MOTROL

AN INTERNATIONAL JOURNAL
ON OPERATION OF FARM
AND AGRI-FOOD INDUSTRY MACHINERY

Polish Academy of Sciences
University of Engineering and Economics in Rzeszów
University of Life Sciences in Lublin

MOTROL

COMMISSION OF MOTORIZATION AND ENERGETICS IN AGRICULTURE

AN INTERNATIONAL JOURNAL
ON OPERATION OF FARM
AND AGRI-FOOD INDUSTRY MACHINERY

Vol. 19, No 3

LUBLIN – RZESZÓW 2017

Linguistic consultant: Ivan Rogovskii

Typeset: Dmytro Mischuk, Adam Niezbecki

Cover design: Hanna Krasowska-Kołodziej

Photo on the cover: Janusz Laskowski

All the articles are available on the webpage:
http://www.pan-ol.lublin.pl/wydawnictwa/Teka-Motrol.html

All the scientific articles received positive evaluations by independent reviewers

ISSN 1730-8658

Editorial Office address
Polish Academy of Sciences Branch in Lublin
Pałac Czartoryskich, Plac Litewski 2, 20-080 Lublin, Poland
e-mail: eugeniusz.krasowski@up.lublin.pl

Publishing Office address
National University of Life and Environmental Science of Ukraine
Geroyiv Oborony Str., 41, Kyiv, Ukraine, 03041
e-mail: irogovskii@gmail.comt

Printing
AgroMediaGroup, Novokonstantinovska Str. 4a, 04-080 Kiev, Ukraine
phone: +38 044 246 2735

Edition 150+16 vol.

REALIZATION OF OPTIMUM BREAKTHROUGH MODE OF REVERSAL OF ROLLER FORMING INSTALLATION

Vyacheslav Loveykin

National University of Life and Environmental Sciences of Ukraine
Str. Heroiv Oborony, 15, Kyiv, Ukraine. E-mail: lovvs@ukr.net

Konstantin Pochka

Kyiv National University of Construction and Architecture
Povitroflots'kyi Avenue, 31, Kyiv, 03680, Ukraine. E-mail: shanovniy@ukr.net

Received February 6.2017: accepted May 24.2017

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 with a breakthrough reversal is calculated. Kinematic characteristics of the forming cart at the optimum breakthrough mode of a reversal 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 reciprocating the movements of the forming cart with the optimum breakthrough mode of a reversal. 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 combined mode of back and forth motion of the forming cart with the optimum breakthrough mode of a reversal is calculated.

Kinematic characteristics of the forming cart are calculated at combined reciprocating the movements of the forming cart with the optimum breakthrough mode of a reversal.

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 combined back and forth motion of the forming cart with the optimum breakthrough mode of a reversal is offered.

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 the movement, step engine, drive.

INTRODUCTION

In the existing installations of superficial consolidation of concrete goods the crank ram or hydraulic drive of back and forth motion of the forming cart with the condensing rollers is used [1-3]. During the constant starting and brake modes of the movement there are considerable dynamic loadings in elements of the driving mechanism and in elements of the forming cart which can lead to premature getting out of installation of the working condition.

ANALYSIS OF RECENT RESEARCHES AND PUBLICATIONS

In the existing theoretical and pilot studies of cars of roller formation of concrete goods it is proved their design data and efficiency [1-3]. At the same time not enough attention is paid to a research to the operating dynamic loadings and the modes of the movement that considerably influences work of installation and quality of finished goods [4-19]. During the constant starting and brake modes of the movement there are considerable dynamic loadings in elements of the driving mechanism and in elements of the forming cart that can lead to premature getting out of installation of the working condition [4-19]. Therefore urgent there is a problem of improvement of the driving mechanism of roller forming installation for the purpose of providing such mode of the movement of the forming cart at which dynamic loadings in elements of installation would decrease and its durability increased.

OBJECTIVES

The purpose of work consists in improvement of a design of the driving mechanism of roller forming installation for increase in her reliability and durability.

THE MAIN RESULTS OF THE RESEARCH

For roller forming installation at consolidation of concrete mix it is desirable to have the constant speed of back and forth motion of the forming cart on all the site that positively would influence quality of finished product. However in practice such mode of the movement can't be carried out as in him there are no sites of start-up and braking without which there can't be a cyclic movement. Therefore it is offered to realize such mode of the movement of the forming cart at her movement from one extreme situation to another in which there would be sites of a reversal with the minimum dynamic loadings and movement sites with a constant speed.

For smooth process of a reversal of the forming cart it is offered to carry out him on the optimum breakthrough mode of the movement [20]. At the same time the speed and acceleration of the forming cart change smoothly, without creating considerable dynamic loadings in installation that in turn positively influences its durability.

Coefficients of unevenness of the movement and dynamism can be criteria of the mode of the movement of mechanisms and cars [20]. In this work as criterion of the mode of the movement the criteria action which is integral on time with sub integral function which expresses a measure of the movement or action of system is used. For the optimum breakthrough mode of a reversal we will have criterion of an optimality of the movement in a look:

$$I_W = \int_0^{t_r} W\,dt \to \min, \tag{1}$$

where: t – time, t_r – reversal duration, W – energy of breakthroughs:

$$W = \frac{1}{2}\cdot m \cdot \dddot{x}^2, \tag{2}$$

where: m – mass of the forming cart, $\dddot{x}$ – breakthrough (acceleration of the second order).

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

$$\frac{\partial W}{\partial x} - \frac{d}{dt}\frac{\partial W}{\partial \dot{x}} + \frac{d^2}{dt^2}\frac{\partial W}{\partial \ddot{x}} - \frac{d^3}{dt^3}\frac{\partial W}{\partial \dddot{x}} = 0, \tag{3}$$

where: x, $\dot{x}$, $\ddot{x}$ – movement coordinate, speed and acceleration of the cart respectively.

From expression (3) it is possible to write down:

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

From the last equation (4) we receive the differential equation and its decisions:

$$\begin{aligned} &\overset{VI}{x} = 0; \quad \overset{V}{x} = C_1; \quad \overset{IV}{x} = C_1 \cdot t + C_2; \\ &\dddot{x} = \frac{1}{2}\cdot C_1 \cdot t^2 + C_2 \cdot t + C_3; \\ &\ddot{x} = \frac{1}{6}\cdot C_1 \cdot t^3 + \frac{1}{2}\cdot C_2 \cdot t^2 + C_3 \cdot t + C_4; \\ &\dot{x} = \frac{1}{24}\cdot C_1 \cdot t^4 + \frac{1}{6}\cdot C_2 \cdot t^3 + \frac{1}{2}\cdot C_3 \cdot t^2 + C_4 \cdot t + C_5; \\ &x = \frac{1}{120}\cdot C_1 \cdot t^5 + \frac{1}{24}\cdot C_2 \cdot t^4 + \frac{1}{6}\cdot C_3 \cdot t^3 + \frac{1}{2}\cdot C_4 \cdot t^2 + C_5 \cdot t + C_6, \end{aligned} \tag{5}$$

where: C_1, C_2, C_3, C_4, C_5, C_6 – integration constants which are defined from boundary conditions.

We will divide process of a reversal into two stages: braking and start-up.

When braking by entry conditions is: $t=0$: $x=-x_1$, $\dot{x}=\dot{x}_e$, $\ddot{x}=0$. Final conditions when braking: $t=t_b$: $x=0$, $\dot{x}=0$, $\ddot{x}=0$. Here x_1 – the coordinate of the beginning of process of braking, $\dot{x}_e$ – speed of the movement of the cart on established the mode prior to braking.

At start-up by entry conditions is: $t=0$: $x=0$, $\dot{x}=0$, $\ddot{x}=0$. Final conditions at start-up: $t=t_s$: $x=-x_1$, $\dot{x}=-\dot{x}_e$, $\ddot{x}=0$.

We will consider braking process. Having substituted boundary conditions of braking in the equations (5), we receive:

$$t=0: \quad C_6 = -x_1; \quad \tilde{N}_5 = \dot{x}_e; \quad \tilde{N}_4 = 0; \tag{6}$$

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

Having solved system of the equations (7), we receive integration constants C_1, C_2 and C_3:

$$C_1 = \frac{360\cdot\left(2\cdot\frac{x_1}{t_b} - \dot{x}_e\right)}{t_{\grave{o}}^4}, \quad C_2 = \frac{24\cdot\left(8\cdot\dot{x}_e - 15\cdot\frac{x_1}{t_b}\right)}{t_b^3}, \quad C_3 = \frac{12\cdot\left(5\cdot\frac{x_1}{t_b} - 3\cdot\dot{x}_e\right)}{t_b^2}. \tag{8}$$

After substitution of certain constants of integration (6) and (8) in system of the equations (5) we receive function of change of breakthrough of the forming cart in the course of braking from the established speed $\dot{x}_e$ to a full stop:

$$\dddot{x} = 180\cdot\left(2\cdot\frac{x_1}{t_b} - \dot{x}_e\right)\cdot\frac{t^2}{t_b^4} + 24\cdot\left(8\cdot\dot{x}_e - 15\cdot\frac{x_1}{t_b}\right)\cdot\frac{t}{t_b^3} + 12\cdot\left(5\cdot\frac{x_1}{t_b} - 3\cdot\dot{x}_e\right)\cdot\frac{1}{t_b^2} \tag{9}$$

or

$$\ddot{x} = \frac{12}{t_b^2} \cdot \left[\begin{array}{l} 15 \cdot \left(2 \cdot \frac{x_1}{t_b} - \dot{x}_e \right) \cdot \frac{t^2}{t_b^2} + \\ + 2 \cdot \left(8 \cdot \dot{x}_e - 15 \cdot \frac{x_1}{t_b} \right) \cdot \frac{t}{t_b} + \\ + \left(5 \cdot \frac{x_1}{t_b} - 3 \cdot \dot{x}_e \right) \end{array} \right]. \quad (10)$$

After that the criterion of an optimality of the movement in the course of braking taking into account expression (2) and (10) will have an appearance:

$$I_{Wb} = \frac{m}{2} \cdot \int_0^{t_b} \ddot{x}^2 \, dt =$$

$$= \frac{72 \cdot m}{t_b^4} \int_0^{t_b} \left[\begin{array}{l} 15 \cdot \left(2 \cdot \frac{x_1}{t_b} - \dot{x}_e \right) \cdot \frac{t^2}{t_b^2} + \\ + 2 \cdot \left(8 \cdot \dot{x}_e - 15 \cdot \frac{x_1}{t_b} \right) \cdot \frac{t}{t_b} + \\ + \left(5 \cdot \frac{x_1}{t_b} - 3 \cdot \dot{x}_e \right) \end{array} \right]^2 dt = \quad (11)$$

$$= \frac{72 \cdot m}{t_b^3} \cdot \left[5 \cdot \frac{x_1^2}{t_b^2} - 5 \cdot \frac{x_1}{t_b} \cdot \dot{x}_e + \frac{4}{3} \cdot \dot{x}_e^2 \right].$$

We will consider start-up process. Having substituted boundary conditions of start-up in the equations (5), we receive:

$$t = 0: \quad C_4 = 0; \quad \tilde{N}_5 = 0; \quad \tilde{N}_6 = 0; \quad (12)$$

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

Having solved system of the equations (13), we receive integration constants C_1, C_2 and C_3:

$$C_1 = \frac{360 \cdot \left(\dot{x}_e - 2 \cdot \frac{x_1}{t_s} \right)}{t_s^4},$$

$$C_2 = \frac{24 \cdot \left(15 \cdot \frac{x_1}{t_s} - 7 \cdot \dot{x}_e \right)}{t_s^3}, \quad (14)$$

$$C_3 = \frac{12 \cdot \left(2 \cdot \dot{x}_e - 5 \cdot \frac{x_1}{t_s} \right)}{t_s^2}.$$

After substitution of certain constants of integration (12) and (14) in system of the equations (5) we receive function of change of breakthrough of the forming cart in the course of start-up from a condition of rest to an exit to the set mode of the movement:

$$\begin{aligned} \ddot{x} = & 180 \cdot \left(\dot{x}_e - 2 \cdot \frac{x_1}{t_s} \right) \cdot \frac{t^2}{t_s^4} + \\ & + 24 \cdot \left(15 \cdot \frac{x_1}{t_s} - 7 \cdot \dot{x}_e \right) \cdot \frac{t}{t_s^3} + \\ & + 12 \cdot \left(2 \cdot \dot{x}_e - 5 \cdot \frac{x_1}{t_s} \right) \cdot \frac{1}{t_s^2} \end{aligned} \quad (15)$$

or

$$\ddot{x} = \frac{12}{t_s^2} \cdot \left[\begin{array}{l} 15 \cdot \left(\dot{x}_e - 2 \cdot \frac{x_1}{t_s} \right) \cdot \frac{t^2}{t_s^2} + \\ + 2 \cdot \left(15 \cdot \frac{x_1}{t_s} - 7 \cdot \dot{x}_e \right) \cdot \frac{t}{t_s} + \\ + \left(2 \cdot \dot{x}_e - 5 \cdot \frac{x_1}{t_s} \right) \end{array} \right]. \quad (16)$$

After that the criterion of an optimality of the movement in the course of start-up taking into account expression (2) and (16) will have an appearance:

$$I_{Ws} = \frac{m}{2} \cdot \int_0^{t_s} \ddot{x}^2 \, dt =$$

$$= \frac{72 \cdot m}{t_s^4} \cdot \int_0^{t_s} \left[\begin{array}{l} 15 \cdot \left(\dot{x}_e - 2 \cdot \frac{x_1}{t_s} \right) \cdot \frac{t^2}{t_s^2} + \\ + 2 \cdot \left(15 \cdot \frac{x_1}{t_s} - 7 \cdot \dot{x}_e \right) \cdot \frac{t}{t_s} + \\ + \left(2 \cdot \dot{x}_e - 5 \cdot \frac{x_1}{t_s} \right) \end{array} \right]^2 dt = \quad (17)$$

$$= \frac{72 \cdot m}{t_s^3} \cdot \left[5 \cdot \frac{x_1^2}{t_s^2} - 5 \cdot \frac{x_1}{t_s} \cdot \dot{x}_e + \frac{4}{3} \cdot \dot{x}_e^2 \right].$$

The general criterion of an optimality of the movement in the course of a reversal (11) and (17) will be defined with expressions by the following expression:

$$\begin{aligned} I_W = & I_{Wb} + I_{Ws} = \\ = & \frac{72 \cdot m}{t_b^3} \cdot \left[5 \cdot \frac{x_1^2}{t_b^2} - 5 \cdot \frac{x_1}{t_b} \cdot \dot{x}_e + \frac{4}{3} \cdot \dot{x}_e^2 \right] + \\ & + \frac{72 \cdot m}{t_s^3} \cdot \left[5 \cdot \frac{x_1^2}{t_s^2} - 5 \cdot \frac{x_1}{t_s} \cdot \dot{x}_e + \frac{4}{3} \cdot \dot{x}_e^2 \right]. \end{aligned} \quad (18)$$

Having accepted equality of duration of braking of the cart and its start-up $t_b = t_s = t_1$, expression (18) can be given in the following look:

$$I_W = \frac{144 \cdot m}{t_1^3} \cdot \left[5 \cdot \frac{x_1^2}{t_1^2} - 5 \cdot \frac{x_1}{t_1} \cdot \dot{x}_e + \frac{4}{3} \cdot \dot{x}_e^2 \right]. \quad (19)$$

For ensuring performance of inequality (1) it is necessary to satisfy a condition:

$$\frac{\partial I_W}{\partial x_1}=\frac{144\cdot m}{t_1^3}\cdot\left[10\cdot\frac{x_1}{t_1^2}-5\cdot\frac{\dot{x}_e}{t_1}\right]=$$
$$=\frac{720\cdot m}{t_1^4}\cdot\left[2\cdot\frac{x_1}{t_1}-\dot{x}_e\right]=0. \quad (20)$$

From expression (20) it is possible to receive:

$$2\cdot\frac{x_1}{t_1}-\dot{x}_e=0 \quad \Rightarrow \quad x_1=\frac{1}{2}\cdot\dot{x}_e\cdot t_1. \quad (21)$$

Having substituted the second expression (21) in equalities (6) and (8) integration constants in the course of braking of the forming cart are received:

$$C_1=0,\quad C_2=12\cdot\frac{\dot{x}_e}{t_1^3},\quad C_3=-6\cdot\frac{\dot{x}_e}{t_1^2},$$
$$\tilde{N}_4=0,\quad \tilde{N}_5=\dot{x}_e,\quad C_6=-\frac{1}{2}\cdot\dot{x}_e\cdot t_1. \quad (22)$$

After that taking into account constants of integration (22) functions of change of movement, speed, acceleration and breakthrough of the forming cart in the course of braking are received:

$$x=\frac{1}{2}\cdot\dot{x}_e\cdot\left(\frac{t^4}{t_1^3}-2\cdot\frac{t^3}{t_1^2}+2\cdot t-t_1\right);$$
$$\dot{x}=\dot{x}_e\cdot\left(2\cdot\frac{t^3}{t_1^3}-3\cdot\frac{t^2}{t_1^2}+1\right); \quad (23)$$
$$\ddot{x}=6\cdot\dot{x}_e\cdot\left(\frac{t^2}{t_1^3}-\frac{t}{t_1^2}\right);\quad \dddot{x}=6\cdot\dot{x}_e\cdot\left(2\cdot\frac{t}{t_1^3}-\frac{1}{t_1^2}\right).$$

Having substituted the second expression (21) in equalities (12) and (14) integration constants in the course of launch of the forming cart are received:

$$C_1=0,\quad C_2=12\cdot\frac{\dot{x}_e}{t_1^3},\quad C_3=-6\cdot\frac{\dot{x}_e}{t_1^2},$$
$$\tilde{N}_4=0,\quad \tilde{N}_5=0,\quad C_6=0. \quad (24)$$

After that taking into account constants of integration (24) functions of change of movement, speed, acceleration and breakthrough of the forming cart in the course of start-up are received:

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

On the set mode of the movement of the forming cart the coordinate of movement, speed, acceleration and breakthrough of her center of masses are described by the equations [20]:

$$x=x_{0e}+\frac{(x_{1e}-x_{0e})\cdot t}{t_e};$$
$$\dot{x}=\frac{(x_{1e}-x_{0e})}{t_e}=const; \quad (26)$$
$$\ddot{x}=0;\quad \dddot{x}=0,$$

where: x_{0e} and x_{1e} – coordinates of initial and final provisions of the center of mass of the cart at the established movement, t_e – duration of the established movement.

In expressions (26) we accept the coordinate of initial position of the center of mass of the cart at the established movement x_{0e} equal x_1. Then, having accepted amplitude of movement of the cart from one extreme situation in another Δx, the final coordinate of position of the center of mass of the cart at the established movement can be determined $x_{1e}=\Delta x-x_1$.

Having substituted the received coordinates x_{0e} and x_{1e} in the second expression (26) dependence for determination of speed of the movement of the cart on the established movement is received $\dot{x}_e$:

$$\dot{x}_e=\frac{\Delta x-2\cdot x_1}{t_e}=\frac{\Delta x-\dot{x}_e\cdot t_1}{t_e}\Rightarrow\dot{x}_e=\frac{\Delta x}{t_e+t_1}. \quad (27)$$

Having accepted the general time of the movement of the forming cart from one extreme situation in another t_g, he can be divided into three parts: starting time – t_s, time of the established movement – t_e, braking time – t_b. For ensuring consolidation of concrete mix with the forming cart with a constant speed of the movement on the majority of her working course we will accept time of the established movement, for example, $t_e={}^2\!/_3\cdot t_g$. Then, having set by a condition of equality of time of start-up and braking, they can be determined by corresponding expressions: $t_s=t_b=t_1={}^1\!/_6\cdot t_g$.

After this expression of speed of the movement of the cart on the established movement and coordinates x_1 will have an appearance:

$$\dot{x}_e=\frac{6\cdot\Delta x}{5\cdot t_g},\qquad x_1=\frac{\Delta x}{10}. \quad (28)$$

Considering the movement of the forming cart from one extreme situation in another and having substituted expressions (28) in equalities (23), (25) and (26), we receive functions of change of movement, speed, acceleration and breakthrough of the forming cart

– on the site of start-up:

$$x=\frac{216\cdot\Delta x}{5}\cdot\left(\frac{t^3}{t_g^3}-3\cdot\frac{t^4}{t_g^4}\right);$$
$$\dot{x}=\frac{648\cdot\Delta x}{5}\cdot\left(\frac{t^2}{t_g^3}-4\cdot\frac{t^3}{t_g^4}\right); \quad (29)$$
$$\ddot{x}=\frac{1296\cdot\Delta x}{5}\cdot\left(6\cdot\frac{t^2}{t_g^4}-\frac{t}{t_g^3}\right);$$
$$\dddot{x}=\frac{1296\cdot\Delta x}{5}\cdot\left(\frac{1}{t_g^3}-12\cdot\frac{t}{t_g^4}\right);$$

– on the site of the established movement:

$$x=\frac{\Delta x}{10}+\frac{6\cdot\Delta x\cdot t}{5\cdot t_g};\quad \dot{x}=\frac{6\cdot\Delta x}{5\cdot t_g}=const;\qquad \ddot{x}=0;\quad \dddot{x}=0; \tag{30}$$

– on the site of braking:

$$x=\frac{3\cdot\Delta x}{5}\cdot\left(216\cdot\frac{t^4}{t_g^4}-72\cdot\frac{t^3}{t_g^3}+2\cdot\frac{t}{t_g}+\frac{3}{2}\right);$$

$$\dot{x}=\frac{6\cdot\Delta x}{5}\cdot\left(432\cdot\frac{t^3}{t_g^4}-108\cdot\frac{t^2}{t_g^3}+\frac{1}{t_g}\right); \tag{31}$$

$$\ddot{x}=\frac{1296\cdot\Delta x}{5}\cdot\left(6\cdot\frac{t^2}{t_g^4}-\frac{t}{t_g^3}\right);$$

$$\dddot{x}=\frac{1296\cdot\Delta x}{5}\cdot\left(12\cdot\frac{t}{t_g^4}-\frac{1}{t_g^3}\right). \tag{31}$$

Having accepted amplitude of movement of the forming cart $\Delta x=0{,}4m$ and duration of the movement of the forming cart from one extreme situation to another $t_g=3s$, on the equations (29)-(31) kinematic characteristics have been calculated and schedules of change of movement (Fig. 1, a), speeds (Fig. 1, b), accelerations (Fig. 1, c) and breakthrough are constructed (Fig. 1, d) at the movement of the forming cart from one extreme situation to another and in the opposite direction with the optimum breakthrough mode of a reversal.

The law of the movement of the cart described by the equations (29)-(31) can be carried out by the drive from the high-moment step engine which is built in the rolling rollers of the forming cart of installation. At the same time the law of change of angular speed of the driving step engine is described by the equations:

– on the site of start-up:

$$\dot{\varphi}_s=\frac{1}{R}\cdot\frac{648\cdot\Delta x}{5}\cdot\left(\frac{t^2}{t_g^3}-4\cdot\frac{t^3}{t_g^4}\right), \tag{32}$$

– on the site of the established movement:

$$\dot{\varphi}_e=\frac{1}{R}\cdot\frac{6\cdot\Delta x}{5\cdot t_g}, \tag{33}$$

– on the site of braking:

$$\dot{\varphi}_b=\frac{1}{R}\cdot\frac{6\cdot\Delta x}{5}\cdot\left(432\cdot\frac{t^3}{t_g^4}-108\cdot\frac{t^2}{t_g^3}+\frac{1}{t_g}\right). \tag{34}$$

where: R – radius of the rolling rollers.

Having accepted time of start-up of the forming cart $t_s=\frac{1}{6}\cdot t_g$, time of the established movement – $t_e=\frac{2}{3}\cdot t_g$ and braking time – $t_b=\frac{1}{6}\cdot t_g$ we receive the law of change of angular speed of the driving step engine at the movement of the forming cart from one extreme situation to another:

$$\dot{\varphi}=\frac{648\cdot\Delta x}{5\cdot R}\cdot\left(\frac{t^2}{t_g^3}-4\cdot\frac{t^3}{t_g^4}\right),\quad 0\le t\le\frac{t_g}{6}, \tag{35}$$

$$\dot{\varphi}=\frac{6\cdot\Delta x}{5\cdot R\cdot t_g},\quad \frac{t_g}{6}<t<\frac{5\cdot t_g}{6}, \tag{36}$$

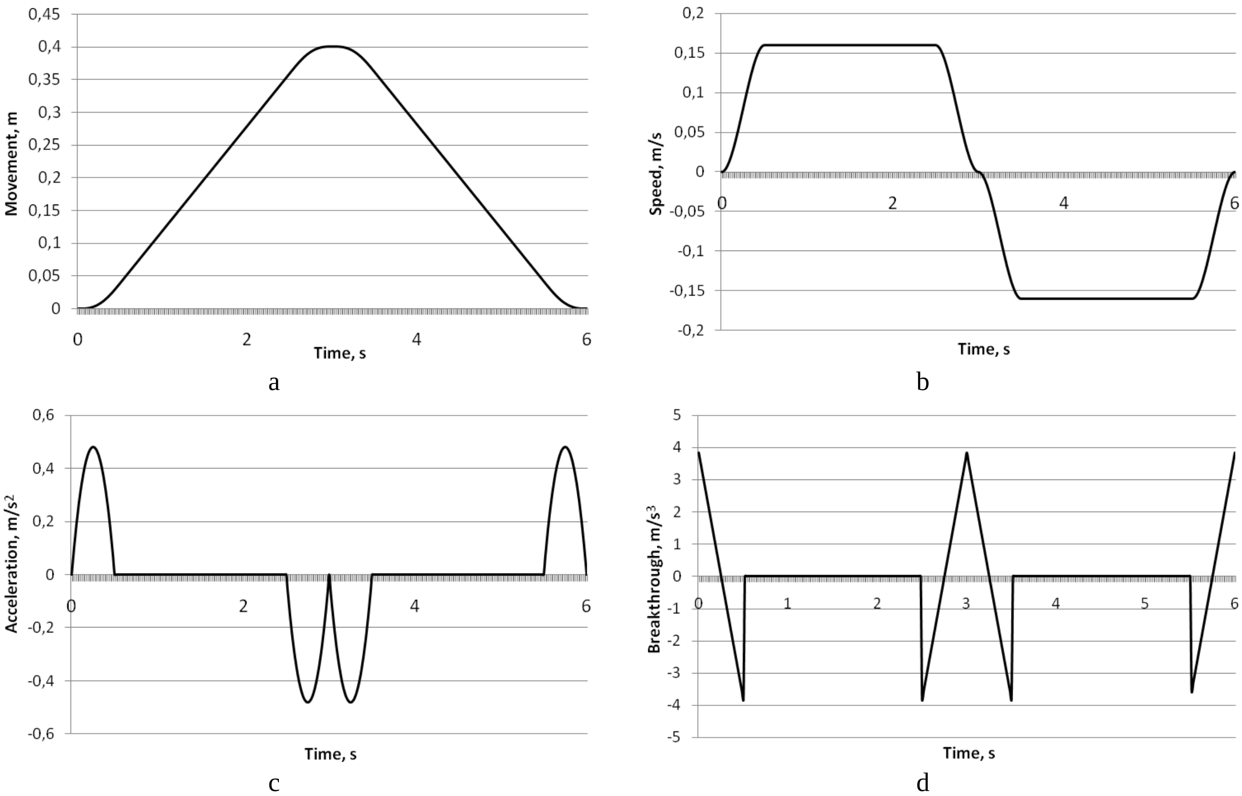

Fig. 1. Schedules of change of movement – a, speed – b, acceleration – c and breakthrough – d at the movement of the forming cart with the optimum breakthrough mode of a reversal.

$$\dot{\varphi} = \frac{6\Delta x}{5R}\left(432\frac{\left(t-\frac{5t_g}{6}\right)^3}{t_g^4} - 108\frac{\left(t-\frac{5t_g}{6}\right)^2}{t_g^3} + \frac{1}{t_g} \right), \quad \frac{5t_g}{6} < t \le t_g . \quad (37)$$

Similarly the law of change of angular speed of the driving step engine at the movement of the forming cart is defined in the opposite direction:

$$\dot{\varphi} = -\frac{648 \cdot \Delta x}{5 \cdot R} \cdot \left[\frac{(t-t_g)^2}{t_g^3} - 4\frac{(t-t_g)^3}{t_g^4} \right], \quad t_g \le t \le \frac{7 \cdot t_g}{6}, \quad (38)$$

$$\dot{\varphi} = -\frac{6 \cdot \Delta x}{5 \cdot R \cdot t_g}, \qquad \frac{7 \cdot t_g}{6} < t < \frac{11 \cdot t_g}{6}, \quad (39)$$

$$\dot{\varphi} = -\frac{6\Delta x}{5R}\left[432\frac{\left(t-\frac{11t_g}{6}\right)^3}{t_g^4} - 108\frac{\left(t-\frac{11t_g}{6}\right)^2}{t_g^3} + \frac{1}{t_g} \right], \quad \frac{11t_g}{6} < t \le 2t_g . \quad (40)$$

For the purpose of reduction of dynamic loadings in elements of installation and for increase in her reliability the design of roller forming installation with the drive from the high-moment step engine for ensuring back and forth motion of the forming cart with the optimum breakthrough mode of a reversal (Fig. 2) is offered. Installation consists from the forming cart 1 which is mounted on the portal 2 and carries out back and forth motion in guides 3 over emptiness of a form 4. The forming cart contains the giving bunker 5 and the rolling rollers 6 on axis 7.

The cart is set in back and forth motion by means of the high-moment step engine which is built in rollers, and the axis of a roller plays a stator role, and a roller – a rotor [21].

When using in installation of the drive from the high-moment step engine which is built in the rolling rollers which law of change of angular speed is described by the equations given above quality of the processed concrete mix increases, dynamic loadings in drive elements decrease, excess destructive loads of a frame design decrease and, respectively, durability of installation in general increases.

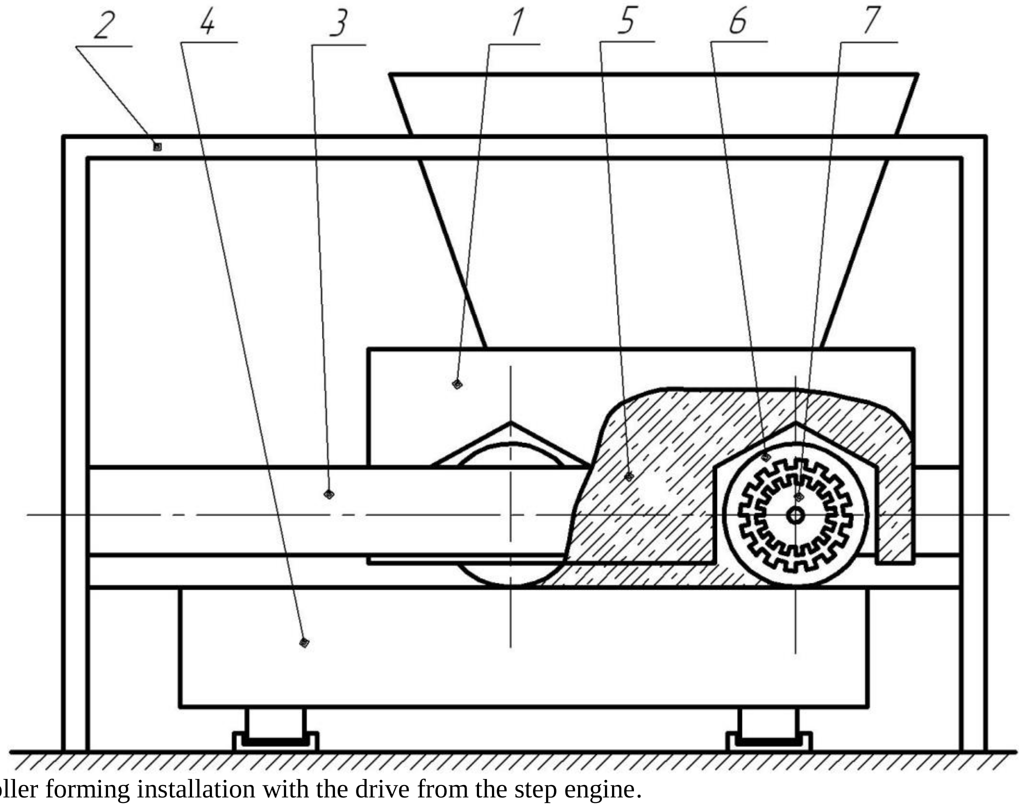

Fig. 2. Roller forming installation with the drive from the step engine.

CONCLUSIONS

1. As a result of the conducted researches for the purpose of increase in reliability and durability of roller forming installation the combined mode of back and forth motion of the forming cart with the optimum breakthrough mode of a reversal is calculated.

2. Kinematic characteristics of the forming cart are calculated at combined reciprocating the movements of the forming cart with the optimum breakthrough mode of a reversal.

3. 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 combined back and forth motion of the forming cart with the optimum breakthrough mode of a reversal is offered.

4. 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.

REFERENCES

1. **Garnec V.M. 1991.** Progresivni betonofor-mujuchi agregati i kompleksi. Kyiv. Budivel'nik. 144.
2. **Kuzin V.N. 1981.** Tehnologija rolikovogo formovanija ploskih izdelij iz melkozernistyh betonov: Avtoref. dis. kand. nauk. Moscow. 20.
3. **Rjushin V.T. 1986.** Issledovanie rabochego processa i razrabotka metodiki rascheta mashin rolikovogo formovanija betonnyh smesej: Dissertacija na soiskanie uchenoj stepeni kandidata tehnicheskih nauk. Kyiv. 20.
4. **Lovejkin V.S. 2004.** Patent Ukraini na vina-hid № 67091 A. Ustanovka dlja formuvannja virobiv z betonnih sumishej / V.S. Lovejkin, V.M. Garnec, K.I. Pochka № u2003076371 zajavl. 08.07.2003, opubl. 15.06.2004, Bjul. № 6.
5. **Lovejkin V.S. 2004.** Dinamichnij analiz roli-kovoї formovochnoї ustanovki z rekuperacij-nim privodom / V.S. Lovejkin, K.I. Pochka // Dinamika, micnist i nadijnist silskogospodar-skih mashin: Pr. I-ї Mizhnarod-noї naukovo-tehnichnoї konferencії (DSR AM-I), 4-7 zhov-tnja 2004 r. – Ternopil' (Ukraїna). 507-514.
6. **Lovejkin V.S. 2003.** Silovij analiz rolikovoї formovochnoї ustanovki z rekuperacijnim pri-vodom / V.S. Lovejkin, K.I. Pochka // Tehnika budivnictva. Kyiv. Vyp. 14. 27-37.
7. **Lovejkin V.S. 2005.** Analiz nerivnomirnosti ruhu rolikovoї formovochnoї ustanovki z rekuperacijnim privodom / V.S. Lovejkin, K.I. Pochka // Naukovo-tehnichnij ta virobnichij zhurnal «Pidjomno-transportna tehnika». Vyp. 4. 19-33.
8. **Lovejkin V.S. 2004.** Optimizacija konstruk-tivnih parametriv privodnogo mehanizmu roli-kovoї formovochnoї ustanovki z rekuperacijnim privodom / V.S. Lovejkin, D.A. Palamarchuk, K.I. Pochka // Naukovo-tehnichnij zhurnal «Tehnika budivnictva». № 15. – 40-48.
9. **Pochka K.I. 2008.** Rozrobka ta analiz roli-kovoi formuvalnoi ustanovki z rekuperacijnim privodom: Avtoref. dis. kand. nauk. / K.I. Pochka. K.: KNUBA. 24.
10. **Lovejkin V.S. 2010.** Dinamichnij analiz rolikovoї formuvalnoї ustanovki z energetichno vrivnovazhenim privodom / V.S. Lovejkin, V.P. Kovbasa, K.I. Pochka // Naukovij visnik Nacionalnogo universitetu bioresursiv i priro-dokoristuvannja Ukraini. Serija: tehnika ta energetika APK. K. Vyp. 144, ch. 5. 338-344.
11. **Lovejkin V.S. 2011.** Silovij analiz roliko-voї formuvalnoї ustanovki z energetichno vrivnovazhenim privodom. / V.S. Lovejkin, V.P. Kovbasa, K.I. Pochka // Naukovij visnik Tavrijs'kogo derzhavnogo agrotehnologichnogo universitetu. – Melitopol: TDATU. – Vyp. 1, Tom 2. – 16-23.
12. **Lovejkin V.S. 2010.** Analiz nerivnomir-nosti ruhu rolikovoї formuvalnoї ustanovki z energetichno vrivnovazhenim privodom / V.S. Lovejkin, K.I. Pochka // Vibracії v tehnici ta tehnologijah. – № 4 (60). – 20-29.
13. **Lovejkin V.S. 2010.** Optimizacija kons-truktivnih parametriv privodnogo mehanizmu roli-kovoї formuvalnoї ustanovki z energetichno vrivnovazhenim privodom / V.S. Lovejkin, K.I. Pochka // MOTROL. Motorization and power industry in agriculture. – Tom 12 B. – Lublin. – 9-18.
14. **Lovejkin V.S. 2004.** Analiz ruhu rolikovoї formovochnoї ustanovki z vrivnovazhenim privodom. / V.S. Lovejkin, K.I. Pochka // Visnik Harkivs'kogo nacional'nogo avtomobilno-do-rozhnogo universitetu. – № 27. – 95-101.
15. **Lovejkin V.S. 2005.** Silovij analiz rolikovo formovochnoї ustanovki z vrivnovazhenim privodom / V.S. Lovejkin, K.I. Pochka // Naukovij visnik Nacionalnogo agrarnogo universitetu. Vyp. 80. 346-356.
16. **Lovejkin V.S. 1989.** Ocenka dvizhenija mehanizmov i mashin // Podyemno-transport-noe oborudovanie. K.: Tjehnika. 16-18.
17. **Lovejkin V.S. 2011.** Optimizacija rezhimu zmini vilotu vantazhu bashtovogo krana za odinichnimi kinematichnimi kriterijami. / V.S. Lovejkin, Ju.O. Romasevich, G.V. Shumilov // MOTROL. Motorization and power industry in agriculture. –Tom 13 B. – Lublin. – 167-174.
18. **Lovejkin V.S. 2015.** Analiz neravnomer-nosti dvizhenija rolikovoj formovochnoj ustano-vki s uravnoveshennym privodom / V.S. Lovej-kin, K.I. Pochka // MOTROL. Commission of Motorization and Energetics in Agriculture – Vol. 17, No 3. – Lublin-Rzeszow. 17-27.
19. **Lovejkin V.S. 2016.** Analiz dinamichesko-go uravnoveshivanija privodov mashin roliko-vogo formovanija / V.S. Lovejkin, K.I. Pochka // MOTROL. Commission of Motorization and Energetics in Agriculture – Vol. 18, No 3. Lublin-Rzeszow. 41-52.
20. **Lovejkin V.S. 1990.** Raschjoty optimal'nyh rezhimov dvizhenija mehanizmov stroitel'nyh mashin. Uchebnoe posobie. / V.S. Lovejkin. – Kiev: UMK VO. 168.
21. **Lovejkin V.S. 2014.** Patent Ukraini na vi-nahid № 105744. Ustanovka dlja formuvannja virobiv z betonnih sumishej / V.S. Lovejkin, K.I. Pochka, Ju.V. Chovnjuk, M.G. Dikteruk. – № a201309305 zajavl. 25.07.2013, opubl. 10.06.2014, Bjul. № 11.