INVESTIGATION OF THE GEOMETRIC AND KINEMATIC PARAMETERS OF THE EXCAVATOR, TAKING INTO ACCOUNT THE ENERGY SPENT ON DIGGING THE SOIL

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Abstract. In this article have discussed geometric and kinematic parameters of the excavator, taking into account the energy spent on digging the soil.

Key words. kinematic parameters, energy spent, digging

For the mechanisms of the working equipment of the excavator, the main functions are to perform the required movements in a given coordinate plane. Hence, one of the research tasks is an adequate description of the movements of the mechanism, taking into account the coordinates of points and links, their trajectory, speed and acceleration. It must be remembered that there are kinematic characteristics that do not depend on the dynamics of the initial links, determined by the structure of the mechanism, the dimensions of its links and generalized coordinates. Therefore, it is necessary to consider the mechanism position function, which characterizes the dependence of the angular and linear movement of the mechanism link on time or generalized coordinate. Next, it is necessary to study the derivatives of the position function by generalized coordinates. The first and second derivatives of the position function characterize the kinematic transfer function.

The working mechanism of the excavator is presented in the form of a three-link group with one degree of freedom. To study the dynamics of the working mechanism, we determine the dependencies of the output coordinates x1, x2, ..., xm, which determine the positions of the links, from the given input coordinates q1, q2, ..., qn (geometric analysis). Then, when determining the speed modes of the points of the mechanism, as well as the dynamic components of its link, we apply kinematic analysis of mechanisms, the essence of which is to solve the direct and inverse problems of kinematic analysis. Having solved the direct problem of kinematic analysis, we will determine the first and second time derivatives of the position functions under the given laws of the input coordinates qk(t) and their derivatives q k(t), q k(t). Solving the inverse problem of kinematic analysis will help to determine the first and second time derivatives of the input coordinates from the known values of the output coordinates and their derivatives.

The kinematic characteristics of the mechanism obtained during the analysis will help to evaluate not only its quality, but also to solve subsequent dynamic problems. In our case, in a single–moving mechanism, where

Derivatives N′ q , N′′ q , depending on geometric characteristics of the mechanism, are respectively analogs of speeds and accelerations. For geometric and kinematic analysis, we introduce group coordinates characterizing the positions of the links (Figure 1).

Figure 1 − Generalized scheme for determining geometric and kinematic parameters

Let 's make group equations for these groups:

here

$xB = xL + LB \cdot \cos(\alpha 1 - \delta 2)$;

$yB = yL + LB \cdot \sin(\alpha 1 - \delta 2)$;

$xC = xB - BC \cdot \cos(\alpha 2 + \alpha 3)$;

$yC = yB - BC \cdot \sin(\alpha 2 + \alpha 3)$;

$x\text{к} = x\text{A} + AK \cdot \cos(\alpha 6 + \alpha 1)$;

$y\text{к} = y\text{A} + AK \cdot \sin(\alpha 6 + \alpha 1)$;

$xI = xJ - JI \cdot \cos(\alpha 2 + \delta 4)$;

$yI = yJ - JI \cdot \sin(\alpha 2 + \delta 4)$.

Squaring and adding both parts of the equations , then we get

$\cos(\delta 1$

$- \alpha 1$

$) = ML2 + AL2 -(xA - xM)2-(yA - yM)2$;

$2ML \cdot AL$

$\sin(\delta 1 - \alpha 1) = \sqrt{}1 - \cos 2(\delta 1 - \alpha 1)$.

Using the calculated value of the relative angle, applying a system of linear equations, we obtain

$(ML - AL \cdot \cos(\delta 1 - \alpha 1)) \cdot \cos \delta 1 - AL \cdot \sin(\delta 1 - \alpha 1) \cdot \sin \delta 1 = xA - xM$ }.

$AL \sin(\delta 1 - \alpha 1) \cdot \cos \delta 1 + (ML - AL \cdot \cos(\delta 1 - \alpha 1)) \cdot \sin \delta 1 = yA - yM$

Далее определим cos $\delta 1$ и sin $\delta 1$:

$\cos \delta 1$

$\sin \delta 1$

$== (xA - xM)(ML - AL \cdot \cos(\delta 1 - \alpha 1)) + (yA - yM) \cdot AL \cdot \sin(\delta 1 - \alpha 1)$; $(ML - AL \cdot \cos(\delta 1 - \alpha 1))2 + (AL \cdot \sin(\delta 1 - \alpha 1))2$

$== (yA - yM)(ML - AL \cdot \cos(\delta 1 - \alpha 1)) + (xA - xM) \cdot AL \cdot \sin(\delta 1 - \alpha 1)$. $(ML - AL \cdot \cos(\delta 1 - \alpha 1))2 + (AL \cdot \sin(\delta 1 - \alpha 1))2$

In a similar sequence, we define the following angles.

Determining the kinematic parameters of the excavator, we differentiate the group equations in time:

where s1 characterizes the stroke of the piston. From the system of equations we define $\delta 1$ and $\alpha 1^{\cdot}$.

$\delta 1^{\cdot}$
$= \quad s1^{\cdot}$
$ML \tan(\delta 1 - \alpha 1)$
$= 0; \alpha 1$
$= \quad s1^{\cdot}$.
$AL \cdot \sin(\delta 1 - \alpha 1)$

It follows from the formulas obtained that the position function $\alpha 1(s1)$ is monotonic; the position function $\delta 1(s1)$ has an extremum when the hydraulic cylinder rod is perpendicular to the boom. The structural group of links (cylinder-rod-boom) falls into a special position if the hinges A, L and M will lie on the same straight line ($\sin(\delta 1 - \alpha 1) = 0$).

Differentiating the system of equations in time, we obtain a system of linear equations

Thus, the law of movement of the excavator links is mathematically described, given by the input coordinates, which makes it possible to determine the first and second time derivatives of the input coordinates from the known values of the output coordinates, taking into account the kinematic features of the working equipment.

One of the most important tasks of the dynamics of mechanisms in the study of the energy efficiency of processes performed by road vehicles is the mathematical description of the forces acting in the mechanisms and their characteristics. In fact, it is necessary to solve two problems of dynamics:

- according to the formulated law of motion, to establish the forces applied to its links, and, accordingly, the reaction of forces in the kinematic pairs of working equipment;

- according to the known forces applied to the mechanism, determine the adequate law of movement of the working equipment.

When constructing a mathematical model of the movement of working equipment and excavator mechanisms from the standpoint of energy efficiency, we will take into account the complex process of changing kinetic energy, depending on the acting forces and moments.

To develop a mathematical model, the forces and moments acting on the mechanisms are divided into groups:

- forces and moments that set the dynamics of mechanisms and perform positive work per cycle;
- forces and moments of resistance spent on performing negative work during the cycle;
- gravity of mobile working equipment;
- the forces acting in kinematic pairs, and according to Newton's 3rd law, are always reciprocal.

For a more objective study, we will conditionally divide the working equipment into two mechanisms: 1) "arrow-handle-bucket" having one degree of freedom, N; 2) a rotary platform also with one degree of freedom, N.

Each of the mechanisms with one degree of freedom is represented by a dynamic model. Our model takes into account the reduced moment of inertia $J\sum$, the value of which is not constant in time, and the total reduced moment $M\sum$ applied to it. Previous researchers in their works associate the law of motion of the model with the law of movement of the initial link of the mechanism.

T $= J\Sigma \cdot \omega 2$.

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Expressing the load applied to the mechanism in terms of the total reduced moment $M\sum$, the amount of work is equal to

Figure 2 - Graphical differentiation

Based on the results of theoretical studies, it was concluded that in the dynamic model of the excavator's working equipment, transients are the most difficult to interpret. The study of angular velocity ω and acceleration ε during acceleration and deceleration of the rotary platform of the excavator will help to establish the relationship between dynamic loads and energy efficiency of the process.In addition, the total energy consumption of the process is affected by the following factors: the moment of inertia and the driving moment. The magnitude of the critical values of the limits of angular velocity and acceleration will allow us to develop a number of measures to smooth out the boundary processes of unsteady operating modes.

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