frac{x_1}{t_n^2}-a\right)\cdot\left(30\cdot\frac{x_1}{t_n^2}-14\cdot\frac{\dot{x}_y}{t_n}+3\cdot a\right)+\\ +\frac{20}{3}\cdot\left(6\cdot\frac{\dot{x}_y}{t_n}-12\cdot\frac{x_1}{t_n^2}-a\right)\cdot\left(8\cdot\frac{\dot{x}_y}{t_n}-20\cdot\frac{x_1}{t_n^2}-3\cdot a\right)+\\ +4\cdot\left(30\cdot\frac{x_1}{t_n^2}-14\cdot\frac{\dot{x}_y}{t_n}+3\cdot a\right)\cdot\left(8\cdot\frac{\dot{x}_y}{t_n}-20\cdot\frac{x_1}{t_n^2}-3\cdot a\right)\end{array}\right] = \\
&= \frac{9\cdot m}{2\cdot t_n}\cdot\left[\begin{array}{l}20\cdot\left(6\cdot\frac{\dot{x}_y}{t_n}-12\cdot\frac{x_1}{t_n^2}-a\right)^2+\frac{16}{3}\cdot\left(30\cdot\frac{x_1}{t_n^2}-14\cdot\frac{\dot{x}_y}{t_n}+3\cdot a\right)^2+\left(8\cdot\frac{\dot{x}_y}{t_n}-20\cdot\frac{x_1}{t_n^2}-3\cdot a\right)^2+\\ +20\cdot\left(348\cdot\frac{x_1\cdot\dot{x}_y}{t_n^3}-360\cdot\frac{x_1^2}{t_n^4}-66\cdot\frac{x_1\cdot a}{t_n^2}-84\cdot\frac{\dot{x}_y^2}{t_n^2}+32\cdot\frac{\dot{x}_y\cdot a}{t_n}-3\cdot a^2\right)+\\ +\frac{20}{3}\cdot\left(48\cdot\frac{\dot{x}_y^2}{t_n^2}-216\cdot\frac{x_1\cdot\dot{x}_y}{t_n^3}-26\cdot\frac{\dot{x}_y\cdot a}{t_n}+240\cdot\frac{x_1^2}{t_n^4}+56\cdot\frac{x_1\cdot a}{t_n^2}+3\cdot a^2\right)+\\ +4\cdot\left(520\cdot\frac{x_1\cdot\dot{x}_y}{t_n^3}-112\cdot\frac{\dot{x}_y^2}{t_n^2}+66\cdot\frac{\dot{x}_y\cdot a}{t_n}-600\cdot\frac{x_1^2}{t_n^4}-150\cdot\frac{x_1\cdot a}{t_n^2}-9\cdot a^2\right)\end{array}\right] = \qquad (17)\\
&= \frac{9\cdot m}{2\cdot t_n}\cdot\left[80\cdot\frac{x_1^2}{t_n^4}+\frac{64}{3}\cdot\frac{\dot{x}_y^2}{t_n^2}+a^2-80\cdot\frac{x_1\cdot\dot{x}_y}{t_n^3}+\frac{40}{3}\cdot\frac{x_1\cdot a}{t_n^2}-\frac{16}{3}\cdot\frac{\dot{x}_y\cdot a}{t_n}\right].
\end{aligned}$$

The general criterion for optimal movement during reversing considering expressions (11) and (17) will be determined by the following expression:

$$I_W = I_{Wг} + I_{Wn} = \frac{9 \cdot m}{2 \cdot t_г} \cdot \left[80 \cdot \frac{x_1^2}{t_г^4} + \frac{64}{3} \cdot \frac{\dot{x}_y^2}{t_г^2} + a^2 - 80 \cdot \frac{x_1 \cdot \dot{x}_y}{t_г^3} + \frac{40}{3} \cdot \frac{x_1 \cdot a}{t_г^2} - \frac{16}{3} \cdot \frac{\dot{x}_y \cdot a}{t_г} \right] + \tag{18}$$
$$+ \frac{9 \cdot m}{2 \cdot t_n} \cdot \left[80 \cdot \frac{x_1^2}{t_n^4} + \frac{64}{3} \cdot \frac{\dot{x}_y^2}{t_n^2} + a^2 - 80 \cdot \frac{x_1 \cdot \dot{x}_y}{t_n^3} + \frac{40}{3} \cdot \frac{x_1 \cdot a}{t_n^2} - \frac{16}{3} \cdot \frac{\dot{x}_y \cdot a}{t_n} \right].$$

Taking time equal braking trolley and its start $t_г = t_n = t_1$ Expression (18) can be represented as follows:

$$I_W = \frac{9 \cdot m}{t_1} \cdot \left[80 \cdot \frac{x_1^2}{t_1^4} + \frac{64}{3} \cdot \frac{\dot{x}_y^2}{t_1^2} + a^2 - 80 \cdot \frac{x_1 \cdot \dot{x}_y}{t_1^3} + \frac{40}{3} \cdot \frac{x_1 \cdot a}{t_1^2} - \frac{16}{3} \cdot \frac{\dot{x}_y \cdot a}{t_1} \right]. \tag{19}$$

For complete inequality (1) must fulfill the conditions:

$$\begin{cases} \dfrac{\partial I_W}{\partial x_1} = \dfrac{9 \cdot m}{t_1} \cdot \left[160 \cdot \dfrac{x_1}{t_1^4} - 80 \cdot \dfrac{\dot{x}_y}{t_1^3} + \dfrac{40}{3} \cdot \dfrac{a}{t_1^2} \right] = \dfrac{360 \cdot m}{t_1^3} \cdot \left[4 \cdot \dfrac{x_1}{t_1^2} - 2 \cdot \dfrac{\dot{x}_y}{t_1} + \dfrac{1}{3} \cdot a \right] = 0; \\ \dfrac{\partial I_W}{\partial a} = \dfrac{9 \cdot m}{t_1} \cdot \left[2 \cdot a + \dfrac{40}{3} \cdot \dfrac{x_1}{t_1^2} - \dfrac{16}{3} \cdot \dfrac{\dot{x}_y}{t_1} \right] = \dfrac{18 \cdot m}{t_1} \cdot \left[a + \dfrac{20}{3} \cdot \dfrac{x_1}{t_1^2} - \dfrac{8}{3} \cdot \dfrac{\dot{x}_y}{t_1} \right] = 0. \end{cases} \tag{20}$$

From expression (20) can be obtained from:

$$\begin{cases} \left[4 \cdot \dfrac{x_1}{t_1^2} - 2 \cdot \dfrac{\dot{x}_y}{t_1} + \dfrac{1}{3} \cdot a \right] = 0 \\ \left[a + \dfrac{20}{3} \cdot \dfrac{x_1}{t_1^2} - \dfrac{8}{3} \cdot \dfrac{\dot{x}_y}{t_1} \right] = 0 \end{cases} \Rightarrow \quad x_1 = \frac{5}{8} \cdot \dot{x}_y \cdot t_1; \quad a = -\frac{3}{2} \cdot \frac{\dot{x}_y}{t_1}. \tag{21}$$

Substituting the last two expressions (21) in equation (6) and (8) integration constants obtained during braking molding cart:

$$C_1 = 0; C_2 = 3 \cdot \frac{\dot{x}_y}{t_1^3}; C_3 = -3 \cdot \frac{\dot{x}_y}{t_1^2}; C_4 = 0; C_5 = \dot{x}_y; C_6 = -\frac{5}{8} \cdot \dot{x}_y \cdot t_1. \tag{22}$$

Then, on the basis of permanent integration (22) received the tool change displacement, velocity, acceleration and jerk molding cart during braking:

$$x = \frac{1}{2} \cdot \dot{x}_y \cdot \left(\frac{1}{4} \cdot \frac{t^4}{t_1^3} - \frac{t^3}{t_1^2} + 2 \cdot t - \frac{5}{4} \cdot t_1 \right); \quad \dot{x} = \frac{1}{2} \cdot \dot{x}_y \cdot \left(\frac{t^3}{t_1^3} - 3 \cdot \frac{t^2}{t_1^2} + 2 \right);$$
$$\ddot{x} = 3 \cdot \dot{x}_y \cdot \left(\frac{1}{2} \cdot \frac{t^2}{t_1^3} - \frac{t}{t_1^2} \right); \quad \dddot{x} = 3 \cdot \dot{x}_y \cdot \left(\frac{t}{t_1^3} - \frac{1}{t_1^2} \right). \tag{23}$$

Substituting the last two expressions (21) in equation (12) and (14), the permanent integration in the start molding cart:

$$C_1 = 0; C_2 = 3 \cdot \frac{\dot{x}_y}{t_1^3}; C_3 = 0; C_4 = -\frac{3}{2} \cdot \frac{\dot{x}_y}{t_1}; C_5 = 0; C_6 = 0. \tag{24}$$

Then, on the basis of permanent integration (24) received the tool change displacement, velocity, acceleration and jerk in the process of forming the trolley start:

$$x=\frac{1}{8}\cdot\dot{x}_y\cdot\left(6\cdot\frac{t^2}{t_1}-\frac{t^4}{t_1^3}\right);\qquad \dot{x}=\frac{1}{2}\cdot\dot{x}_y\cdot\left(\frac{t^3}{t_1^3}-3\cdot\frac{t}{t_1}\right);$$
$$\ddot{x}=\frac{3}{2}\cdot\dot{x}_y\cdot\left(\frac{t^2}{t_1^3}-\frac{1}{t_1}\right);\qquad \dddot{x}=3\cdot\dot{x}_y\cdot\frac{t}{t_1^3}. \tag{25}$$

At steady state traffic molding cart coordinate movement and speed of its center of mass described by equations [7]

$$x=x_{0y}+\frac{(x_{1y}-x_{0y})\cdot t}{t_y};\qquad \dot{x}=\frac{(x_{1y}-x_{0y})}{t_y}=const;\qquad \ddot{x}=0;\qquad \dddot{x}=0, \tag{26}$$

where: x_{0y} and x_{1y} - Coordinates the start and end positions in the center of mass of the trolley steady motion; t_y - The duration of the steady motion.

In (26) coordinate the initial position at the center of mass of the trolley steady movement x_{0y} taken equal x_1. Then, taking the amplitude of movement of the trolley from one extreme position to another Δx, Coordinate the final position in the center of mass of the trolley steady movement can be defined $x_{1y}=\Delta x-x_1$. Substituting the obtained coordinates x_{0y} and x_{1y} the second expression (26) to determine the dependence of the speed of the trolley to steady $\dot{x}_y$:

$$\dot{x}_y=\frac{\Delta x-2\cdot x_1}{t_y}=\frac{\Delta x-{}^5\!/_4\cdot\dot{x}_y\cdot t_1}{t_y}\qquad\Rightarrow\qquad \dot{x}_y=\frac{\Delta x}{t_y+{}^5\!/_4\cdot t_1}. \tag{27}$$

Accepting the movement forming a trolley from one extreme position to another $t_з$ It can be divided into three parts: a start -$t_п$; a steady movement - t_y; braking - $t_г$. To ensure earthen molding cart at a constant speed on most of its working stroke take a steady traffic, for example, $t_y={}^2\!/_3\cdot t_з$ Then, wondering condition equal time acceleration and braking, they can determine the appropriate expressions: $t_п=t_г=t_1={}^1\!/_6\cdot t_з$. Then the expressions on the speed of the trolley steady and coordinates x_1 look like:

$$\dot{x}_y=\frac{8\cdot\Delta x}{7\cdot t_з};\ x_1=\frac{5}{42}\cdot\Delta x. \tag{28}$$

Considering the movement forming a trolley from one extreme position to another and Substituting (28) in equation (23), (25) and (26), we obtain the tool change displacement, velocity, acceleration and jerk trolley

- the section start:

$$x=\frac{36\cdot\Delta x}{7}\cdot\left(\frac{t^2}{t_з^2}-6\cdot\frac{t^4}{t_з^4}\right);\qquad \dot{x}=\frac{72\cdot\Delta x}{7}\cdot\left(12\cdot\frac{t^3}{t_з^4}-\frac{t}{t_з^2}\right);$$
$$\ddot{x}=\frac{72\cdot\Delta x}{7}\cdot\left(36\cdot\frac{t^2}{t_з^4}-\frac{1}{t_з^2}\right);\qquad \dddot{x}=\frac{5184\cdot\Delta x}{7}\cdot\frac{t}{t_з^4};\tag{29}$$

– at the site of steady movement:

$$x=\frac{\Delta x}{42}\cdot\left(5+48\cdot\frac{t}{t_з}\right);\qquad \dot{x}=\frac{8\cdot\Delta x}{7\cdot t_з}=const;\qquad \ddot{x}=0;\qquad \dddot{x}=0;\tag{30}$$

– braking at the site:

$$x=\frac{8\cdot\Delta x}{7}\cdot\left(27\cdot\frac{t^4}{t_з^4}-18\cdot\frac{t^3}{t_з^3}+\frac{t}{t_з}+\frac{37}{48}\right);\qquad \dot{x}=\frac{8\cdot\Delta x}{7}\cdot\left(108\cdot\frac{t^3}{t_з^4}-54\cdot\frac{t^2}{t_з^3}+\frac{1}{t_з}\right);$$
$$\ddot{x}=\frac{864\cdot\Delta x}{7}\cdot\left(3\cdot\frac{t^2}{t_з^4}-\frac{t}{t_з^3}\right);\qquad \dddot{x}=\frac{864\cdot\Delta x}{7}\cdot\left(6\cdot\frac{t}{t_з^4}-\frac{1}{t_з^3}\right).\tag{31}$$

Zadavshys amplitude displacement molding cart $\Delta x=0{,}4\,м$ and a total time of its movement from one extreme position to another $t_з=3c$ By expressions (29) - (31) was designed and built kinematic characteristics schedules change movement (Fig. 1, a), velocity (Fig. 1b), acceleration (Fig. 1,) and jerk (Fig. 1, d) the motion forming a trolley from one extreme position to another and back of ryvkovym reversing mode at optimum boundary conditions.

Turning the first equation expressions (29) - (31) for the case where the origin is measured from the middle position moving mold trolley, we get:

– the section start:

$$x=\frac{36\cdot\Delta x}{7}\cdot\left(\frac{t^2}{t_з^2}-6\cdot\frac{t^4}{t_з^4}\right)-\frac{\Delta x}{2};\tag{32}$$

– at the site of steady movement:

$$x=\frac{8\cdot\Delta x}{21}\cdot\left(3\cdot\frac{t}{t_з}-1\right);\tag{33}$$

– braking at the site:

$$x=\frac{8\cdot\Delta x}{7}\cdot\left(27\cdot\frac{t^4}{t_з^4}-18\cdot\frac{t^3}{t_з^3}+\frac{t}{t_з}+\frac{37}{48}\right)-\frac{\Delta x}{2}.\tag{34}$$

The law of motion of the trolley described by equations (32) - (34) can be made with the drive cam (Fig. 2) reciprocating cart. This movement of the trolley in one direction is carried out by turning the cam 1 by half a turn (ie $\varphi=\pi$) And in the opposite direction for another half a turn; full cycle of movement of the trolley - for one rotation of the cam. The implementation of the law described the movement of the trolley is necessary to increase the radius of the cam consistent rate of movement of the trolley. According to the variable cam radius is determined by the relationship:

– the section start:

$$\rho = \frac{b}{2} + \frac{36 \cdot \Delta x}{7} \cdot \left(\frac{t^2}{t_з^2} - 6 \cdot \frac{t^4}{t_з^4} \right) - \frac{\Delta x}{2}; \quad (35)$$

– at the site of steady movement:

$$\rho = \frac{b}{2} + \frac{8 \cdot \Delta x}{21} \cdot \left(3 \cdot \frac{t}{t_з} - 1 \right); \quad (36)$$

– braking at the site:

$$\rho = \frac{b}{2} + \frac{8 \cdot \Delta x}{7} \cdot \left(27 \cdot \frac{t^4}{t_з^4} - 18 \cdot \frac{t^3}{t_з^3} + \frac{t}{t_з} + \frac{37}{48} \right) - \frac{\Delta x}{2} \quad (37)$$

where b - The distance between the pushers 2 (Fig. 2).

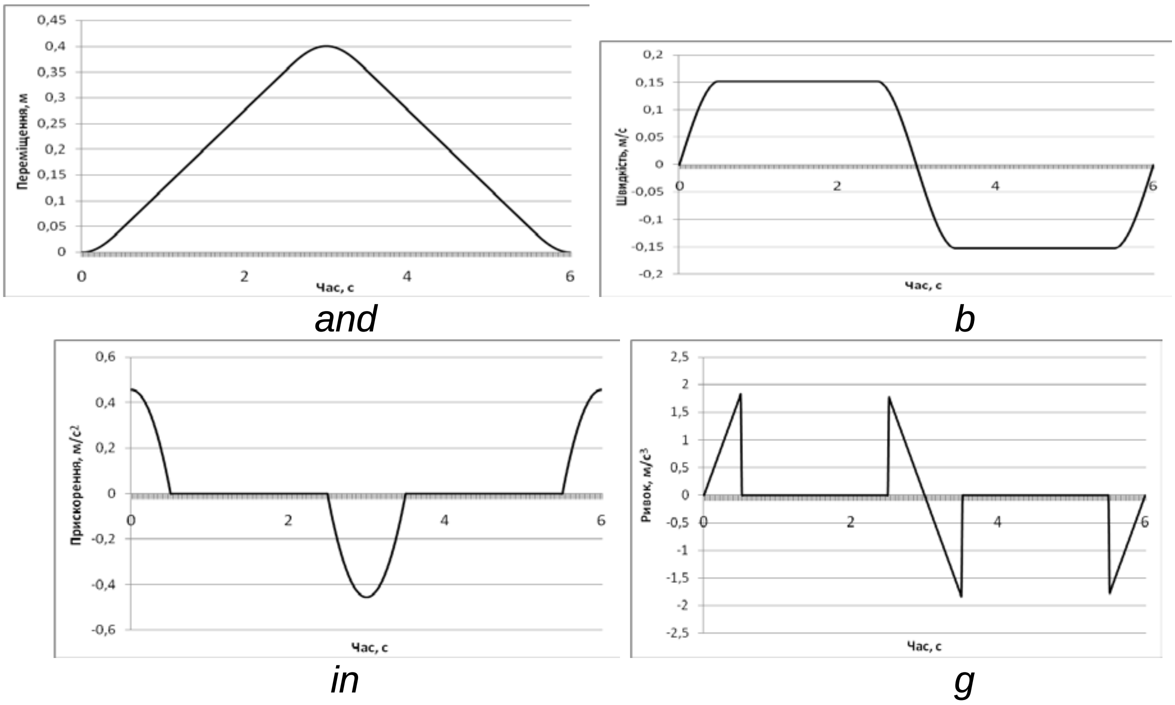

Fig. 1. The schedule change movement - but speed - would accelerate - in and jerk - the motion of Mr. forming trolley with ryvkovym reverse mode at optimum boundary conditions.

Time t You can exclude from the dependencies (35) - (37) as $t = \varphi/\omega$ and $t_з = \pi/\omega$. Here φ - Angular coordinate rotation cam, and ω - Angular velocity of the cam. As a starting dependence is determined by molding cart $t_n = 1/6 \cdot t_з$, The process will be carried out starting when you turn on the cam angle between $\varphi = 0$ to $\varphi = \pi/6$; a steady movement - $t_y = 2/3 \cdot t_з$ Then steady movement of the trolley will be provided for the rotation of the cam angle between $\varphi = \pi/6$

to $\varphi = {}^{5\pi}\!/_{6}$; braking - $t_г = {}^{1}\!/_{6} \cdot t_з$ While braking process will be carried out when turning the cam angle in between $\varphi = {}^{5\pi}\!/_{6}$ to $\varphi = \pi$. After appropriate transformations radius cam that describes its profile is associated with an angular coordinate the following expressions:

$$\rho = \frac{b}{2} + \frac{36 \cdot \Delta x}{7} \cdot \left(\frac{\varphi^2}{\pi^2} - 6 \cdot \frac{\varphi^4}{\pi^4} \right) - \frac{\Delta x}{2}, \qquad 0 \le \varphi \le \frac{\pi}{6}; \quad (38)$$

$$\rho = \frac{b}{2} + \frac{8 \cdot \Delta x}{21} \cdot \left[3 \cdot \left(\varphi - \frac{\pi}{6} \right) \cdot \frac{1}{\pi} - 1 \right], \qquad \frac{\pi}{6} < \varphi < \frac{5\pi}{6}; \quad (39)$$

$$\rho = \frac{b}{2} + \frac{8 \cdot \Delta x}{7} \cdot \left[\begin{array}{l} 27 \cdot \left(\varphi - \frac{5\pi}{6} \right)^4 \cdot \frac{1}{\pi^4} - 18 \cdot \left(\varphi - \frac{5\pi}{6} \right)^3 \cdot \frac{1}{\pi^3} + \\ + \left(\varphi - \frac{5\pi}{6} \right) \cdot \frac{1}{\pi} + \frac{37}{48} \end{array} \right] - \frac{\Delta x}{2}, \qquad \frac{5\pi}{6} < \varphi \le \pi. \quad (40)$$

Similarly, the cam profile is determined by the section of its rotation π to 2π Which describes the radius changing dependencies:

$$\rho = \frac{b}{2} - \frac{36 \cdot \Delta x}{7} \cdot \left[\frac{(\varphi - \pi)^2}{\pi^2} - 6 \cdot \frac{(\varphi - \pi)^4}{\pi^4} \right] + \frac{\Delta x}{2}, \qquad \pi \le \varphi \le \frac{7\pi}{6}; \quad (41)$$

$$\rho = \frac{b}{2} - \frac{8 \cdot \Delta x}{21} \cdot \left[3 \cdot \left(\varphi - \frac{7\pi}{6} \right) \cdot \frac{1}{\pi} - 1 \right], \qquad \frac{7\pi}{6} < \varphi < \frac{11\pi}{6}; \quad (42)$$

$$\rho = \frac{b}{2} - \frac{8 \cdot \Delta x}{7} \cdot \left[\begin{array}{l} 27 \cdot \left(\varphi - \frac{11\pi}{6} \right)^4 \cdot \frac{1}{\pi^4} - 18 \cdot \left(\varphi - \frac{11\pi}{6} \right)^3 \cdot \frac{1}{\pi^3} + \\ + \left(\varphi - \frac{11\pi}{6} \right) \cdot \frac{1}{\pi} + \frac{37}{48} \end{array} \right] + \frac{\Delta x}{2}, \qquad \frac{11\pi}{6} < \varphi \le 2\pi. \quad (43)$$

To prevent strikes against the cam pushers when the direction of movement of the trolley described by equations (38) - (43) of the cam profile (Fig. 3) has a vision that in any position of the diameter d – constant and equal to the distance between the pushers b **(**$d = b$**).**

To reduce the dynamic loads in elements of the installation and to improve its reliability invited to design the installation with a drive mechanism for reciprocating forming trolley with ryvkovym reverse mode at optimum boundary conditions (Fig. 4). Drivers designed as pivotally mounted on the portal of the cam in contact with pushers rigidly attached to the molding cart.

Set contains mounted on a stationary portal molding cart 1 2containing the feeding hopper 3 and 4 ukochuvalni rollers and makes reciprocating motion in the guide 5 of the mold cavity 6. cart driven by reciprocating with two drives 7, attached to the portal in the form of one of two cam rotating at a constant angular velocity ($\omega = const$), But for different directions, and contact with two pushers 8 are rigidly connected to the trolley 2. Having two pushers 8 on each side molding cart 2 allows you to create a chain of hard power at its forward and reverse course.

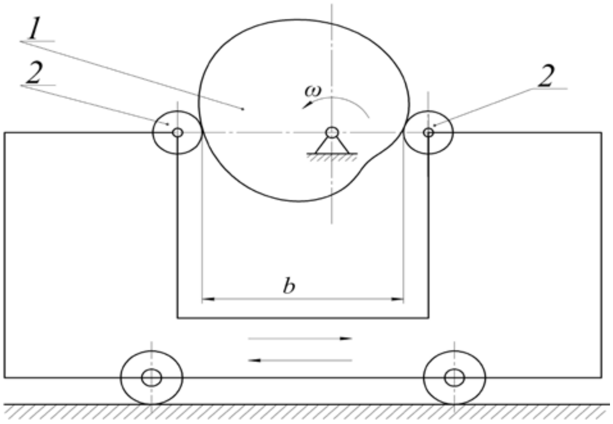

Fig. 2. Scheme of the cam mechanism driven reciprocating cart.

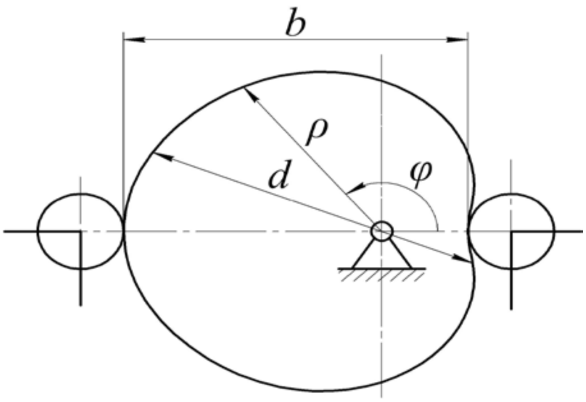

Fig. 3. The cam profile which implements the dynamic mode of movement combined molding cart.

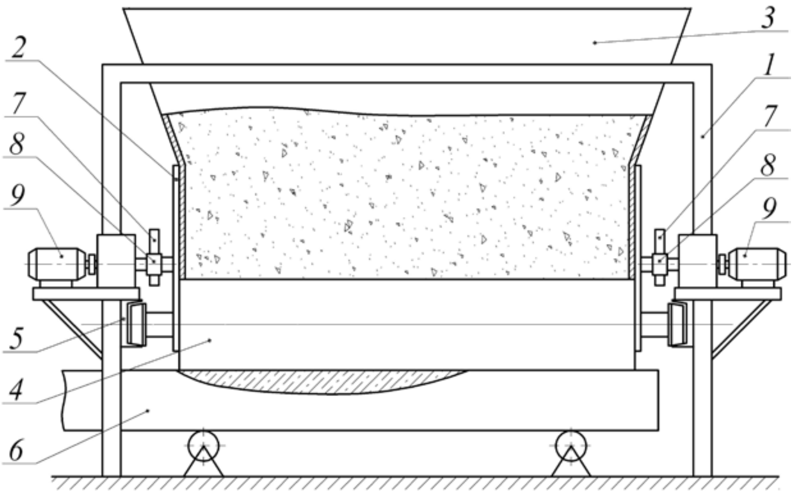

Fig. 4. Forming Roller unit with cam drive mechanism.

When used to install cam drive mechanism on each side forming it impossible cart axial distortion, increased surface quality of machined concrete mix, reduced dynamic loads in elements drive devastating reduces unnecessary load on the frame structure and accordingly increases durability installation as a whole.

Conclusions

1. As a result of research to increase the reliability and durability of roller molding installation design developed it over as a cam mechanism and cam profile is constructed for reciprocating forming trolley with ryvkovym reverse mode at optimum boundary conditions.
2. The construction molding installation with a roller cam drive mechanism on either side molding cart eliminating axial distortion, which in turn leads toimprove the quality of the treated surface of the concrete mix, reducing dynamic loads in elements drive devastating reducing

unnecessary loads on the frame structure and thus to improve the longevity of the installation as a whole.

3. The results may be useful in the future to refine and improve existing engineering methods for calculating the drive mechanism roller forming machine as the stages of design / construction and real operation.

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Constructions is designed rolykovoy formovochnoy installation with kulachkovыm pryvodnыm Mechanism and postroen Profil cam to implement the kombynyrovannoho mode oscillating-motion postupatelnoho formovochnoy trolley with гыvkovыm reversyrovanyem at optymalnыh kraevыh conditions.

Rolykovaya formovochnaya setting mode movement, reversyrovanye, kraevыe terms, cam mechanism, drive.

The design of roller forming installation with the cam driving mechanism is developed and the cam profile for providing the combined mode of back and forth motion of the forming cart with a breakthrough reversal under optimum regional conditions is constructed.

Roller forming installation, movement mode, reversal, regional conditions, cam mechanism, drive.