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THE ANALYSIS OF REGULAR WHEEL LOADINGS DISTRIBUTION AT A STATICALLY UNSTABLE RUNNING SYSTEM OF AN AGRICULTURAL MACHINE ON A ROUGH SURFACE

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Summary. The article presents an algorithm of definition of regular wheel loadings at a statically unstable running system of an agricultural machine on a rough surface.

Key words: agricultural machine, statically unstable running system, method of regular wheel loadings definition

INTRODUCTION

Maintenance of necessary effectiveness of wheel agricultural machines running on rough soil surfaces is provided with application of wide-profile tyres of the big dimension, and also a complete set of running system dual tyres. Additionaly, low average and maximum pressure upon the base, small depths of the left tracks and small forces of rotating wheels resistance are achieved as well. Deformation characteristics of such tyres allow to do without a system of springing wheels, and for low speed technological machines - to use statically unstable running systems, that considerably simplifies and reduces the price of a design of such machines. In case of doubling of wheels, for example wheels of a tractor which initially had a statically stable running system, each bridge separately becomes statically unstable. The listed features of modern running systems of agricultural machines complicate an exact definition of the valid forces during the contact of tyres with the running surface, at research of traction dynamics of such machines, especially in case of movement on a rough deformable soil surface. Therefore, the working out of a method of analytical definition of the valid normal loadings on the wheels equipped with pneumatic tyres, as a part of statically unstable running systems of agricultural machines is fairly significant [7].

Pull-coupling properties of the agricultural machine are in many respects defined by normal loadings to a basic surface on wheels. Distribution of these loadings depends on a number of factors: the design-layout scheme of the running system; mass-geometrical parametres: positions of the centre of weights, the moments of inertia concerning axes of cross-section and longitudinal-angular fluctuations; rigid characteristics and geometrical parametres of tires; deformation characteristics and characteristics of microprofiles of a basic surface on trajectories of movement of wheels of different boards and machine bridges; a mode of movement of the machine; influences of the working tools aggregated with machine at their working and transport position [8].

Growth power and tonnages for load agricultural machines leads to a considerable increase of working speeds as inertia due to weights of transmissions and active working bodies, volumes and weights of the working bodies in the machine increase and the process equipment lump grows. All these reasons lead to an increase in dynamics of redistribution of regular loadings on machine wheels [10].

The purpose of the present article consists in the working out of a method of definition of normal reactions in support of wheels of the agricultural machine with statically unstable running system on a rough soil surface [9].

METHOD OF DEFINITION OF REGULAR LOADINGS ON WHEELS

Study of distribution of loadings has to be carried out separately for the following cases:

1) static position of the machine,

2) movements with the established speed on a smooth surface and on a real rough field,

3) beginning of motion from a place and speeding up of the machine till the established speed.

For the statement of an essence of the method it is enough to consider static position of the machine. The corresponding settlement of dynamic systems of the machine with statically unstable running system is presented in Fig. 1.

Because the running system of the considered machine is statically unstable at four wheel support, in addition to the equations of static balance, the equation of compatibility of deformation of support is worked out, considering the case when the machine block is not deformed. In case of five and more support, similar equations are made. The following equation should represent the equation of the plane which is being passed by the set four points, that is through the centers of points of contact of tires with the ground. We will consider the settlement scheme in greater detail. The scheme is generalized and extends also to the case of one bridge of the machine with dual wheels, thus value of size L_{td} is equal to zero.

At various size of wheels of forward and back bridges of the machine the corresponding scheme is presented in Figure 1. Thus points *A, B, C, D* on the scheme are structurally always in one plane, and deformations of all the local subsystems "tire-ground" are connected with one another so that reactions R_A, R_B, R_C, R_D counterbalance the machine weight.

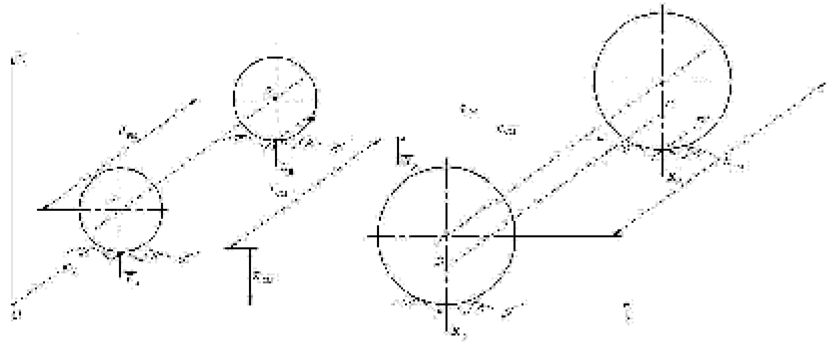

Fig. 1. The settlement scheme of statically unstable running system

Let us accept an assumption that deformation characteristics of soil under all wheels are identical and do not depend on a microprofile of a surface of a field on the track of each of wheels.

Let us write down the balance equations in the accepted system of co-ordinates:

$$\begin{cases} Z = 0: \quad G_M - R_A - R_B - R_C - R_D = 0, \\ M_{OY} = 0: \quad R_D \cdot l_M + R_C \cdot l_M - G_M \left(L_M - a_{OM} \right) = 0, \\ Z = 0: \quad R \dfrac{B_{ZM} - B_{PM}}{2} + R_B \left(\dfrac{B_{ZM} - B_{PM}}{2} + B_{PM} \right) + R_C \cdot B_{PM} - G_M \cdot Y_{CM} = 0. \end{cases} \qquad (1)$$

Expressions for co-ordinates of the centre of weights of the machine are received on the basis of the scheme (Fig. 2) at transport position of the hinged equipment.

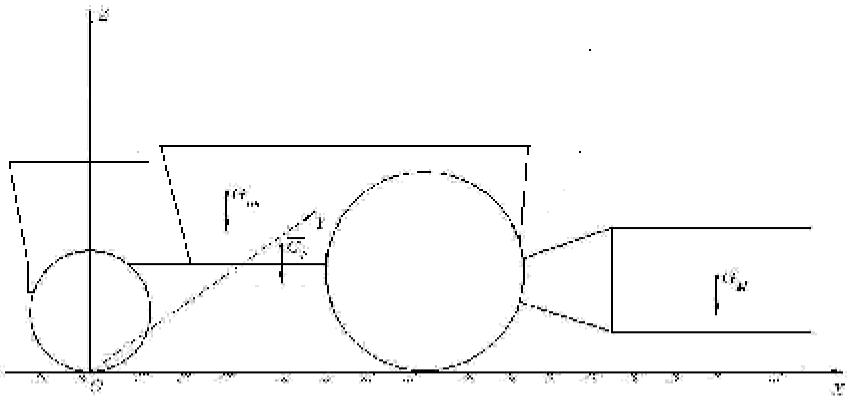

Fig. 2. The scheme for definition of co-ordinates of the centre of weights of the machine

$$X_C = \frac{G_K \cdot X_K + G_H \cdot X_H + G_{GR} \cdot X_{GR}}{G_K + G_H + G_{GR}}, \qquad (2)$$

$$Y_C = \frac{G_K \cdot Y_K + G_H \cdot Y_H + G_{GR} \cdot Y_{GR}}{G_K + G_H + G_{GR}}, \qquad (3)$$

$$Z_C = \frac{G_K \cdot Z_K + G_H \cdot Z_H + G_{GR} \cdot Z_{GR}}{G_K + G_H + G_{GR}}. \qquad (4)$$

At the account tyre and ground deposits the valid co-ordinates, for example points A, in the accepted system of co-ordinates are defined from the expression:

$$Z_A = Z_A^* \quad \left(\xi_C \quad \xi_A \right) \quad \frac{R_A}{e_{prA}}, \qquad (5)$$

where: ξ_A, ξ_C - ordinates of a profile of a field under wheels $A..C$.

Let us work out the equations of joint deformation of stains of contacts of tires of the machine with a ground.

From the machine drawing at the hung out wheels (a dot contact of wheels of a ground) we measure co-ordinates of points in the accepted system of co-ordinates (X'_A, Y'_A, Z'_A) etc. Then the machine will be placed on a basic surface, thus the true value of co-ordinates Z_i will decrease for sizes, accordingly:

$$\Delta_i = R_i / \; C_{pr\,i}, \tag{6}$$

where:

$C_{pr\,i}$ - the resulted rigidity of the support in the form of the tire-ground system (Fig. 3), and become equal to:

$$Z_A = \left(Z^*_A \quad \frac{R_{AB}}{C_{prA}} \right); Z_B = \left(Z^*_B \quad \frac{R}{C_{prB}} \right), \tag{7}$$

$$Z_C = \left(Z^*_C \quad \frac{R_C}{C_{prC}} \right); Z_D = \left(Z^*_D \quad \frac{R_D}{C_{prD}} \right). \tag{8}$$

Then the additional equation will arise:

$$\begin{vmatrix} X - X_D & Y - Y_D & Z - Z_D \\ X_C - X_D & Y_C - Y_D & Z_C - Z_D \\ X_B - X_C & Y_B - Y_C & Z_B - Z_C \end{vmatrix} - 0 \;, \tag{9}$$

And as co-ordinates (X,Y,Z) concern point A, we will enter designations:

$$X_A - X_D = a;\; Y_A - Y_D = b;\; X_C - X_D = c;\; Y_C - Y_D = d; X_B - X_C = \varepsilon;\; Y_B - Y_C = f.$$

At an assumption about small deviations from vertical moving of the points at load machines in weight of technological cargo, and that the entered designations are constants,

the equation (9) will become:

$$\begin{vmatrix} a & b & \left(Z^*_A \;\; {}_A e_{pr\,A} \cdot R \quad \right)_D & \left(Z^*{}_{prD} e \quad {}_D \cdot R \quad \right) \\ c & d & \left(Z^*_C \quad e_{pr\,C} \cdot R_C \right) & \left(Z^*_D \quad e_{pr\,D} \cdot R_D \right) \\ \varepsilon & f & \left(Z^*_B \quad e_{pr\,B} \cdot R_B \right) & \left(Z^*_C \quad e_{pr\,C} \cdot R_C \right) \end{vmatrix} = 0. \tag{10}$$

If to "put" the machine on a rough microprofile in expression (10) it is necessary to consider a difference between the level of a profile of a field under each wheel in comparison with the highest point. For example, microprofile heights under wheels $\xi_A, \xi_B, \xi_C, \xi_D$ and

$$\xi_A > \xi_B > \xi_C > \xi_D$$

then the expression will arise:

$$Z_A - \left[Z_A^{*} - (\xi_{C_0} - \xi_A) - \frac{R_A}{C_{pr\ A}} \right] - \left[Z_A^{*} - (\xi_{C_0} - \xi_A) - e_{pr\ A} \cdot R_A \right], \tag{11}$$

$$Z_B - \left[Z_B^{*} - (\xi_{C_0} - \xi_B) - e_{pr\ B} \cdot R_B \right], \tag{12}$$

$$Z_C - \left[Z_C^{*} - (\xi_{C_0} - \xi_C) - e_{pr\ C} \cdot R_C \right] - \left[Z_C^{*} - e_{pr\ C} \cdot R_C \right], \tag{13}$$

$$Z_D - \left[Z_D^{*} - (\xi_{C_0} - \xi_D) - e_{pr\ D} \cdot R_D \right]. \tag{14}$$

where: ξ_{C_0} - is basic ordinate.

As the movement on casual microprofiles of a parity between heights will vary all the time, therefore, considering distributions of loadings in support, on each step of calculations it is necessary to define in the beginning the maximum ordinate from microprofile ordinates over which there are wheels, and then, having accepted it as basic $\xi_{C_0} = \xi_i$ to count distribution of loadings.

Let us open a determinant (10) taking into account expressions (11-14) by the Sarrius rule:

$$\begin{vmatrix} a & b & \left(Z_A^{*} \quad \left(\xi_{C_0} \quad \xi_A\right) \quad e_{pr} \quad \cdot R_A\right) & \left(Z_D^{*} \quad \left(\xi_{C_0} \quad \xi_D\right) \quad e_{prD} \cdot R_D\right) \\ c & d & \left(Z_C^{*} \quad \left(\xi_{C_0} \quad \xi_C\right) \quad e_{prC} \cdot R_C\right) & \left(Z_D^{*} \quad \left(\xi_{C_0} \quad \xi_D\right) \quad e_{prD} \cdot R_D\right) \\ \varepsilon & f & \left(Z_B^{*} \quad \left(\xi_{C_0} \quad \xi_B\right) \quad e_{prB} \cdot R_B\right) & \left(Z_C^{*} \quad \left(\xi_{C_0} \quad \xi_C\right) \quad e_{prC} \cdot R_C\right) \end{vmatrix} = 0. \tag{15}$$

$$\begin{gathered} a \cdot d \cdot \left\{ \left(Z_B^{*} \quad \left(\xi_{C_0} \quad \xi_B\right) \quad e_{prB} \cdot R_B\right) \quad \left(Z_C^{*} \quad \left(\xi_{C_0} \quad \xi_C\right) \quad e_{prC} \cdot R_C\right) \right\} + \\ + b \cdot \varepsilon \cdot \left\{ \left(Z_C^{*} \quad \left(\xi_{C_0} \quad \xi_C\right) \quad e_{prC} \cdot R_C\right) \quad \left(Z_D^{*} \quad \left(\xi_{C_0} \quad \xi_D\right) \quad e_{xprD} \cdot R_D\right) \right\} + \\ + c \cdot f \cdot \left\{ \left(Z_A^{*} \quad \left(\xi_{C_0} \quad \xi_A\right) \quad e_{pr\ A} \cdot R_A\right) \quad \left(Z_D^{*} \quad \left(\xi_{C_0} \quad \xi_D\right) \quad e_{pr\ D} \cdot R_D\right) \right\} \\ \varepsilon \cdot d \cdot \left\{ \left(Z_A^{*} \quad \left(\xi_{C_0} \quad \xi_A\right) \quad e_{prA} \cdot R_A\right) \quad \left(Z_D^{*} \quad \left(\xi_{C_0} \quad \xi_D\right) \quad e_{prD} \cdot R_D\right) \right\} \\ b \cdot c \cdot \left\{ \left(Z_B^{*} \quad \left(\xi_{C_0} \quad \xi_B\right) \quad e_{prB} \cdot R_B\right) \quad \left(Z_C^{*} \quad \left(\xi_{C_0} \quad \xi_C\right) \quad e_{prC} \cdot R_C\right) \right\} \\ a \cdot f \cdot \left\{ \left(Z_C^{*} \quad \left(\xi_{C_0} \quad \xi_C\right) \quad e_{prC} \cdot R_C\right) \quad \left(Z_D^{*} \quad \left(\xi_{C_0} \quad \xi_D\right) \quad e_{pr\ D} \cdot R_D\right) \right\} = 0. \end{gathered} \tag{16}$$

Let us enter a designation and we will reduce the equation (16) to the kind:

$$R_A = A_B \cdot R_B + A_C \cdot R_C + A_D \cdot R_D + Q, \tag{17}$$

or

$$-R_A + A_B \cdot R_B + A_C \cdot R_C + A_D \cdot R_D = -Q; \tag{18}$$

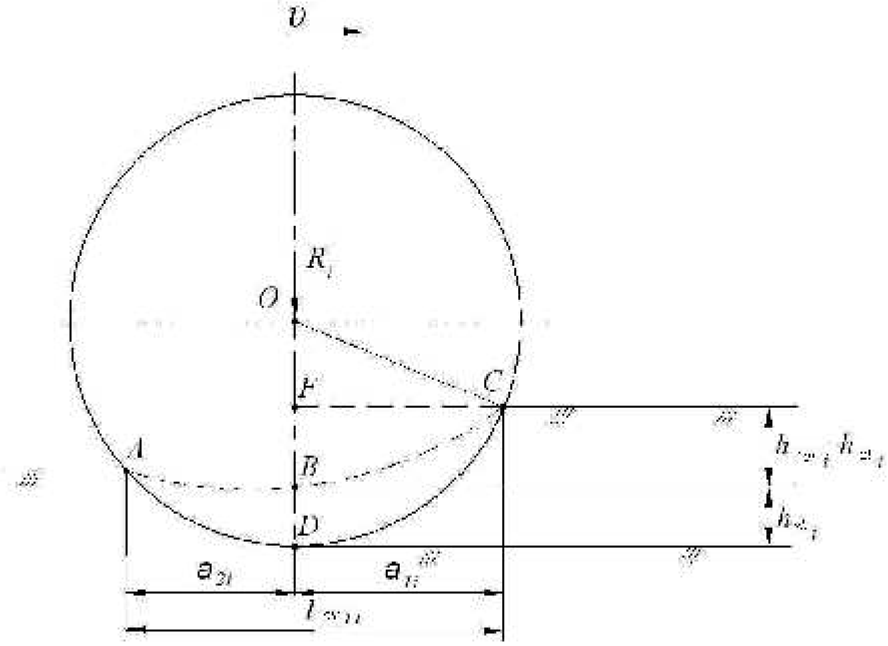

Fig. 3 - The scheme of deformation of the tyre and the ground under a wheel

The resulted pliability of support, rigidity $e_{pri} = \frac{C_{sh\,i} + C_{gr\,i}}{C_{sh\,i} \cdot C_{gr\,i}}$,

$C_{pr} = \frac{1}{e_{pr}} = \frac{C_{sh\,i} \cdot C_{gr\,i}}{C_{sh\,i} + C_{gr\,i}}$, then total moving of a wheel at support $O'O$ is equal to:

$$\left(h_{kol\,i} + h_{sh\,i}\right) = \frac{R_j}{C_{pri}} = R_j \cdot e_{pr\,i} = R_j \cdot \frac{C_{sh\,i} + C_{gr\,i}}{C_{sh\,i} \cdot C_{gr\,i}}, \qquad h_{kol\,i} + h_{sh\,i},$$

and this deformation between the tyre and ground is in inverse proportion to the shares on a part:

$$h_{kol\,i} = \frac{C_{gr\,i}}{C_{sh\,i} \cdot C_{gr\,i}} \cdot R_j; \; h_{sh\,i} = \frac{C_{sh\,i}}{C_{sh\,i} \cdot C_{gr\,i}} \cdot R_j \text{ or} \tag{19}$$

$$h_{kol\,i} = \frac{R_j}{C_{sh\,i}}; \; h_{sh\,i} = \frac{R_j}{C_{sh\,i}}, \tag{20}$$

Let us define a_1 and a_2 on geometrical grounds (Fig. 3):

$$BD = h_{sh\,i};\; BF = h_{kol\,j\,i};\; OA = \frac{D_{sh\,i}}{2} = OD,$$

then:

$$a_2 = AB = \sqrt{\left(\frac{D_{sh\,i}}{2}\right)^2 \quad \left(\frac{D_{sh\,i}}{2} \quad h_{sh\,i}\right)^2} = \tag{21}$$

$$= \sqrt{\frac{D_{sh\,i}{}^2}{4} \quad \frac{D_{sh\,i}{}^2}{4} \quad D_{sh\,i}\cdot h_{sh\,i} + h_{sh\,i}{}^2} = \sqrt{\frac{R_j^2}{C_{gr\,i}} \quad D_{sh\,i}\cdot\frac{R_j}{C_{gr\,i}}},$$

$$a_1 = \sqrt{\frac{D_{sh\,i}{}^2}{4} \quad \left(\frac{D_{sh\,i}}{2} \quad h_{sh\,i} \quad h_{gr\,i}\right)^2} = \tag{22}$$

$$= \sqrt{\frac{D_{sh\,i}{}^2}{4} \quad \left[\frac{D_{sh\,i}{}^2}{4} \quad R_j^2\cdot\frac{\left(C_{sh\,i}+C_{gr\,i}\right)^2}{C_{sh\,i}{}^2\cdot C_{gr\,i}{}^2} + D_{sh\,i}\cdot R_j\cdot\frac{\left(C_{sh\,i}+C_{gr\,i}\right)}{C_{sh\,i}\cdot C_{gr\,i}}\right]} =$$

$$= \sqrt{D_{sh\,i}\cdot R_j\cdot\frac{\left(C_{sh\,i}+C_{gr\,i}\right)}{C_{sh\,i}\cdot C_{gr\,i}} \quad R_j^2\cdot\frac{\left(C_{sh\,i}+C_{gr\,i}\right)^2}{C_{sh\,i}{}^2\cdot C_{gr\,i}{}^2}} \;.$$

Considering that as the first approximation, the width of a trace in a ground after pass of each wheel is equal to the width of a profile of the tyre, then the average pressure l_{sr} is equal at the point of contact in length:

$$q_{sp} = \frac{R_j}{\left(a_{1\,i} + a_{2\,i}\right)\cdot B_i}. \tag{23}$$

From experience parities between average and maximum pressure which are characterized by the factor of non-uniformity of distribution of pressure there are known:

$$K_q = \frac{q_{sp}}{q_{max}}, \tag{24}$$

So for tires of low pressure K_q = 0,38...0,54, for arch and wide-profile K_q = 0,45...0,8 [1].

Therefore, it is possible to use these values for the definition as the first approximation of the maximum pressure at points of contact of tires with the ground.

We will define average pressure as the first approximation from geometrical parities, knowing tire deformation.

At loading R_i on axis i – oro of the wheel equipped with the tire, under the formula from the source [1]:

- force of resistance of rolling wheels on the ground:

$$P_{f\,i} = \frac{B_i \cdot q_{0i}^2}{K_i} \cdot l_i \cdot c \cdot h \cdot \frac{K_i}{q_{0i}} \cdot H, \tag{25}$$

$$h_{\text{kol}\,i} = \sqrt[3]{\frac{9 \cdot R_i^2}{B_i^2 \cdot D_{\text{Pr}\,i} \cdot \left(1 + \alpha_i^{\frac{3}{2}}\right)^2 \cdot K_i^2}}, \tag{26}$$

$$D_{\text{Pr}\,i} = D_i \cdot \left(1 + \frac{h_{\text{sh}\,i}}{h_{\text{kol}\,i}}\right), \tag{27}$$

where:
D_i - diameter of a free wheel,
$q_{0\,i}$ - bearing ability of soil,
$h_{\text{sh}\,i}$ - deformation of the tire of the wheel,
$h_{\text{kol}\,i}$ - full immersing of the wheel in soil,

$\alpha_i \; \frac{h_{y\,i}}{h_{\text{kol}\,i}}$ - factor of elasticity of soil,

$$h_{y\,i} = \sqrt[3]{\frac{9 \cdot R_i^2 \cdot \alpha_i^3}{B_i^2 \cdot D_{\text{Pr}\,i} \cdot \left(1 + \alpha_i^{\frac{3}{2}}\right)^2 \cdot K_i^2}}, \tag{28}$$

where:
h_{yi} - size of reversible deformation for the
soils possessing appreciable elastic properties;
α_i - accepted from skilled data.

At $\alpha_i = 0$ expression for $h_{\text{kol}\,i}$ coincides with the formulas resulted in works [3-5], $h_{\text{sh}\,i}$ is defined under the formulas resulted in work [2].

Expression (8) can be transformed as follows.

$$a \cdot d \cdot \left\{\left[Z_B^* - \left(\xi_{C_0} - \xi_B\right)\right] - \left[Z_C^* - \left(\xi_{C_0} - \xi_C\right)\right]\right\} - R_B \cdot a \cdot d \cdot e_{pr\,B} + R_C \cdot a \cdot d \cdot e_{pr\,C} + \tag{29}$$

$$+ b \cdot \varepsilon \cdot \left\{\left[Z_C^* - \left(\xi_{C_0} - \xi_C\right)\right] - \left[Z_D^* - \left(\xi_{C_0} - \xi_D\right)\right]\right\} - R_C \cdot b \cdot \varepsilon \cdot e_{pr\,C} + R_D \cdot b \cdot \varepsilon \cdot e_{pr\,D} +$$

$$+ c \cdot f \cdot \left\{\left[Z_A^* - \left(\xi_{C_0} - \xi_A\right)\right] - \left[Z_D^* - \left(\xi_{C_0} - \xi_D\right)\right]\right\} - R_A \cdot c \cdot f \cdot e_{pr} \quad + R_D \cdot c \cdot f \cdot e_{pr\,D} -$$

$$-\varepsilon \cdot d \cdot \left\{ \left[Z_A^* - \left(\xi_{C_0} - \xi_A \right) \right] - \left[Z_D^* - \left(\xi_{C_0} - \xi_D \right) \right] \right\} + R_A \cdot \varepsilon \cdot d \cdot e_{pr} \quad - R_D \cdot \varepsilon \cdot d \cdot e_{pr\,D} -$$

$$-b \cdot c \cdot \left\{ \left[Z_B^* - \left(\xi_{C_0} - \xi_B \right) \right] - \left[Z_C^* - \left(\xi_{C_0} - \xi_C \right) \right] \right\} + R_B \cdot b \cdot c \cdot e_{pr\,B} - R_C \cdot b \cdot c \cdot e_{pr\,C} -$$

$$-a \cdot f \cdot \left\{ \left[Z_C^* - \left(\xi_{C_0} - \xi_C \right) \right] - \left[Z_D^* - \left(\xi_{C_0} - \xi_D \right) \right] \right\} + R_C \cdot a \cdot f \cdot e_{pr\,C} - R_D \cdot a \cdot f \cdot e_{pr\,D} - 0.$$

$\underbrace{\qquad\qquad}_{q}$ - the designation of the sizes entering into braces.

Let us express from the equation (29) size R_A, having entered the designation:

$$R_A = \frac{1}{c \cdot f \cdot e_{pr\,A} \quad \varepsilon \cdot d \cdot e_{pr\,A}} \cdot \left\{ R_B \cdot \left(b \cdot c \quad a \cdot d \right) \cdot e_{pr\,B} + \right. \tag{30}$$

$$+R_C \cdot \left[\left(a \cdot d + a \cdot f \right) \quad \left(b \cdot \varepsilon + b \cdot c \right) \right] \cdot e_{pr\,C} +$$

$$\left. +R_D \cdot \left[\left(b \cdot \varepsilon + c \cdot f \right) \quad \left(\varepsilon \cdot d + a \cdot f \right) \right] \cdot e_{pr\,D} + q \right\}.$$

Let us also designate:

$$A_B = \frac{\left(b \cdot c \quad a \cdot d \right) \cdot e_{pr\,B}}{\left(c \cdot f \quad \varepsilon \cdot d \right) \cdot e_{pr\,A}}, \; A_C = \frac{\left[a \cdot \left(d + f \right) \quad b \cdot \left(\varepsilon + c \right) \right] \cdot e_{pr\,C}}{\left(c \cdot f \quad \varepsilon \cdot d \right) \cdot e_{pr\,A}}, \tag{31}$$

$$A_D = \frac{\left[\left(b \cdot \varepsilon + c \cdot f \right) \quad \left(\varepsilon \cdot d + a \cdot f \right) \right] \cdot e_{pr\,D}}{\left(c \cdot f \quad \varepsilon \cdot d \right) \cdot e_{pr\,A}}. \tag{32}$$

$$Q = \frac{q}{\left(c \cdot f \quad \varepsilon \cdot d \right) \cdot e_{pr\,A}}. \tag{33}$$

Sizes A_B, A_C, A_D, Q on each step of the account - the constants defined in the sizes of the car, ordinates of a microprofile and rigid characteristics of tires and a ground under wheels.

Solving in the common system the equations (1) and the equation (17, 18), we will define the unknown values R_A, R_4, R_C, R_D.

In connection with absence of data about laws of change of microprofiles of a surface of movement of a combine under different wheels, we will define an admissible difference of ordinates of microprofiles under wheels by criterion of average pressure of the tire on the ground and admissible deformation of the ground.

For the machine decision the received equations (9) and (31-33) will lead to a standard kind:

$$\begin{cases} a_{11} \cdot R_1 + a_{12} \cdot R_2 + a_{13} \cdot R_3 + a_{14} \cdot R_4 = b_1, \\ a_{21} \cdot R_1 + a_{22} \cdot R_2 + a_{23} \cdot R_3 + a_{24} \cdot R_4 = b_2, \\ a_{31} \cdot R_1 + a_{32} \cdot R_2 + a_{33} \cdot R_3 + a_{34} \cdot R_4 = b_3, \\ a_{41} \cdot R_1 + a_{42} \cdot R_2 + a_{43} \cdot R_3 + a_{44} \cdot R_4 = b_4, \end{cases} \tag{34}$$

Here: $R_1 = R_A$; $R_2 = R_B$; $R_3 = R_C$; $R_4 = R_D$, then from the system of equations (1):

$$\begin{cases} 1\cdot R_1 \quad 1\cdot R_2 \quad 1\cdot R_3 \quad 1\cdot R_4 = \quad G_M, \\ 0\cdot R_1 + 0\cdot R_2 + L_M\cdot R_3 + L_M\cdot R_4 = G_M\cdot\left(L_M \quad a_{CM}\right), \\ \dfrac{B_{ZM} \quad \hat{A}_{PM}}{2}\cdot R_1 + \dfrac{B_{ZM} + \hat{A}_{PM}}{2}\cdot R_2 + B_{ZM}\cdot R_3 + 0\cdot R_4 = G_M\cdot Y_{CM}, \\ 1\cdot R_1 + A_B\cdot R_2 + A_C\cdot R_3 + A_D\cdot R_4 = \quad Q, \end{cases} \tag{35}$$

where

$$\begin{aligned} & a_{11} = \quad 1;\ a_{12} = \quad 1;\ a_{13} = \quad 1;\ a_{14} = \quad 1;\ b_1 = \quad G_M, \\ & a_{21} = 0;\ a_{22} = 0;\ a_{23} = L_M;\ a_{24} = L_M;\ b_2 = G_M\cdot\left(L_M \quad a_{CM}\right), \\ & a_{31} = \frac{B_{ZM} \quad \hat{A}_{PM}}{2};\ a_{32} = \frac{B_{ZM} + \hat{A}_{PM}}{2};\ a_{33} = B_{ZM};\ a_{34} = 0;\ b_3 = G_M\cdot a_{CM}, \\ & a_{41} = \quad 1;\ a_{42} = A_B;\ a_{43} = A_C;\ a_{44} = A_D;\ b_4 = \quad Q. \end{aligned} \tag{36}$$

All factors in the system of equations (35) are the constants calculated on each step of calculations.

In case of the scheme of statically stable running system of a machine, for example agricultural tractor with a shaking beam of the bridge of operated wheels distribution of loadings to wheels of this bridge to equally half of loading on the bridge, and taking into account some displacement of the centre of weights of a tractor concerning a longitudinal-vertical plane of symmetry of loading on wheels of the back bridge are distributed in inverse proportion to distances across from the centre of weights of a tractor to corresponding middle planes of the left and right wheel.

Change of normal loadings on bridges of the tractor unit because of the hung equipment, change of pressure of air in tyres and their complete set lead to redistribution of the twisting moments in the branched-out drive to driving wheels and to active working bodies. All this affects the overall performance of the indicators of machine

wheels. The casual character of shocks from a deformable basic surface on wheels and working bodies of the machine contributes to the dynamics of movement of the unit and its operational indicators.

By proper parametres of the working bodies and the connected tools in tires of wheels it is possible to change pressure of air in the set of tires and to influence the efficiency of the running system of a machine.

CONLUSIONS

Thus, the method of calculation of reactions in the support of a machine with statically unstable running system has been developed at movement on both smooth and rough soil surfaces.

The developed method is convenient for the carrying out of the analysis of the dynamics of an agricultural machine. On the basis of such an analysis the decision of many practical problems is possible, for example, problems of the proper choice of parameters of the running system, the analysis of traction and coupling properties of a machine, choice of the hinged equipment and parameters definition by the accepted criteria of development of the given kind of machines.

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BADANIE ROZKŁADU NORMALNYCH OBCIĄŻEŃ KÓŁ STATYCZNIE NIESTABILNEGO UKŁADU JEZDNEGO MASZYNY ROLNICZEJ NA DEFORMOWANYM PODŁOŻU

Streszczenie. W publikacji przedstawiono algorytm określenia normalnych obciążeń na kołach statycznie nieokreślonego układu jezdnego maszyny rolniczej przy ruchu na deformowanym podłożu.

Słowa kluczowe: maszyna rolnicza, statycznie niestabilny układ jezdny, metodyka określenia normalnych obciążeń na kołach