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THE INFLUENCE OF THE CONNECTING ROD-ROCKER KINEMATIC PAIR LOCATION ON OSCILLATION OF THE IMPACT MECHANISM MO-10

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Keywords: crank-rocker impact mechanism, housing oscillation, forcing moment, amplitude, frequency, rational arrangement of the connecting rod-rocker kinematic pair.
Abstract. A description of the design and principle of the MO-10 crank-rocker impact mechanism operation for cleaning the inner surfaces of the power plant coal bunkers is given. A brief review of previous work on modeling the mechanism housing oscillation under the action of a forcing moment arising due to rocker inertial forces is given. The problem of establishing the location influence of the connecting rod-rocker kinematic pair on the amplitude and frequency of the driving moment is solved. Based on the results obtained, recommendations on the location of this kinematic pair are formulated which provide a decrease in the amplitude of the forcing moment acting on the mechanism housing without a significant change in its frequency.

ВЛИЯНИЕ РАСПОЛОЖЕНИЯ КИНЕМАТИЧЕСКОЙ ПАРЫ ШАТУН-КОРОМЫСЛО НА КОЛЕБАНИЯ КРИВОШИПНО-КОРОМЫСЛОВОГО УДАРНОГО МЕХАНИЗМА МО-10

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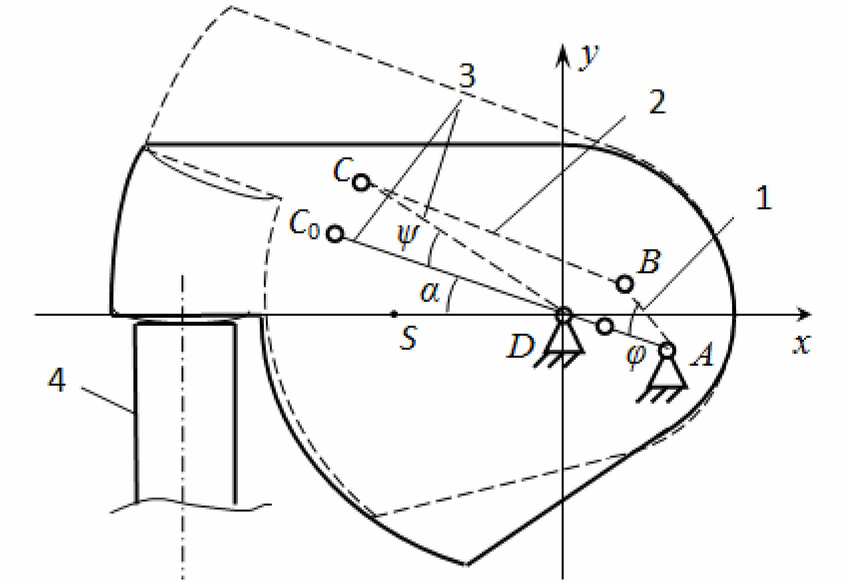
Ключевые слова: кривошипно-коромысловый ударный механизм, колебания корпуса, вынуждающий момент, амплитуда, частота, рациональное расположение кинематической пары шатун-коромысло.
Аннотация. Приведено описание конструкции и принципа действия кривошипно-коромыслового ударного механизма МО-10 для очистки внутренних поверхностей угольных бункеров ТЭЦ. Дан краткий обзор предшествующих работ по моделированию колебаний корпуса этого механизма под действием вынуждающего момента, возникающего из-за инерционных сил коромысла. Решена задача установления влияния расположения кинематической пары шатун-коромысло на амплитуду и частоту вынуждающего момента. На основе полученных результатов сформулированы рекомендации по расположению этой кинематической пары, обеспечивающие снижение амплитуды вынуждающего момента, действующего на корпус механизма без существенного изменения его частоты.

In previous years, MO-10 crank-rocker impact mechanism was developed at the Engineering Academy of the Kyrgyz Republic and Institute of Engineering Science of the NAS Kyrgyz Republic [1], which was installed on the outer walls of coal bunkers of the Bishkek power plant. With its periodic inclusion, the inner surfaces of the bunker were cleaned of adhering coal mass.

The crank – rocker impact mechanism consists of crank 1, connecting rod 2 and rocker 3 (Fig. 1). Kinematic pairs *A* and *D* are located in the housing of the impact mechanism. When the crank is rotated, the rocker, making oscillating movements about the *D* axis, strikes the tool, which rests on the surface being machined.



1 – crank; 2 – connecting rod; 3 – rocker; 4 – tool

Fig. 1. Crank-rocker impact mechanism scheme

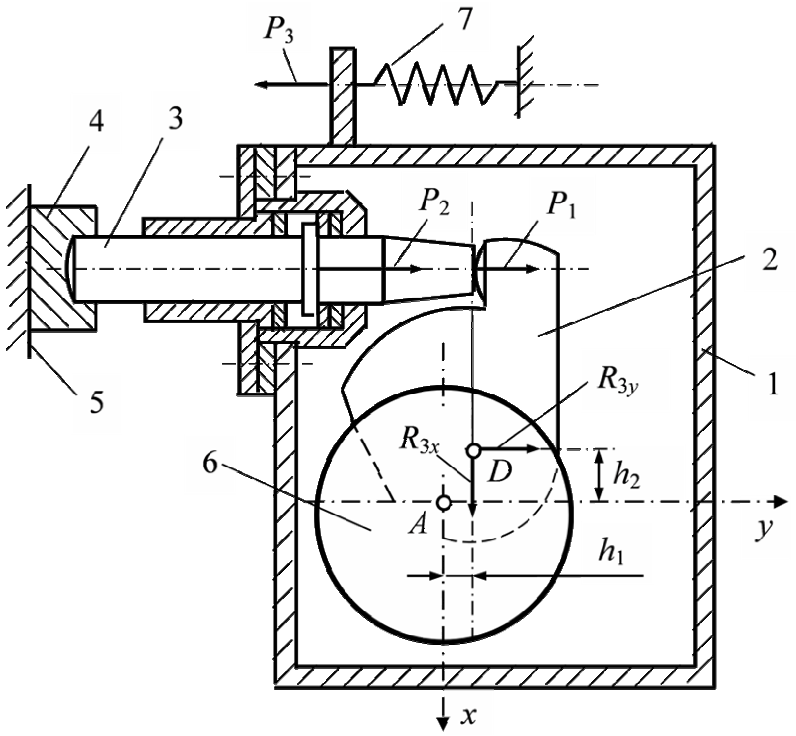
In this figure, φ is the angle of crank rotation, which is taken as a generalized coordinate; ψ, β are the rotation angles of the rocker arm and connecting rod respectively, depending on the generalized coordinate; α is the angle between the lines DC_0 and *DS*, which determines the position of the connecting rod-rocker kinematic on the rocker body.

To reduce the dynamic loads on the axis of the rocker arm at the moment of impact, its shape is chosen in a way so that the center of gravity of the rocker arm (point *S*) is located on the line connecting its axis of rotation *D* with the contact point of the rocker arm and tool at a distance l_{DS} satisfying the condition:

$$l_{DS} = \frac{J_k}{ml_{DH}},$$

where J_k – is the moment of inertia of the rocker relative to the axis of rotation, kgm^2; *m* – is the mass of the rocker, kg; l_{DH} – is the distance from the axis of rotation of the rocker to the point of contact of the rocker with the tool, m.

In fig. 2, a structural diagram of the impact mechanism MO-10 is presented. The crank-rocker mechanism is located in the housing 1 (Fig. 2), which can rotate relative to the axis of the crank *A*. When the mechanism is working, reactions occurring in the bearings of the rocker and crank act on its housing. The reactions in the rocker bearing create a driving moment, which leads to angular oscillation of the mechanism housing relative to the axis of the crank *A*.



1 – housing; 2 – rocker; 3 – tool; 4 – sole; 5 – processed surface; 6 – bearings; 7 – clamping mechanism of the housing to the tool; P_1, P_2, P_3 – respectively, the force in contact of the rocker with the tool, the housing with the tool and the pressure force of the housing to the tool

Fig. 2. Structural scheme of the impact mechanism MO-10

The kinematics and dynamics of crank-rocker impact mechanisms were considered in detail in articles [2-5]. Significantly less attention in previous works was given to the study of dynamic processes that occur during the interaction of the impact mechanism with the mechanism of its clamping to the working tool. But as practice has shown, these processes have a significant impact on the durability of the machine parts and the tool.

This led to solving the problem of choosing the magnitude of the pressing force of the impact mechanism with the tool to the work surface, which ensures a decrease in dynamic loads on its housing.

In the article [6], the requirements for the clamping device of the impact mechanism are presented. The clamping device has to return the impact mechanism housing with the tool to the work surface before each subsequent impact. This is achieved by imposing certain conditions on the amplitude of the housing driving moment and the speed of its impact with the bead of the working tool. The fulfillment of these conditions is ensured by the choice of the spring device stretching and rigidity.

In this regard, in the article [7], interconnections of the springs' parameters with the oscillations amplitude of the housing and its collision speed with the tool were established. The results obtained make it possible to select the parameters of the clamping device that satisfy the accepted restrictions with the known law of the driving moment change.

As noted above, the forcing moment is determined by the reactions R_{3x} and R_{3y} acting on the housing of the impact mechanism the rocker bearing (Fig. 2). Studies conducted in [8] showed that these reactions depend on the position of the "connecting rod-rocker" kinematic pair located on the rocker (Fig. 1). In this regard, the objectives of this work were to establish the influence of the position of the indicated pair on the driving moment acting on the housing of the MO-10 mechanism.

For the mechanism in the paper [8], it was found:

$$R_{3x} = R_{03}^{\tau}\sin(\psi+\alpha) + R_{03}^{n}\cos(\psi+\alpha)\,; \qquad (1)$$

$$R_{3y} = R_{03}^{\tau}\cos(\psi+\alpha) - R_{03}^{n}\sin(\psi+\alpha)\,, \qquad (2)$$

where

$$R_{03}^{\tau} = \frac{M_u}{l_3} + P_u^n \sin\alpha\,; \qquad (3)$$

$$R_{03}^{n} = \frac{P_u^n \sin\left[(\psi-\beta)-\alpha\right] + P_u^{\tau}\cos\left[(\psi-\beta)-\alpha\right]}{\sin(\psi-\beta)}\,; \qquad (4)$$

$$R_{12} = \frac{P_u^n \sin\alpha + P_u^{\tau}\cos\alpha}{\sin(\psi-\beta)}\,. \qquad (5)$$

Inertial forces at a constant speed of rotation of the crank are determined by the formulas:

$$P_u^n = m\omega_1^2 u_{31} l_{DS}\,; \quad P_u^{\tau} = m\omega_1^2 u_{31}' l_{DS}\,; \quad M_u = J_k \omega_1^2 u_{31}'\,, \qquad (6)$$

where ω_1 – is the angular speed of rotation of the crank, s^{-1}; u_{31}, u_{31}' – are analogues of the speeds and accelerations of the rocker respectively; l_{DS} – is the distance from the axis of the rocker to its center of gravity, m.

The driving moment acting on the mechanism housing was found for positive angles α according to the formulas:

$$M = -M_x + M_y = -h_1 R_{3x} + h_2 R_{3y}\,,$$

and for negative angles

$$M = M_x + M_y = h_1 R_{3x} + h_2 R_{3y}\,.$$

where h_1 and h_2 – are the arms of reactions relative to axis A.

In Fig. 3, as an example, the dependences of the driving moments on the rotation angle of the crank at various angle α values are shown.

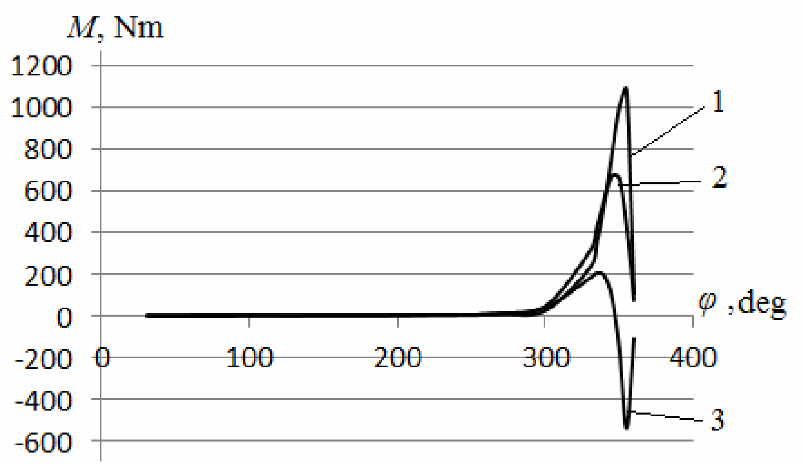


Fig. 3. Dependences of the driving moments from the rotation angle of the crank for various angle values of α: –40° (curve 1), 0° (curve 2), +40° (curve 3)

In the article [7], it was proposed to approximate these dependences with a half-wave sinusoid with amplitude H and frequency μ.

$$0 < t < t_1, \quad M = 0;$$
$$t_1 < t < T, \quad M = H \sin \mu t;$$
$$\mu = \pi / (T - t_1),$$

where T – is the rotation period of the crank, s; t_1 – is the beginning of the driving moment action, s; μ – is the frequency of the driving moment change, s^{-1}.

In this case, the time moment t_1 and the frequency μ are found from the condition of equality of the kinetic moment in the real and approximating functions. In Fig. 4, the obtained dependences of the driving moment amplitude and frequency on the angle α are shown.

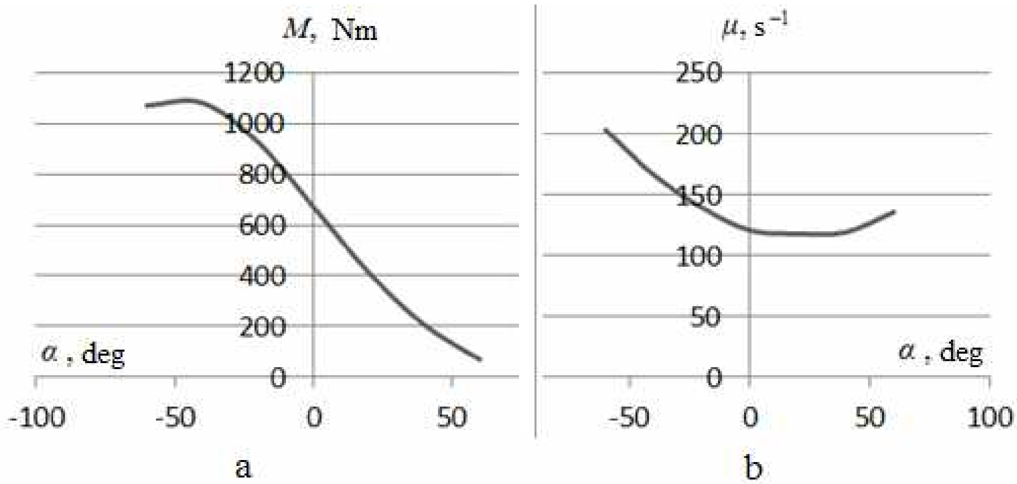


Fig. 4. Dependences of driving moment amplitude (a) and frequency (b) from angle α

From Fig. 4a, it follows that in order to reduce the driving moment, it is necessary that the angle α is positive and have the greatest value that the rocker design allows. When the angle α changes from –20° to 40°, the dependence $M(\alpha)$ with an uncertainty not exceeding 6% can be approximated by a linear function:

$$M_{\max} = 675 - 12\alpha.$$

As the angle α decreases from –60° to 0°, the frequency of the driving load decreases almost by half, and then practically does not change with increasing α to +40°.

Based on the results of the research, the following conclusions can be drawn. To reduce the dynamic loads acting on the impact mechanism housing and the elements of the mechanism of its clamping to the tool when cleaning the bunkers, the angle α should be positive. It is necessary to strive to increase this angle, as far as the design of the rocker allows. In this range of α variation, a constant of the driving moment change frequency is provided, which is equal to 117–120 s^{-1}. These conclusions allow to choose the design parameters of the rocker, satisfying the accepted conditions.

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