

Synthesis Roller Cam Drive Mechanism Molding Installation with Combined Mode Movement Acceleration Fourth Order

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Summary. For the purpose of increase in reliability and durability of roller forming installation the optimum mode of back and forth motion of the forming cart on acceleration of the fourth order is calculated. Kinematic characteristics of the forming cart at the optimum mode of the movement on acceleration of the fourth order are calculated. The design of roller forming installation with the drive from the high-moment step engine which is built in the rolling rollers of the forming cart is offered and provides the optimum mode of back and forth motion of the forming cart on acceleration of the fourth order. Use in installation of the specified driving mechanism leads to improvement of quality of a surface to the processed concrete mix, reduction of dynamic loadings in elements of the driving mechanism, to disappearance of excess destructive loads of a frame design and, respectively, to increase in reliability and durability of installation in general. As a result of the conducted researches for the purpose of increase in reliability and durability of roller forming installation the optimum mode of back and forth motion of the forming cart on acceleration of the fourth order is calculated.

Kinematic characteristics of the forming cart at the optimum mode of back and forth motion on acceleration of the fourth order are calculated.

The design of roller forming installation with the drive from the high-moment step engine which is built in the rolling rollers of the forming cart with a possibility of realization of the optimum mode of back and forth motion on acceleration of the fourth order is offered.

The design of the drive of installation in a type of the cam mechanism is offered and the cam profile for providing the optimum mode of back and forth motion of the forming cart on acceleration of the fourth order is constructed.

Results of work can be used further for specification and improvement of the existing engineering methods of calculation of driving mechanisms of cars of roller formation both at design/designing stages, and in the modes of real operation. Also results of work can be useful at

design or improvement of mechanisms with back and forth motion of executive elements.

Key words: roller forming installation, mode of movement, step engine, drive.

INTRODUCTION

In installations roller forming concrete products during their work there are considerable dynamic loads in elements of the drive mechanism and the elements forming carts [1-13]. Despite the fairly extensive study of the process of forming concrete products bezvibratsiynym roller method [14-25]. So far not been investigated dynamics of forming the trolley and its impact on the process of formation. Few paid attention to efforts occurring in the elements of drive mechanism and forming the cart.

THE ANALYSIS OF RECENT RESEARCHES AND PUBLICATIONS

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 research current and dynamic load driving mode, which greatly affect the operation of the installation and the quality of the finished product. During regular puskohalmivnyh movement modes having significant dynamic loads in elements of the drive mechanism and the elements forming the trolley, which can lead to premature failure of the installation[4, 5]. So important is the task of improving a roller drive mechanism forming installation to ensure that such a regime movement forming trolley in which dynamic loads have decreased in the elements of installation and increased durability.

OBJECTIVE

The aim of this work is to improve the design roller drive mechanism forming units for increasing its reliability and durability.

THE MAIN RESULTS OF THE RESEARCH

For roller molding installation with earthen desirable constant speed reciprocating mold carts throughout the area that have positively affected the quality of the finished product. However, in practice such a mode of motion exercise is impossible, because it lacks plot acceleration and braking, without which there can be cyclic motion. It is therefore proposed to implement a regime of movement during its formative trolley moving from one extreme position to another, which would be the areas of acceleration and deceleration with minimal dynamic loads of movement and constant speed.

For smooth acceleration and braking process of forming the trolley suggested to carry them for optimal regimes movement acceleration fourth order [6]. At that speed, acceleration, acceleration of the second order (jerk) and acceleration of order (feeling) forming carts vary smoothly without creating significant dynamic loads in the installation, which in turn positively affect its longevity.

Criteria mode of movement mechanisms and machines can be uneven rates of movement and dynamism. [6] In this paper as a criterion motion mode used by criteria act which is integral with the time integral of the function that expresses the extent of movement or action system. For optimal mode for acceleration and braking acceleration fourth-order optimality criterion motion will have the form:

$$I_z = \int_0^{t_{p,z}} Q dt \rightarrow \min, \quad (1)$$

where: t – time, $t_{p,z}$ – lengthy process of acceleration or deceleration of the trolley mold, Q – energy acceleration fourth order:

$$Q = \frac{1}{2} \cdot m \cdot x^v \quad (2)$$

where: m – bulk molding cart, x – acceleration fourth order.

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

$$\frac{\partial Q}{\partial x} - \frac{d}{dt} \frac{\partial Q}{\partial \dot{x}} + \frac{d^2}{dt^2} \frac{\partial Q}{\partial \ddot{x}} - \frac{d^3}{dt^3} \frac{\partial Q}{\partial \overset{IV}{x}} + \frac{d^4}{dt^4} \frac{\partial Q}{\partial \overset{V}{x}} - \frac{d^5}{dt^5} \frac{\partial Q}{\partial \overset{VI}{x}} = 0 \quad (3)$$

where: x , \dot{x} , \ddot{x} , $\overset{IV}{x}$, $\overset{V}{x}$ – coordinate displacement, velocity, acceleration, acceleration of the second order (jerk) and acceleration of order (feeling) trolley respectively.

From the expression (3) can be written:

$$\frac{\partial Q}{\partial x} = \frac{\partial Q}{\partial \dot{x}} = \frac{\partial Q}{\partial \ddot{x}} = \frac{\partial Q}{\partial \overset{IV}{x}} = \frac{\partial Q}{\partial \overset{V}{x}} = 0,$$

$$\frac{\partial Q}{\partial x} = m \cdot x^v, \quad \frac{d^5}{dt^5} \frac{\partial Q}{\partial \overset{VI}{x}} = m \cdot x^x = 0. \quad (4)$$

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

$$\overset{x}{x} = 0, \quad \overset{IX}{x} = C_1, \quad \overset{VIII}{x} = C_1 \cdot t + C_2,$$

$$\overset{VII}{x} = \frac{1}{2} \cdot C_1 \cdot t^2 + C_2 \cdot t + C_3,$$

$$\overset{VI}{x} = \frac{1}{6} \cdot C_1 \cdot t^3 + \frac{1}{2} \cdot C_2 \cdot t^2 + C_3 \cdot t + C_4,$$

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

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

$$\overset{III}{x} = \frac{1}{720} \cdot C_1 \cdot t^6 + \frac{1}{120} \cdot C_2 \cdot t^5 + \frac{1}{24} \cdot C_3 \cdot t^4 +$$

$$+ \frac{1}{6} \cdot C_4 \cdot t^3 + \frac{1}{2} \cdot C_5 \cdot t^2 + C_6 \cdot t + C_7,$$

$$\overset{II}{x} = \frac{1}{5040} \cdot C_1 \cdot t^7 + \frac{1}{720} \cdot C_2 \cdot t^6 + \frac{1}{120} \cdot C_3 \cdot t^5 +$$

$$+ \frac{1}{24} \cdot C_4 \cdot t^4 + \frac{1}{6} \cdot C_5 \cdot t^3 + \frac{1}{2} \cdot C_6 \cdot t^2 + C_7 \cdot t + C_8,$$

$$\overset{I}{x} = \frac{1}{40320} \cdot C_1 \cdot t^8 + \frac{1}{5040} \cdot C_2 \cdot t^7 + \frac{1}{720} \cdot C_3 \cdot t^6 +$$

$$+ \frac{1}{120} \cdot C_4 \cdot t^5 + \frac{1}{24} \cdot C_5 \cdot t^4 + \frac{1}{6} \cdot C_6 \cdot t^3 +$$

$$+ \frac{1}{2} \cdot C_7 \cdot t^2 + C_8 \cdot t + C_9,$$

$$x = \frac{1}{362880} \cdot C_1 \cdot t^9 + \frac{1}{40320} \cdot C_2 \cdot t^8 + \frac{1}{5040} \cdot C_3 \cdot t^7 +$$

$$+ \frac{1}{720} \cdot C_4 \cdot t^6 + \frac{1}{120} \cdot C_5 \cdot t^5 + \frac{1}{24} \cdot C_6 \cdot t^4 +$$

$$+ \frac{1}{6} \cdot C_7 \cdot t^3 + \frac{1}{2} \cdot C_8 \cdot t^2 + C_9 \cdot t + C_{10},$$

where: $C_1, C_2, C_3, C_4, C_5, C_6, C_7, C_8, C_9, C_{10}$ – integration constant, determined from boundary conditions.

To disperse the areas forming the cart after peace to enter the steady movement of the boundary conditions have the following meanings: $t=0: x=0, \dot{x}=0,$

$$\ddot{x}=0, \quad \overset{IV}{x}=0, \quad \overset{V}{x}=0 \quad \text{and} \quad t=t_p: \dot{x}=\dot{x}_y, \quad \ddot{x}=0,$$

$$\overset{IV}{x}=0, \quad \overset{V}{x}=0, \quad \overset{VI}{x}=0. \quad \text{Here } t_p \text{ – duration of acceleration}$$

molding cart since the rest to enter the steady movement, \dot{x}_y – speed of the trolley at steady state.

Substituting the above boundary conditions into the equation (5), we get:

$$t=0: C_{10}=0, C_9=0, C_8=0, C_7=0, C_6=0, \quad (6)$$

(7)
Solving the system of equations (7), we obtain the constants of integration C_1, C_2, C_3, C_4 and C_5 :

$$C_1 = 1411200 \cdot \frac{\dot{x}_y}{t_p^8}, \quad C_2 = -806400 \cdot \frac{\dot{x}_y}{t_p^7},$$

$$C_3 = 201600 \cdot \frac{\dot{x}_y}{t_p^6}, \quad C_4 = -26880 \cdot \frac{\dot{x}_y}{t_p^5}, \quad C_5 = 1680 \cdot \frac{\dot{x}_y}{t_p^4}. \quad (8)$$

Substituting defined constants of integration (6) and (8) in equation (5), we obtain expressions for kinematic characteristics forming the trolley during acceleration since the rest to enter the steady movement:

$$x_p = x_{0p} + \dot{x}_y \cdot \left(\frac{35}{9} \cdot \frac{t^4}{t_p^4} - 20 \cdot \frac{t^3}{t_p^3} + 40 \cdot \frac{t^2}{t_p^2} - \frac{112}{3} \cdot \frac{t}{t_p} + 14 \right) \cdot \frac{t^5}{t_p^4},$$

$$\dot{x}_p = \dot{x}_y \cdot \left(35 \cdot \frac{t^4}{t_p^4} - 160 \cdot \frac{t^3}{t_p^3} + 280 \cdot \frac{t^2}{t_p^2} - 224 \cdot \frac{t}{t_p} + 70 \right) \cdot \frac{t^4}{t_p^4},$$

$$\ddot{x}_p = 280 \cdot \dot{x}_y \cdot \left(\frac{t^4}{t_p^4} - 4 \cdot \frac{t^3}{t_p^3} + 6 \cdot \frac{t^2}{t_p^2} - 4 \cdot \frac{t}{t_p} + 1 \right) \cdot \frac{t^3}{t_p^4}, \quad (9)$$

$$\ddot{\ddot{x}}_p = 280 \cdot \dot{x}_y \cdot \left(7 \cdot \frac{t^4}{t_p^4} - 24 \cdot \frac{t^3}{t_p^3} + 30 \cdot \frac{t^2}{t_p^2} - 16 \cdot \frac{t}{t_p} + 3 \right) \cdot \frac{t^2}{t_p^4},$$

$$\overset{IV}{x}_p = 1680 \cdot \dot{x}_y \cdot \left(7 \cdot \frac{t^4}{t_p^4} - 20 \cdot \frac{t^3}{t_p^3} + 20 \cdot \frac{t^2}{t_p^2} - 8 \cdot \frac{t}{t_p} + 1 \right) \cdot \frac{t}{t_p^4},$$

$$\overset{V}{x}_p = 1680 \cdot \dot{x}_y \cdot \left(35 \cdot \frac{t^4}{t_p^4} - 80 \cdot \frac{t^3}{t_p^3} + 60 \cdot \frac{t^2}{t_p^2} - 16 \cdot \frac{t}{t_p} + 1 \right) \cdot \frac{1}{t_p^4},$$

where x_{0p} – coordinate the initial position of the center of mass of the trolley during acceleration.

At steady state traffic molding cart coordinate movement and speed of its center of mass described by equations [6]:

$$x_y = x_{0y} + \frac{(x_{1y} - x_{0y}) \cdot t}{t_y},$$

$$\dot{x}_y = \frac{(x_{1y} - x_{0y})}{t_y} = const, \quad (10)$$

$$\ddot{x}_y = 0, \quad \overset{IV}{\ddot{x}}_y = 0, \quad \overset{V}{x}_y = 0, \quad \overset{V}{x}_y = 0,$$

where: x_{0y} and x_{1y} – coordinates the start and end positions in the center of mass of the trolley steady motion, t_y – duration steady motion.

For braking areas forming trolley boundary conditions have the following meanings: $t = 0$: $\dot{x} = \dot{x}_y$,

$\ddot{x} = 0$, $\overset{IV}{\ddot{x}} = 0$, $\overset{V}{x} = 0$, $\overset{V}{x} = 0$ and $t = t_2$: $x = x_{12}$,
 $\dot{x} = 0$, $\ddot{x} = 0$, $\overset{IV}{\ddot{x}} = 0$, $\overset{V}{x} = 0$. Here t_2 – the duration of inhibition after steady movement to a complete stop, x_{12} – coordinate the final braking process.

Substituting the above boundary conditions into the equation (5), we get:

$$t = 0: \quad C_9 = \dot{x}_y, \quad C_8 = 0, \quad C_7 = 0, \quad C_6 = 0, \quad (11)$$

$$C_5 = 0,$$

$$t = t_2: \quad \begin{cases} \frac{1}{362880} \cdot C_1 \cdot t_2^9 + \frac{1}{40320} \cdot C_2 \cdot t_2^8 + \frac{1}{5040} \cdot C_3 \cdot t_2^7 + \\ + \frac{1}{720} \cdot C_4 \cdot t_2^6 + \dot{x}_y \cdot t_2 + C_{10} = x_{12}, \\ \frac{1}{40320} \cdot C_1 \cdot t_2^8 + \frac{1}{5040} \cdot C_2 \cdot t_2^7 + \frac{1}{720} \cdot C_3 \cdot t_2^6 + \\ + \frac{1}{120} \cdot C_4 \cdot t_2^5 + \dot{x}_y = 0, \\ \frac{1}{5040} \cdot C_1 \cdot t_2^7 + \frac{1}{720} \cdot C_2 \cdot t_2^6 + \frac{1}{120} \cdot C_3 \cdot t_2^5 + \\ + \frac{1}{24} \cdot C_4 \cdot t_2^4 = 0, \\ \frac{1}{720} \cdot C_1 \cdot t_2^6 + \frac{1}{120} \cdot C_2 \cdot t_2^5 + \frac{1}{24} \cdot C_3 \cdot t_2^4 + \\ + \frac{1}{6} \cdot C_4 \cdot t_2^3 = 0, \\ \frac{1}{120} \cdot C_1 \cdot t_2^5 + \frac{1}{24} \cdot C_2 \cdot t_2^4 + \frac{1}{6} \cdot C_3 \cdot t_2^3 + \\ + \frac{1}{2} \cdot C_4 \cdot t_2^2 = 0. \end{cases} \quad (12)$$

Solving the system of equations (12), we obtain the constants of integration C_1, C_2, C_3, C_4 and C_{10} :

$$C_1 = 1411200 \cdot \frac{\dot{x}_y}{t_2^8}, \quad C_2 = -604800 \cdot \frac{\dot{x}_y}{t_2^7},$$

$$C_3 = 100800 \cdot \frac{\dot{x}_y}{t_2^6}, \quad C_4 = -6720 \cdot \frac{\dot{x}_y}{t_2^5}, \quad C_5 = x_{12} - \frac{5}{9} \cdot \dot{x}_y \cdot t_2.$$

Substituting defined constants of integration (11) and (13) in equation (5), we obtain expressions for kinematic characteristics forming the trolley during braking after steady movement to a complete stop:

$$x_2 = x_{12} + \dot{x}_y \cdot \left(\frac{35}{9} \cdot \frac{t^9}{t_2^8} - 15 \cdot \frac{t^8}{t_2^7} + 20 \cdot \frac{t^7}{t_2^6} - \right. \\ \left. - \frac{28}{3} \cdot \frac{t^6}{t_2^5} + t - \frac{5}{9} \cdot t_2 \right),$$

$$\dot{x}_2 = \dot{x}_y \cdot \left(35 \cdot \frac{t^8}{t_2^8} - 120 \cdot \frac{t^7}{t_2^7} + 140 \cdot \frac{t^6}{t_2^6} - \right. \\ \left. - 56 \cdot \frac{t^5}{t_2^5} + 1 \right),$$

$$\ddot{x}_2 = 280 \cdot \dot{x}_y \cdot \left(\frac{t^3}{t_2^3} - 3 \cdot \frac{t^2}{t_2^2} + 4 \cdot \frac{t}{t_2} - 1 \right) \cdot \frac{t^4}{t_2^5},$$

$$\ddot{\ddot{x}}_2 = 280 \cdot \dot{x}_y \cdot \left(7 \cdot \frac{t^3}{t_2^3} - 18 \cdot \frac{t^2}{t_2^2} + 15 \cdot \frac{t}{t_2} - \right. \\ \left. - 4 \right) \cdot \frac{t^3}{t_2^5},$$

$$\overset{IV}{x}_2 = 1680 \cdot \dot{x}_y \cdot \left(7 \cdot \frac{t^3}{t_2^3} - 15 \cdot \frac{t^2}{t_2^2} + 10 \cdot \frac{t}{t_2} - \right. \\ \left. - 2 \right) \cdot \frac{t^2}{t_2^5}, \quad (14)$$

$$\overset{V}{x}_2 = 1680 \cdot \dot{x}_y \cdot \left(35 \cdot \frac{t^3}{t_2^3} - 60 \cdot \frac{t^2}{t_2^2} + 30 \cdot \frac{t}{t_2} - \right. \\ \left. - 4 \right) \cdot \frac{t}{t_2^5}.$$

In (9), (10) and (14) coordinates the initial position the center of mass of the trolley during acceleration x_{0p} coordinate and final braking process x_{1z} meet its extreme positions, however, are unknown speed \dot{x}_y forming trolley to steady state, the initial coordinates x_{0y} and final x_{1y} provisions of the center of mass of the trolley during steady motion.

Divide movement S forming the trolley from one extreme position to another in three areas: 1 – dispersal area, it corresponds to displacement S_p , 2 – a site settled movement, it corresponds to displacement S_y , 3 – part braking, it corresponds to displacement S_z . Subject to dependency (9), (10) and (14) Expressions movement at each site can be represented as:

$$S_p = \int_0^{t_p} \dot{x}_p dt = \dot{x}_y \cdot \int_0^{t_p} \left(35 \cdot \frac{t^8}{t_p^8} - 160 \cdot \frac{t^7}{t_p^7} + 280 \cdot \frac{t^6}{t_p^6} - 224 \cdot \frac{t^5}{t_p^5} + 70 \cdot \frac{t^4}{t_p^4} \right) dt =$$

$$= \dot{x}_y \cdot \left(\frac{35}{9} \cdot \frac{t^9}{t_p^8} - 20 \cdot \frac{t^8}{t_p^7} + 40 \cdot \frac{t^7}{t_p^6} - \frac{112}{3} \cdot \frac{t^6}{t_p^5} + 14 \cdot \frac{t^5}{t_p^4} \right) \Big|_0^{t_p} =$$

$$= \frac{5}{9} \cdot \dot{x}_y \cdot t_p, \quad (15)$$

$$S_y = \int_0^{t_y} \dot{x}_y dt = \dot{x}_y \cdot t_y = \dot{x}_y \cdot t_y, \quad (16)$$

$$S_z = \int_0^{t_z} \dot{x}_z dt = \dot{x}_y \cdot \int_0^{t_z} \left(35 \cdot \frac{t^8}{t_z^8} - 120 \cdot \frac{t^7}{t_z^7} + 140 \cdot \frac{t^6}{t_z^6} - 56 \cdot \frac{t^5}{t_z^5} + 1 \right) dt =$$

$$= \dot{x}_y \cdot \left(\frac{35}{9} \cdot \frac{t^9}{t_z^8} - 15 \cdot \frac{t^8}{t_z^7} + 20 \cdot \frac{t^7}{t_z^6} - \frac{28}{3} \cdot \frac{t^6}{t_z^5} + t \right) \Big|_0^{t_z} = \frac{5}{9} \cdot \dot{x}_y \cdot t_z.$$

Then the general expression trolley moving mold can be represented as:

$$S = S_p + S_y + S_z = \frac{5}{9} \cdot \dot{x}_y \cdot t_p +$$

$$+ \dot{x}_y \cdot t_y + \frac{5}{9} \cdot \dot{x}_y \cdot t_z = \dot{x}_y \cdot \left(\frac{5}{9} \cdot t_p + t_y + t_z + \frac{5}{9} \cdot t_z \right). \quad (18)$$

To ensure earthen molding cart with a constant speed on most of its working stroke take a steady traffic, for example, $t_y = \frac{2}{3} \cdot t_3$, where: t_3 – general driving bogie mold from one extreme position to another. Then, wondering condition equal time acceleration and braking

can be defined corresponding expressions: $t_p = \frac{1}{6} \cdot t_3$ and $t_z = \frac{1}{6} \cdot t_3$. Substituting the expression (18) $t_p = \frac{1}{6} \cdot t_3$, $t_y = \frac{2}{3} \cdot t_3$, $t_z = \frac{1}{6} \cdot t_3$ and the amplitude of movement of the trolley from one extreme position to another $\Delta x = S$. We get:

$$\Delta x = \dot{x}_y \cdot \left(\frac{5}{9} \cdot \frac{1}{6} \cdot t_3 + \frac{2}{3} \cdot t_3 + \frac{5}{9} \cdot \frac{1}{6} \cdot t_3 \right) =$$

$$= \frac{23}{27} \cdot \dot{x}_y \cdot t_3 \quad \Rightarrow \quad \dot{x}_y = \frac{27 \cdot \Delta x}{23 \cdot t_3} \quad (19)$$

Position coordinates forming trolley defining end areas of acceleration and steady movement start area x_{0y} . Can be determined from the expressions (15) and (19):

$$x_{0y} = \frac{5}{9} \cdot \dot{x}_y \cdot t_p = \frac{5}{9} \cdot \frac{27 \cdot \Delta x}{23 \cdot t_3} \cdot \frac{1}{6} \cdot t_3 = \frac{5}{46} \cdot \Delta x \quad (20)$$

and coordinate that defines the end areas of steady traffic x_{1y} and start braking areas can be determined from the expressions (16), (19) and (20):

$$x_{1y} = x_{0y} + \dot{x}_y \cdot t_y = \frac{5}{46} \cdot \Delta x + \frac{27 \cdot \Delta x}{23 \cdot t_3} \cdot \frac{2}{3} \cdot t_3 = \frac{41}{46} \cdot \Delta x. \quad (21)$$

Substituting (19)-(21) in equation (9), (10) and (14) and taking $t_p = \frac{1}{6} \cdot t_3$, $t_y = \frac{2}{3} \cdot t_3$, $t_z = \frac{1}{6} \cdot t_3$, Kinematic characteristics forming carts in areas of acceleration, deceleration and steady movement can be represented as:

$$x_p = \frac{69984}{23} \cdot \Delta x \cdot \left(\frac{17640}{7} \cdot \frac{t^4}{t_3^4} - 2160 \cdot \frac{t^3}{t_3^3} + 720 \cdot \frac{t^2}{t_3^2} - 112 \cdot \frac{t}{t_3} + 7 \right) \cdot \frac{t^5}{t_3^5},$$

$$\dot{x}_p = \frac{69984}{23} \cdot \Delta x \cdot \left(22680 \cdot \frac{t^4}{t_3^4} - 17280 \cdot \frac{t^3}{t_3^3} + 5040 \cdot \frac{t^2}{t_3^2} - 672 \cdot \frac{t}{t_3} + 35 \right) \cdot \frac{t^4}{t_3^4},$$

$$\ddot{x}_p = \frac{9797760}{23} \cdot \Delta x \cdot \left(1296 \cdot \frac{t^4}{t_3^4} - 864 \cdot \frac{t^3}{t_3^3} + 216 \cdot \frac{t^2}{t_3^2} - 24 \cdot \frac{t}{t_3} + 1 \right) \cdot \frac{t^3}{t_3^3},$$

$$\ddot{x}_p = \frac{29393280}{23} \cdot \Delta x \cdot \left(3024 \cdot \frac{t^4}{t_3^4} - 1728 \cdot \frac{t^3}{t_3^3} + 360 \cdot \frac{t^2}{t_3^2} - 32 \cdot \frac{t}{t_3} + 1 \right) \cdot \frac{t^2}{t_3^2},$$

$${}^{IV}x_p = \frac{58786560}{23} \cdot \Delta x \cdot \left(9072 \cdot \frac{t^4}{t_3^4} - 4320 \cdot \frac{t^3}{t_3^3} + 720 \cdot \frac{t^2}{t_3^2} - 48 \cdot \frac{t}{t_3} + 1 \right) \cdot \frac{t}{t_3}, \quad (22)$$

$$x_p = \frac{58786560}{23} \cdot \Delta x \cdot \left(\frac{45360 \cdot \frac{t^4}{t_3^4} - 17280 \cdot \frac{t^3}{t_3^3} + 2160 \cdot \frac{t^2}{t_3^2} - 96 \cdot \frac{t}{t_3} + 1}{t_3^5} \right) \cdot \frac{1}{t_3^5}$$

$$x_y = \frac{\Delta x}{46} \cdot \left(5 + 54 \cdot \frac{t}{t_3} \right), \quad \dot{x}_y = \frac{27 \cdot \Delta x}{23 \cdot t_3} = const, \quad (23)$$

$$\ddot{x}_y = 0, \quad \ddot{x}_y = 0, \quad x_y^{IV} = 0, \quad x_y^V = 0,$$

$$x_z = \Delta x + \frac{27}{23} \cdot \Delta x \cdot \left(\frac{6531840 \cdot \frac{t^9}{t_3^9} - 4199040 \cdot \frac{t^8}{t_3^8} + 933120 \cdot \frac{t^7}{t_3^7} - 72576 \cdot \frac{t^6}{t_3^6} + \frac{t}{t_3} - \frac{5}{54} \right),$$

$$\dot{x}_z = \frac{27}{23} \cdot \Delta x \cdot \left(\frac{58786560 \cdot \frac{t^8}{t_3^8} - 33592320 \cdot \frac{t^7}{t_3^7} + 6531840 \cdot \frac{t^6}{t_3^6} - 435456 \cdot \frac{t^5}{t_3^5} + \frac{1}{t_3} \right),$$

$$\ddot{x}_z = \frac{58786560}{23} \cdot \Delta x \cdot \left(\frac{216 \cdot \frac{t^3}{t_3^3} - 108 \cdot \frac{t^2}{t_3^2} + 18 \cdot \frac{t}{t_3} - 1}{t_3^6} \right) \cdot \frac{t^4}{t_3^6},$$

$$\ddot{x}_z = \frac{58786560}{23} \cdot \Delta x \cdot \left(\frac{1512 \cdot \frac{t^3}{t_3^3} - 648 \cdot \frac{t^2}{t_3^2} + 90 \cdot \frac{t}{t_3} - 4}{t_3^6} \right) \cdot \frac{t^3}{t_3^6},$$

$$x_z^{IV} = \frac{705438720}{23} \cdot \Delta x \cdot \left(\frac{756 \cdot \frac{t^3}{t_3^3} - 270 \cdot \frac{t^2}{t_3^2} + 30 \cdot \frac{t}{t_3} - 1}{t_3^6} \right) \cdot \frac{t^2}{t_3^6}, \quad (24)$$

$$x_z^V = \frac{1410877440}{23} \cdot \Delta x \cdot \left(\frac{1890 \cdot \frac{t^3}{t_3^3} - 540 \cdot \frac{t^2}{t_3^2} + 45 \cdot \frac{t}{t_3} - 1}{t_3^6} \right) \cdot \frac{t}{t_3^6}.$$

Amplitude displacement molding cart $\Delta x = 0,4M$ and total time it moves from one extreme position to another $t_3 = 3c$. By expressions (22)-(24) were calculated kinematic characteristics combined motion mode for forming the trolley acceleration fourth order. The calculations graphs change in displacement (Fig. 1, a), velocity (Fig. 1b), acceleration (Fig. 2, c) acceleration of the second order (jerk) (Fig. 1, d), acceleration of order (feeling) (Fig. 1 d) and fourth-order acceleration (Fig. 1, e) forming the motion of the trolley from one extreme position to another.

Turning the first equation expressions (22)-(24) in the case where the origin is measured from the middle position moving mold trolley, we get:

- acceleration at the site:

$$x_p = \frac{69984}{23} \cdot \Delta x \cdot \left(\frac{17640 \cdot \frac{t^4}{t_3^4} - 2160 \cdot \frac{t^3}{t_3^3} + 720 \cdot \frac{t^2}{t_3^2} - 112 \cdot \frac{t}{t_3} + 7}{t_3^5} \right) \cdot \frac{t^5}{t_3^5} - \frac{1}{2} \cdot \Delta x$$

- at the site of steady movement:

$$x_y = \frac{\Delta x}{46} \cdot \left(5 + 54 \cdot \frac{t}{t_3} \right) - \frac{1}{2} \cdot \Delta x, \quad (26)$$

- inhibition at the site:

$$x_z = \frac{1}{2} \cdot \Delta x + \frac{27}{23} \cdot \Delta x \cdot \left(\frac{6531840 \cdot \frac{t^9}{t_3^9} - 4199040 \cdot \frac{t^8}{t_3^8} + 933120 \cdot \frac{t^7}{t_3^7} - 72576 \cdot \frac{t^6}{t_3^6} + \frac{t}{t_3} - \frac{5}{54} \right). \quad (27)$$

The law of motion of the trolley described by equations (25) - (27) can be made with the drive cam (Fig. 2) reciprocating cart. This movement of the trolley in one direction is performed by turning the cam 1 by half a turn ($\varphi = \pi$) And in the opposite direction for another half a turn, full cycle of movement of the trolley - for one rotation of the cam. To implement the described law of motion of the trolley is necessary to increase the radius of the cam consistent growth moving truck. According to the variable cam radius is determined by dependencies:

- acceleration at the site:

$$\rho = \frac{b}{2} + \frac{69984}{23} \cdot \Delta x \cdot \left(\frac{17640 \cdot \frac{t^4}{t_3^4} - 2160 \cdot \frac{t^3}{t_3^3} + 720 \cdot \frac{t^2}{t_3^2} - 112 \cdot \frac{t}{t_3} + 7}{t_3^5} \right) \cdot \frac{t^5}{t_3^5}, \quad (28)$$

$$- \frac{1}{2} \cdot \Delta x$$

- at the site of steady movement:

$$\rho = \frac{b}{2} + \frac{\Delta x}{46} \cdot \left(5 + 54 \cdot \frac{t}{t_3} \right) - \frac{1}{2} \cdot \Delta x, \quad (29)$$

- inhibition at the site:

$$\rho = \frac{b}{2} + \frac{1}{2} \cdot \Delta x + \frac{27}{23} \cdot \Delta x \cdot \left(\frac{6531840 \cdot \frac{t^9}{t_3^9} - 4199040 \cdot \frac{t^8}{t_3^8} + 933120 \cdot \frac{t^7}{t_3^7} - 72576 \cdot \frac{t^6}{t_3^6} + \frac{t}{t_3} - \frac{5}{54} \right) \quad (30)$$

where: b – the distance between the pushers 2 (Fig. 2).

Time t be excluded from the dependence (28) - (30)

as $t = \frac{\varphi}{\omega}$ and $t_3 = \frac{\pi}{\omega}$. Here φ – angular coordinate rotation cam, and ω – angular velocity of the cam. Since the dispersal molding cart by dependence $t_p = \frac{1}{6} \cdot t_3$.

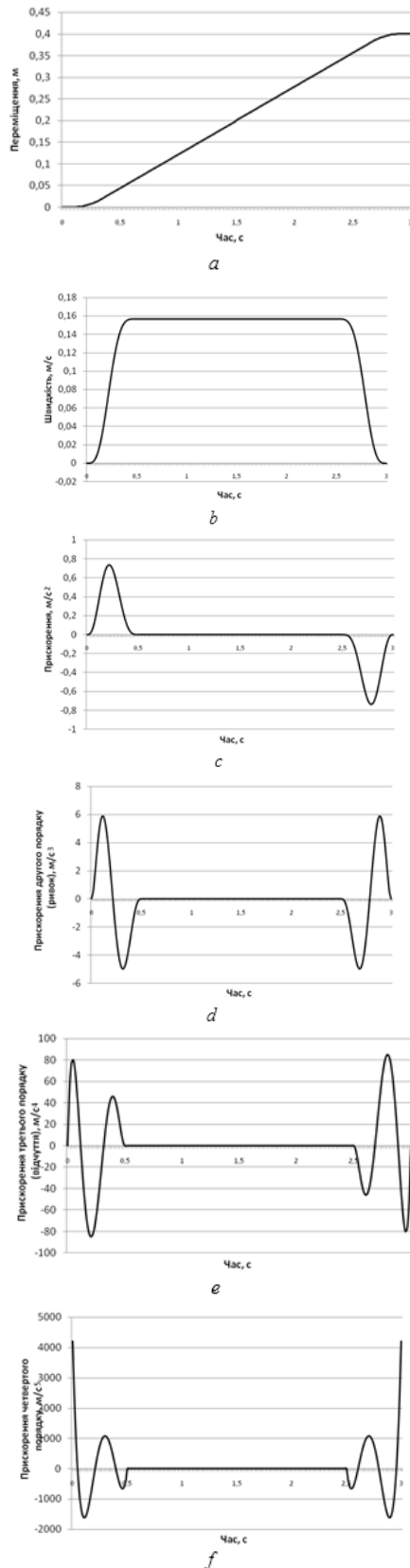


Fig. 1. Graphs of displacement – a, velocity – b, acceleration – c, acceleration of the second order (jerk) – d, the acceleration of the third order (the feeling) – e and acceleration of the fourth order in the combined mode of motion of the trolley with an acceleration of the fourth order – f.

The process will be carried acceleration while turning the cam at an angle of between $\varphi = 0$ to $\varphi = \pi/6$, a steady movement $-t_y = \frac{2}{3} \cdot t_3$. Then steady movement of the trolley will be provided to turn the cam angle ranges from $\varphi = \pi/6$ to $\varphi = 5\pi/6$, braking $-t_z = \frac{1}{6} \cdot t_3$. While braking process will be carried out when turning the cam at an angle of between $\varphi = 5\pi/6$ to $\varphi = \pi$.

After appropriate transformations radius cam that describes its profile is associated with an angular coordinate of the following expressions:

$$\rho = \frac{b}{2} + \frac{69984}{23} \cdot \Delta x \cdot \left(\frac{17640}{7} \cdot \frac{\varphi^4}{\pi^4} - 2160 \cdot \frac{\varphi^3}{\pi^3} + \right) \cdot \frac{\varphi^5}{\pi^5} - \frac{\Delta x}{2}, \quad (31)$$

$$-\frac{\Delta x}{2}, \quad 0 \leq \varphi \leq \frac{\pi}{6}$$

$$\rho = \frac{b}{2} + \frac{\Delta x}{46} \cdot \left[5 + 54 \cdot \left(\varphi - \frac{\pi}{6} \right) \cdot \frac{1}{\pi} \right] - \frac{\Delta x}{2}, \quad \frac{\pi}{6} < \varphi < \frac{5\pi}{6}, \quad (32)$$

$$\rho = \frac{b}{2} + \frac{\Delta x}{2} + \frac{27}{23} \Delta x \cdot \left(\frac{6531840 \left(\varphi - \frac{5\pi}{6} \right)^9 \frac{1}{\pi^9} - 4199040 \left(\varphi - \frac{5\pi}{6} \right)^8 \frac{1}{\pi^8} + 933120 \left(\varphi - \frac{5\pi}{6} \right)^7 \frac{1}{\pi^7} - 72576 \left(\varphi - \frac{5\pi}{6} \right)^6 \frac{1}{\pi^6} + \left(\varphi - \frac{5\pi}{6} \right) \frac{1}{\pi} - \frac{5}{54} \right) \cdot \frac{\varphi^5}{\pi^5} - \frac{\Delta x}{2}, \quad \frac{5\pi}{6} < \varphi \leq \pi. \quad (33)$$

Similarly, the cam profile is determined on the section of its rotation π to 2π . Which describes the radius of the changing relationship:

$$\rho = \frac{b}{2} - \frac{69984}{23} \Delta x \cdot \left[\frac{17640 (\varphi - \pi)^4}{7 \pi^4} - \frac{2160 (\varphi - \pi)^3}{\pi^3} + \frac{(\varphi - \pi)^5}{\pi^5} + \frac{720 (\varphi - \pi)^2}{\pi^2} - \frac{112 (\varphi - \pi)}{\pi} + 7 \right] \cdot \frac{\varphi^5}{\pi^5} + \frac{\Delta x}{2}, \quad \pi \leq \varphi \leq \frac{7\pi}{6}, \quad (34)$$

$$\rho = \frac{b}{2} - \frac{\Delta x}{46} \cdot \left[5 + 54 \cdot \left(\varphi - \frac{7\pi}{6} \right) \cdot \frac{1}{\pi} \right] + \frac{\Delta x}{2}, \quad (35)$$

$$\frac{7\pi}{6} < \varphi < \frac{11\pi}{6}$$

$$\rho = \frac{b}{2} - \frac{\Delta x}{2} + \frac{27}{23} \Delta x \left(\begin{aligned} &6531840 \left(\varphi - \frac{11\pi}{6} \right)^9 \frac{1}{\pi^9} - \\ &- 4199040 \left(\varphi - \frac{11\pi}{6} \right)^8 \frac{1}{\pi^8} + \\ &+ 933120 \left(\varphi - \frac{11\pi}{6} \right)^7 \frac{1}{\pi^7} - \\ &- 72576 \left(\varphi - \frac{11\pi}{6} \right)^6 \frac{1}{\pi^6} + \\ &+ \left(\varphi - \frac{11\pi}{6} \right) \frac{1}{\pi} - \frac{5}{54} \end{aligned} \right), \quad (36)$$

$$\frac{11\pi}{6} < \varphi \leq 2\pi.$$

To prevent strikes against the cam pushers when the direction of movement of the trolley described by equations (31)-(36) of the cam profile (Fig. 3) has the view that in any situation the diameter d – constant and equal to the distance between the pushers b ($d = b$).

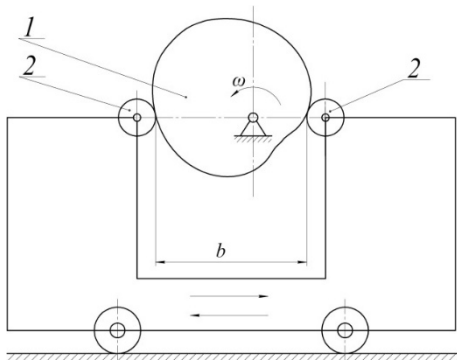


Fig. 2. Scheme of cam mechanism driven reciprocating trolley.

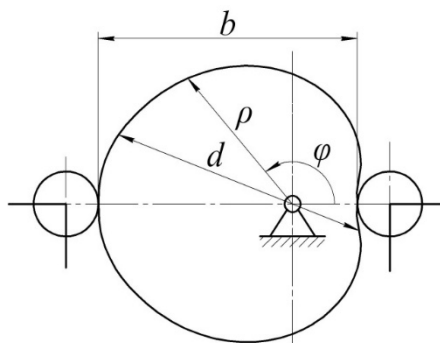


Fig. 3. The cam profile that implements forming a combined mode of movement for the trolley acceleration fourth order

In order to reduce dynamic loads in elements of installation and reliability to improve its proposed construction installation with a drive mechanism for providing reciprocating mold trolley with combined mode of movement acceleration fourth order (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 2 containing the feeding hopper 3 and 4 ukochuvalni rollers and makes reciprocating movement in

the guide 5 of the mold cavity 6. cart driven by reciprocating with two drives 7, attached to the portal 1 as 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 forming the trolley 2 can create hard power circuit with its forward and reverse course.

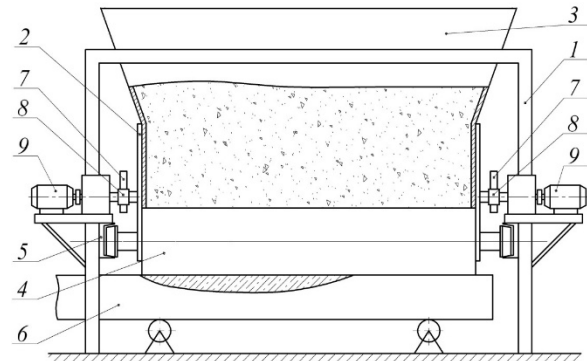


Fig. 4. Forming Roller cam unit with Drivers.

When used to install cam drive mechanism on each side forming trolley impossible its axial distortion, increased surface quality of machined concrete mix, reduced dynamic loads in elements of the drive reduces unnecessary disruptive burden on the frame structure and, consequently, increases the longevity of the installation as a whole.

CONCLUSIONS

1. As a result of studies to increase the reliability and durability of roller molding installations designed Hybrid reciprocating mold trolley acceleration for the fourth order.
2. Calculated cart kinematic characteristics forming the combined mode reciprocating movement acceleration fourth order.
3. The construction drive settings in a cam mechanism and cam profile is constructed to provide a combined mode reciprocating mold trolley acceleration for the fourth order.
4. The results may be useful in the future to refine and improve existing methods of calculation engineering machinery roller drive mechanisms of forming both stages of design/construction and real operation. Also, results may be useful in designing or improving mechanisms of reciprocating actuators.

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СИНТЕЗ КУЛАЧКОВОГО ПРИВОДНОГО
МЕХАНИЗМА РОЛИКОВОЙ ФОРМОВОЧНОЙ
УСТАНОВКИ С КОМБИНИРОВАННЫМ
РЕЖИМОМ ДВИЖЕНИЯ ПО УСКОРЕНИЮ
ЧЕТВЕРТОГО ПОРЯДКА

Аннотация. В целях увеличения надежности и долговечности ролика формируя установки оптимального режима движения вперед и назад в формующей тележки на разгон четвертого порядка рассчитывается. Кинематические характеристики формируя корзину при оптимальном режиме движения

на ускорение четвертого порядка рассчитываются. Дизайн роликовые формовочные установки с приводом от высокого момента шагового двигателя, который построен на прокатных роликах, образующих тележку и обеспечивает оптимальный режим движения вперед и назад формующей тележки на разгон четвертого порядка. Использование в установке указанного приводного механизма приводит к улучшению качества поверхности обрабатываемой бетонной смеси, снижение динамических нагрузок в элементах приводного механизма, к исчезновению лишнего разрушительных нагрузок конструкция рамы и, соответственно, увеличить надежность и долговечность установки в целом. В результате проведенных исследований в целях увеличения надежности и долговечности роликовые формовочные установки оптимального режима движения вперед и назад в формующей тележки на разгон четвертого порядка рассчитывается.

Кинематические характеристики формируя корзину в оптимальный режим движения вперед и назад на ускорение четвертого порядка рассчитываются.

Дизайн роликовые формовочные установки с приводом от высокого момента шагового двигателя, который построен на прокатных роликах, образующих тележку с возможностью реализации оптимального режима движения вперед и назад на ускорение четвертого порядка предлагается.

Проектирование привода установки в виде кулачкового механизма и профиля кулачка для обеспечения оптимального режима движения вперед и назад при формировании корзины на ускорение четвертого порядка строится.

Результаты работы в дальнейшем могут быть использованы для уточнения и совершенствования существующих инженерных методов расчета привода механизмов машин формирования ролика как на дизайн/этапах проектирования, и в режимах реальной эксплуатации. Также результаты работы могут быть полезны при проектировании или усовершенствовании механизмов с возвратно-поступательное движение исполнительных элементов.

Ключевые слова: роликовые формовочные установки, режим движения, шаг двигателя, привод.

