asymmetrical kinds PWS ($A = \pm 1$) nonlinearity $\Phi_1(x)$ – expresses not much more strongly, than in $A = 0$.

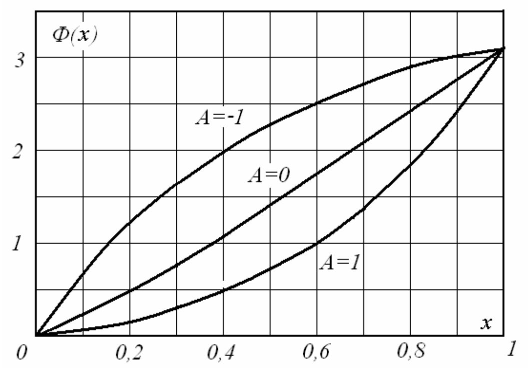

Fig. 5. Nonlinear PWS characteristics

The transfer function of the resulted linear part will be found in the form of discrete Laplasa transformation from (14):

$$W_n^*(q,0) = \frac{1}{b_1}\cdot\frac{\exp\left[-\frac{1}{b_1}\left(1-\bar{t}_1\right)\right]}{\exp[q] - \exp\left[-\frac{1}{b_1}\right]}.$$

Having replaced in this expression q by j (= ωT), we shall receive the peak-phase characteristic of the resulted linear PWS part. Using this detail, it is possible to estimate the PWS stability applying the criteria For example, according to criterion of the absolute position stability balance [2]:

$$\frac{1}{\sigma} + \mathrm{Re}\left[\frac{B}{b_1}\cdot\frac{\exp\left[-\frac{1}{b_1}\left(1-\bar{t}_1\right)\right]}{\exp\left[j\bar{w}\right] - \exp\left[-\frac{1}{b_1}\right]}\right] > 0, .$$

where $\sigma = \left|\frac{\partial\Phi_1(x)}{\partial x}\right|_{\max}$ – is the maximum differential value of factor of equivalent nonlinear element transfer.

In – is the factor of linear strengthening in the PWS pulse tract.

Introducing the connecting processes, offered by L. S. Iuhoni, the method drawn near calculation, has greatly allowed simplifying the problem of the analysis to a stable width-pulsed system in the event of a high order even by its linearities.

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DYNAMIC MODELING OF A BUCKET-WHEEL EXCAVATOR PROPELLING MOTOR

The article reviews algorithmization of a dynamic model of a bucket-wheel excavator propelling motor during its motion. There are essential schemes and formulas used in dynamic modeling algorithmization.

Keywords: algorithmization, propelling motor, contour, moment, reaction.

Multi-support contours as analytical models are considered in order to determine bearing reaction, bearing load and moments which appear in the process of a bucket-wheel excavator motion at the face. This, in its turn, will help to evaluate a technical state of a bucket-wheel excavator [1].

When analyzing the impact of a traveling gear on a bucket-wheel excavator dynamics, we don't consider a set of an excavator motion equations, but focus on specific issues of traveling gears algorithmization and their connections with the whole machine in various operating modes.

The reactions to G force action are determined depending on the position of this force projection on the support contour taking into consideration a projection point shift relative to the support contour center. If an axis of a superstructure does not coincide with a force G projection point and a geometric center, both shifts are taken into account. In this case we should consider two centers of mass, where G_1 is a gravity of a fixed part of a machine, with running-out Q and G_2 is a gravity of a swivel part with a resultant running-out S_0 relative to the steering axis.

Thus, the resultant reaction in the support point of a contour:

$$R_{Tj} = R'_{Tj} + R''_{Tj},$$

where R'_{Tj} is a permanent part of G_1 force reaction; R''_{Tj} is a variable part of G_2 force reaction.

Calculation is carried out by a rigid lever method by solving an algebraic equation set with a Kutta–Joukowski theorem. Support reactions to the action of horizontal inertia forces are determined on the basis of data got in the process of solution of an equation set of an excavator dynamic model motion. In this case we use an algebraic equation system, that turns a moment action of horizontal resultant inertia force applied to a center of mass at a height of H into support reactions [2].

Then the complete support reaction is determined by a sum of three summands:

$$R_{Tj} = R'_{Tj1} + R'_{Tj2} + R''_{Tj},$$

where R'_{Tj1}, R'_{Tj2} are reactions, respectively, to G_1 и G_2 forces; R''_{Tj} are reactions of a moment action from horizontal inertia force action.

The evaluation of a part of R''_{Tj} support reaction relative to a complete R_{Tj} value shows that if $R''_{Tj} / R_{Tj} \le 0.1$, then R_{Tj} value can be neglected. The general analytical models to determine support reaction for multi-support contours are shown in fig. 1, where γ_0 is a constant angular displacement of a fixed part center of mass relative to a geometric support contour center; r_0 is a displacement radius of a swivel part center of mass relative to a turning center and its α_0 angle of displacement from a central point. Calculated dependences to determine support reactions in fig. 1, *a* result from equations of forces moments relative to a reference triangle sides:

$$\left.\begin{array}{l} \Sigma M_{AB}(R) = 0 \to R'_{Cj} \\ \Sigma M_{AC}(R) = 0 \to R'_{Bj} \\ \Sigma M_{CB}(R) = 0 \to R'_{Aj} \end{array}\right| .$$

To determine support reactions of a support contour in fig. 1, *b* we use the following set of equation:

$$\left.\begin{array}{l} M_{AB}(R_D) + M_{AB}(R_C) = M_{AB}(G) = (R_D + R_C)\, l_{AD} \\ M_{CB}(R_A) + M_{CB}(R_D) = M_{CB}(G) = (R_A + R_D)\, l_{AB} \\ M_{DC}(R_A) + M_{DC}(R_B) = M_{DC}(G) = (R_A + R_B)\, l_{AD} \\ M_{AD}(R_B) + M_{AD}(R_C) = M_{AD}(G) = (R_C + R_B)\, l_{AB} \end{array}\right| .$$

Therefore:

$$\left.\begin{array}{l} R'_D + R'_C = M_{AB}(G)/l_{CB} \\ R'_A + R'_D = M_{CB}(G)/l_{AB} \\ R'_A + R'_B = M_{DC}(G)/l_{CB} \\ R'_C + R'_B = M_{AD}(G)/l_{AB} \end{array}\right| . \qquad (1)$$

The equation (1) determines R'_A, R'_B, R'_C, R'_D. The support reactions to the action of horizontal component inertia forces are found according to the scheme in fig. 2. for a three-support contour (fig. 2, *a*). For a three-point contour we take into account the moments from horizontal forces projections in a direction orthogonal to corresponding triangle sides, for instance:

$$M_{AC}(F) = F_{AC1}H_1 + F_{AC2}H_2$$
$$M_{BC}(F) = F_{BC1}H_1 + F_{BC2}H_2 ,$$

where F_{AC1} , F_{AC2} are vertical projections of inertia forces on AC side of the first and second masses at a height of H_1 and H_2 respectively.

Then the reactions:

$$\left.\begin{array}{l} R''_B = M_{AC}(F)/h_B(AC) \\ R''_C = M_{AB}(F)/h_C(AB) \\ R''_A = M_{BC}(F)/h_A(CB) \end{array}\right| ,$$

where $h_B(AC), h_C(AB), h_A(CB)$ are the arms up to support points of corresponding sides.

For a four-support contour (fig. 2, *b*) we take into account the moments from horizontal forces projections, such as $M_{AB}(F) = F_{AB1}H_1 + F_{AB2}H_2$. Then, the reactions are determined by the following set of equations:

$$\left.\begin{array}{l} R_D + R_C = M_{AB}(F)/l_{CD} \\ R_A + R_B = -M_{AB}(F)/l_{CD} \\ R_C + R_B = M_{AB}(F)/l_{AB} \\ R_D + R_A = -M_{AD}(F)/l_{AB} \end{array}\right| .$$

This equation system determines R''_A, R''_B, R''_C, R''_D.

The complete support reactions are found by formulas:

$$R_A = R'_A + R''_A;\; R_B = R'_B + R''_B;$$
$$R_C = R'_C + R''_C;\; R_D = R'_D + R''_D.$$

The values of complete support reactions are used to evaluate the resistance to a machine motion.

An excavator turning resistance during its motion is determined by three factors: tractive force for F_i driving bogies, linear motion resistance for every W_i driving bogie and turning resistance moments relative to general dynamic turning center M_i^W; M_i^S; $F_i^W \cdot l_i$. The machine turning force balance is considered through the following equation system.

A sum of moments relative to a general dynamic turning center:

$$\sum F_i\rho_i - \sum M_i^W - \sum M_i^S - \sum F_i^W \cdot l_i - \sum W_i\ \rho_i = 0 .$$

an overall projections sum on X axis:

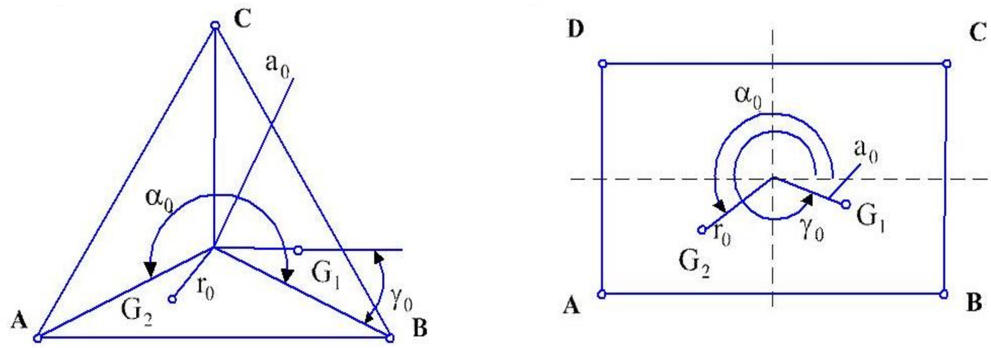
$$\sum F_i \cos\alpha_i - \sum F_i^W \sin\alpha_i - \sum W_i \cos\alpha_i = 0;$$

an overall projections sum on Y axis:

$$\Sigma F_i \sin\alpha_i - \Sigma F_i^W \cos\alpha_i - \Sigma W_i \sin\alpha_i = 0 ,$$

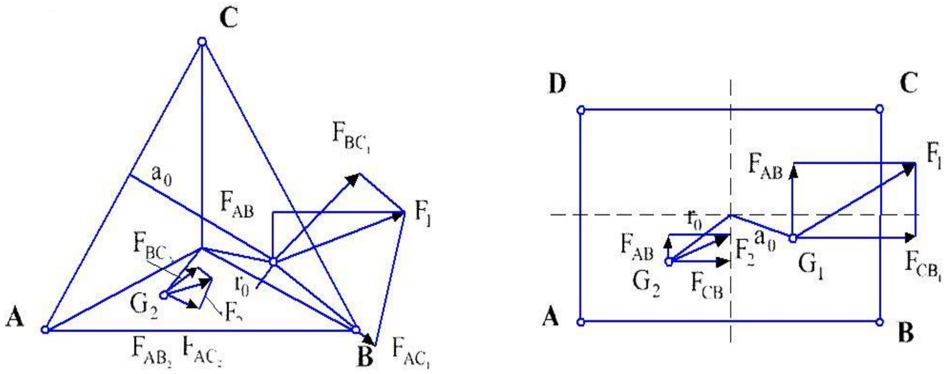
$$F_i^W = 2\mu \cdot R_{Ti} l_i / L' ,$$

where F_i^W is resistance force for F_i driving bogies lateral deviation; L' is the length of a track contacting area; l_i is a displacement of a force application point; F''^W_i is relative to a dynamic turning center (arm of force is F^{W}_i); ρ_i is the radius from a dynamic turning center to the main bogie direct axis; $M_i^{(S)}$ is a moment applied to a tandem of bogies under different motion resistances.



a *b*

Fig. 1. The general analytical models to determine support reaction for multi-support contours:
A, *B*, *C*, *D* are contour determining points; a_0 is an angle of displacement from a central point; r_0 is a displacement radius of a center of mass; G_1 и G_2 are gravities; γ_0 is a constant angular displacement of a fixed part center of mass relative to a geometric support contour center



a *b*

Fig. 2. The general analytical models to determine support reaction for four-support contours:
A, *B*, *C*, *D* are points determining the contour; a_0 is the angle of displacement from a central point; r_0 is a displacement radius of a center of mass; G_1 и G_2 are gravities; γ_0 is a constant angular displacement of a fixed part center of mass relative to a geometric support contour center; F_{AC1} , $F_{AC2} - F_{AC1}$, F_{AC2} are projections on a perpendicular to inertia forces on *AC* side of the first and second masses at a height of H_1 and H_2 respectively

For instance, if a tandem of bogies $i = 1, 2$:

$$M_i^{\,S} = \frac{1}{2}(W_2 - W_1)B/2,$$

where *B* is wheel track (in meters).

Taking into account the adopted dependences we propose the following solution algorithm:

1. One should determine ρ_{Hi} radii up to bogies relative to a dynamic turning center, when l_i = 0, which are the initial conditions:

$$\rho_{ni} = f(\alpha_i).$$

2. We assign tractive force:

$$F_i = A_i K_{1i} K_{2i} - B_i K_{2i} \cdot (\omega_m \rho_i).$$

A machine turn rate is:

$$\omega_m = \frac{\Sigma A_i K_{1i} K_{2i} - \Sigma M_i^{(W)} - \Sigma F_i^{(W)} l_i - \Sigma M_i^{(S)} - \Sigma W_i\ \rho_i}{\Sigma B_i K_{2i} \rho_i}.$$

3. Excess tractive force of bogies is:

$$S_i = F_i - W_i.$$

4. Running-out of $F_i^{(W)}$ force is determined as a function of α turn angels; bogies relative to tandem of bogies centers (coherent support points), R_{Ti} support reactions and some other main design parameters of a support contour:

$$l_i = \Sigma S_i Д_i,$$

where $Д_i = f(a_i, R_{Ti})$; $Д_i$ is a function, depending on a turn angel and R_{Ti} support reactions.

5. One finds the radii from the dynamic machine turning center to the bogies :

$$\rho_i = f(a_i, l_i).$$

6. A substitution of r_i, l_i new values and comparison with acceptable ε deviation is to be done before the inequity is stated:

$$\Delta\Sigma M(\rho_i, l_i) \le \varepsilon \rangle 0.$$

When the iterative calculations are completed, the derived parameters ρ_i, l_i, S_i, ω_i are taken and forces and velocity values are determined.

To sum up, a modeling algorithm of a propelling motor drag resistance should take into account the whole set of drag resistances as well as traction performance of electric motors of driving track bogies.

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MATHEMATICAL MODEL FOR CONTACT RESISTANCE OF COLD CONTACT AT SPOT WELDING

The paper is devoted to the problem of optimizing spot welding modes and contains the description of a mathematical model for the calculation of cold contact initial resistance.

Keywords: spot welding, resistance of cold contact.

The practice of spot welding and the numerous results of published researches unambiguously confirm that one of main conditions of forming quality-welded joints is the optimality of the initial resistance of part -to- part $r_{\text{КТ}}$ contact. Its value and stability essentially influences the sizes of a kernel, the stability of the process against creating splashes and poor penetration. At the same time, until now, the development of spot welding technologies of $r_{\text{КТ}}$ value had been achieved experimentally for each particular welding condition; this is rather labor-intensive.

According to the conducted research it has been concluded that the rod model is the most acceptable engineering technique among all known methods applied in rough surface models for welded contacts; mainly because it describes the mechanism of contact interaction between two rough surfaces with more simplicity and precision (fig. 1).

According to the accepted model of two rough surface contacts, the conductivity in the contact layer is carried out according to n_r number of individually parallel micro conductors of d ($d \to 0$) diameter, and of a length, formed by deformable rods (micro lugs). One of the constituents of the total electric resistance in such a micro contact $r_{\text{КТ}}$ which is caused by the resistance of micro conductors in the contact layer, which has properties different to those of parent metal, is called the internal contact resistance $r_{\text{КВ}}$. The other part, which is formed by current line curvatures j in near contact areas where properties of the parent metal are assumed to not change, is called the micro geometrical contact resistance $r_{\text{МГ}}$. Then the total electric resistance contact will be equal to the sum of these two components:

$$r_{\text{КТ}} = r_{\text{КТ}} + r_{\text{КТ}}.$$

The total internal electric contact resistance $r_{\text{ВН}}$ can be defined in the following manner:

$$r_{\text{ВН}} = \frac{r_{\text{ВН}}}{n_r} = \rho_\Delta \frac{a}{n_r \Delta S} = \rho_\Delta \frac{2R_{\max}(1-\varepsilon)}{A_r}.$$

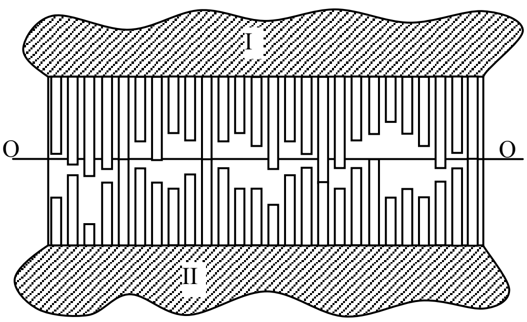

Fig. 1. Contact of two rough surfaces. The rod model

For the accepted model, the micro geometrical resistance for individual contact $r^*_{\text{МГ}}$ can be defined according to the familiar dependence, considering its presence in two parts (fig. 2):

$$r_{\text{МГ}} = 2\rho\left(\frac{1}{d} - \frac{1}{D}\right).$$

The total micro geometrical contact resistivity $r_{\text{МГ}}$ can be defined accepting the following dependence:

$$r_{\text{МГ}} = \frac{r_{\text{МГ}}}{n_r} = \frac{2\rho}{n_r}\left(\frac{1}{d} - \frac{1}{D}\right).$$

To calculate $r_{\text{ВН}}$ and $r_{\text{МГ}}$ it is necessary to define the mechanical parameters of the welded contact and first of all, define the deformation the micro lugs undergo: