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DISTRIBUTION OF LOADINGS IN TRANSMISSION TRACTION POWER MEANS WITH ALL DRIVING WHEELS AND WITH SYSTEM OF PUMPING OF TRUNKS AT WORK WITH HINGED INSTRUMENTS

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Summary. The article presents the developed technique of the parametrical analysis of distribution of loadings in transmission power means with system of pumping of trunks at work with various hinged instruments in structure of the multioperational agricultural unit, the program realizing a technique, and results of alternative calculations on it.

Key words: the tractor hinged unit, loadings in transmission, a technique of the analysis, the program of calculation

INTRODUCTION

Increase of efficiency of application of wheel tractor power means with high specific capacity in agriculture can be achieved at work in structure of multioperational hinged units. For maintenance of high safety in operation such units are created on the basis of tractors with all driving wheels and with strengthened bearing elements of leading bridges. They have the wheel formula 4K4 or 6K6. Running systems are equipped with wheels with trunks of a special complete set, with the purpose of creation of a necessary stock of carrying capacity of running system and high traction properties of the unit at work with heavy hinged instruments [Tajanowskij and Tanaś 2004a].

Change of normal loadings on bridges of the tractor unit because of the hung instruments, in trunks and their complete sets result in change of pressure of air in redistribution of the twisting moments in the ramified drive to driving wheels. All this affects parameters of an overall performance of driving wheels of the unit.

As to pressure of air in trunks of wheels and a complete set of trunks it is possible to change parameters, and to improve efficiency of running in the system of the multioperational hinged unit. Therefore, it is scientifically and practically useful to establish laws of distribution of loadings to transmissions of the traction power means working in structure of multioperational hinged units, depending on the mentioned factors, which is the purpose of the present work.

At creation of such units it is necessary to take into account, that the maximal values of efficiency of a running system of the machine with the blocked inter-axial connections are achieved at minimizing a kinematic mismatch between driving wheels [Tajanowskij and Tanaś 2004b]. At slippings of each driving wheel, characteristic for a linear site of dependence of specific tangents of efforts in stain – contact of the trunk to a basic surface from slipping a wheel, the loss in running system is lesser, than on nonlinear sites of the mentioned dependence [Tajanowskij and Tanaś 2004b]. This implies, that it is meaningful to solve a task in view within the limits of sites of curves of slipping of the driving wheels close to linear [Krasowski (red.) 2005].

THE METHODICAL APPROACH

The basic methodical positions of an estimation of influence of the major factors on a kinematic mismatch of wheels of conducting bridges and on distribution of the twisting moment on driving wheels of tractor power means with all driving wheels, equipped with a system of pumping of trunks, are developed in view of the known laws of the theory of movement of a wheel [Krasowski (red.) 2005].

The system of the centralized pumping of trunks of tractors with the wheel formula 4K4 (6K6) usually is one having pipeline, and cavities of everything, or a part of trunks are informed among themselves. More often such tractors with all driving wheels have the blocked inter-axial drive. Thus distribution of the twisting moments on wheels is defined by the brought twisting moment from a secondary shaft of a box of transfers to distributing unit, transfer relations up to driving wheels and radiuses of movement of wheels, at concrete loading on trunks, pressure of air in trunks and work in structure of the tractor unit, and also elastic characteristics of interaction of trunks with a basic surface.

In the theory of a tractor it is shown that, with other things being equal, the greatest parameters of traction efficiency and efficiency of the running system in a tractor with a blocked inter-axial drive are observed at equality to zero of inter-axial kinematic discrepancy [Krasowski (red.) 2005], that is

$$\eta_{тяг} = \frac{N_{кр} v}{N_{двиг} - N_{BOM}} = \frac{P_{кр} v}{N_{двиг} - N_{BOM}} \rightarrow max,$$

$$\text{at } k_{н12} = \frac{v_{т2} - v_{т1}}{v_{т2}} = 1 - \frac{v_{т1}}{v_{т2}} = 0, \left(k_{í 32} = 1 - \frac{v_{ò 3}}{v_{ò 2}} = 0 \right),$$

where:

N_{SSC} – capacity, on a drive of a shaft of selection of capacity (SSC);

$N_{кр}$ – capacity on a hook;

v – the valid speed of movement of a tractor;

$v_{т1} = r_1^0 \cdot \omega_1$; $v_{т2} = r_2^0 \cdot \omega_2$; $\left(v_{т3} = r_3^0 \cdot \omega_3 \right)$ – district theoretical speeds of wheels of forward and back bridges of a tractor;

ω_1, ω_2 – angular speeds of a rim of driving wheels;
r_1^0, r_2^0, r_3^0 – radiuses of rotation of wheels at the set vertical loading on an equal horizontal dry concrete track with high coupling properties. On numerical value these radiuses are very close to radiuses of rotation of the same wheels in a conducted (free) mode of rotation. And in the theory of movement of the wheel equipped with the trunk, they are accepted as uniform settlement dynamic radius of a wheel (see A.A. Shabarova, V.V. Vantsevicha's works).

Scientists V.A. Petrushov, S.A. Shuklin and V.V. Moskovkin offer experimentally revealed dependence for definition of radius of movement of a wheel in a conducted mode on a concrete track in the function of pressure of air in the trunk and vertical loading on a wheel [Tajanowskij and Tanaś 2004b].

$$r^0{}_j = r_{jc} \cdot \frac{r_{jc} p_{wj} + \nu_{1j} \cdot G_j}{r_{jc} p_{wj} + \nu_{2j} \cdot G_j},$$

where:
ν_{1j}, ν_{2j} – empirical constants of approximation of results of experiments by the offered modeling expression;
p_{wj} – pressure of air in the trunk;
G_j – normal loading on a wheel;
r_{jc} – free radius of a wheel with the trunk.

Feature of the circuit of the centralized pumping trunks will be that at change of distribution of loading on bridges of a tractor it is impossible to achieve $k_{\text{н}ij} = 0$ change of pressure. Therefore, practical interest will be considered at real structures of units and various operating modes.

Values of constants for wheel trunks at universal agricultural tractors are resulted in Table 1.

Table 1. Constants of approximation for trunks of wheel tractors

Trunk	Model	Disk	$\nu_{1j}\,\frac{1}{m}$	$\nu_{2j}\,\frac{1}{m}$	$2 \cdot r_{jc}$, mm
11.2–20	Ф-35	W8	-8.063	5.067	985±9
16.0–20	Ф-64	DW13	-0.534	3.353	1095±6
15.5R38	Ф-62	DW14L	-2.283	1.142	1600±16
16.9R38	Ф-52	W15L	-2.097	1.048	1685±25
18.4R34	Ф-44	DW16	-2.059	1.029	1705±25

In case of connection of instruments with power means even in static vertical loadings G_1 and G_2 on wheels of a tractor are redistributed. Values of these loadings can be defined on the following expressions, from the equations of static balance of a tractor in weight G with the forward and back instrument ($G_{н1}$ on a start c and $G_{н2}$ on a start b) in position of distant transport:

$$G_1 = 0,5\frac{1}{L}\left[G_{í1}\left(L+c\right)+G\cdot a - G_{í2}\cdot b\right];$$
$$G_2 = 0,5(G + G_{í1} + G_{í2} - G_1);$$
$$G_2^{à} = G_2^{â} = \frac{1}{2}G_2 - at\_6\hat{E}6$$
,

where:

a – distance from the center of weights of a tractor up to the back bridge.

The operating mode of the hinged multioperational unit on the so-called distant transport, that is during moving from site to site, is considered owing to the essentially greater speed of movement (up to 37–50 km/hour), the greater dynamic loading of driving wheels of a tractor and necessity in this connection to raise pressure of air in trunks. Whereas at work on a field at speeds up to 12..15 km/hour the process involves equipment in addition to bases on the wheels. Pressure in trunks of a tractor is reduced to provide smaller pressure upon ground, increase of parameters of traction and coupling properties and, in result, increase of passing ability, decrease in slipping and increase of technical and economic parameters of the unit as a whole. For a tractor under the circuit 6K6 with caterpillar contour on back driving wheels putting on of caterpillar contour occurs at the lowered trunks. And for raising work pressure in trunks, also a caterpillar drive is strongly kept on trunks. In the latter case selection of such trunk pairs which have the minimal distinctions in parameters even within the framework of technological admissions on manufacturing is especially important. Otherwise reliability of work of such wheel pairs will be insufficient.

Using the resulted formulas and values v_1 and v_2, we consider influence of combinations G, $G_{н1}$, $G_{н2}$, p_w for a concrete tractor and structure of the unit, at various real combinations of the listed parameters, the identical and different sizes of trunks, on sizes $k_{н12}$, $k_{н32}$. It is necessary to define ranges of change of the listed influencing factors at which $k_{н12}$, $k_{н32}$ are close to zero, and efficiency of running system of the unit will be the greatest, with other things being equal.

Knowing r_j^0 and for concrete trunks - the dependences $\lambda_j(G_j, p_{wj})$ reflecting character of interaction of the trunk j with a basic surface in dependence of academician E.A. Chudakov

$$r_j = r_j^0 - \lambda_j(G_j, p_{wj})\cdot M_j,$$

it is possible to calculate distribution of the twisting moments on wheels of various bridges of the tractor unit under the received formula, considering, that all trunks should work on initial, close to linear, sites of the base characteristic of the trunk $r_j\left(M_j\right)$:

$$M_j = \frac{u_j \cdot M_0 + \sum_{i=1, i\neq j}^{m} \left(\frac{r_j \cdot u_i - r_i^0 \cdot u_j}{u_i \cdot \lambda_i} \right)}{1 + \lambda_j \cdot \sum_{i=1, i\neq j}^{m} \left(\frac{1}{\lambda_i} \right)},$$

where:

M_j – the twisting moment on a wheel with number j;

m – quantity driving wheels i;

M_0 – the moment on the switching centre;

r_i^0, r_j^0 – radiuses of rotation of wheels in a conducted mode;

u_i, u_j – transfer relations of branches of transmission - drives to various bridges with driving wheels.

Processing with use of a method of the least squares of results of tests of tractor trunks by definition $r_j^{\,0}$, at various internal pressure and loadings, has allowed to receive dependences $\lambda_j(G_j, p_{wj})$ for lines of trunks of wheel tractors. It is known, that such dependences can be approximated modelling expression of a kind

$$\lambda_j(G_j, p_{wj}) = \lambda_j^{\,*} \cdot \left[1 - \left(1 - \frac{G_j^{\,*}}{G_j} \right) \cdot \frac{p_{wj}}{p_{wj}^{\,*}} \right],$$

where:

$\lambda_j^{\,*}$, in mm/kN·m – characteristic value of factor of tangential elasticity of a stain of contact j a wheel equipped with the trunk, with a basic surface, at nominal pressure of air $p_{wj}^{\,*}$ in the trunk and normal loading $G_j^{\,*}$ on it. At operational changes G_j and p_{wj} these dependences for trunks of universal agricultural tractors are shown in Figure 1.

Knowing G_i and parameters of rigidity of trunks, under R. Hedekel's well-known formula (or under V.L. Biderman's more exact formula) the normal deflection h_z of the trunk is determined, that, further, allows to estimate and average pressure of trunks upon a ground [Tajanowskij and Tanaś 2006]:

$$h_z = \frac{G_j}{\pi \cdot p_{wj} \sqrt{B_j D_j}}.$$

On values of average pressure upon a basic surface, the basic passing ability of the tractor unit is judged, besides this parameter is necessary at an estimation of allowable hinged loading of power means in structure of the created hinged unit [Tajanowskij 1999, Tajanowskij and Tanaś 2006].

Thus, the technique is generated and the necessary data which allow to estimate influence p_{wj} and G_j on parameters k_{nij} and M_j, determining traction efficiency of a tractor are received. With the help of the presented technique the multiple design analysis is carried out of a tractor and the unit on its base with forward and back instruments, by search of rational design parameters of a created tractor, and also at the coordination of connection of a tractor with technological machines and the equipment.

CALCULATIONS BY THE OFFERED TECHNIQUE

With the purpose of creation of convenient engineering toolkit by the offered technique the program appendix in technology of software product MATHCAD-2003 is developed. It allows to carry out the multiple analysis of distribution of loadings in the blocked drive of driving wheels of the hinged unit on the basis of wheel power means with all driving wheels. Arguments of research can be practically all parameters of the hinged unit or variants of their combinations. Besides the program appendix is applicable for any engine or structure of transfer relations of transmission of power means, that is universal enough.

For the correct task of the initial data on the engine it is necessary to have its high-speed characteristics, or to construct it on the main parameters of the engine assumed to installation on traction power means. The program automatically builds schedules of dependences on files of the initial data determined by the user, and also builds phase portraits for the chosen pairs or sets of phase coordinates.

In Figures 1 and 2 are shown as an example results of alternative calculations on the expressions resulted earlier for a real set of values of the initial data.

In Figure 1 schedules of dependences of radiuses of rotation of driving wheels in a conducted mode from pressure inside trunks are submitted.

In Figure 2 schedules of dependences of factors $\lambda_j(G_j, p_{wj})$ for driving wheels from normal loading and pressure inside trunks, and also distribution of the twisting moments corresponding earlier to the resulted initial data on wheels of conducting{leading} bridges are submitted.

As follows from schedules, radiuses of rotation of wheels in a conducted mode curvilinearly depend on pressure of air in trunks, as is observed at their experimental definition. Factors $\lambda_j(G_j, p_{wj})$, in turn, curvilinearly depend on normal loading on the trunk, that also corresponds to the skilled data. The marked dependences bring also nonlinearity in the process of redistribution of the twisting moments in the blocked transmission of traction power means (Figure 2).

The received expressions have allowed to estimate also change of a kinematic mismatch of district speeds of driving wheels of running system of the unit depending on change of influencing factors. In Figure 1 influence of pressure in trunks of wheels of the forward bridge on the mentioned size is shown. As follows from the Figure, the kinematic mismatch has a negative sign, that is forward wheels are running, and with growth of pressure the process is aggravated.

Therefore, for achievement of zero value of a kinematic mismatch it appears necessary to change parameters of the hung instruments, and to stages of creation of traction power means – to change transfer relations to driving wheels, or to select other trunks.

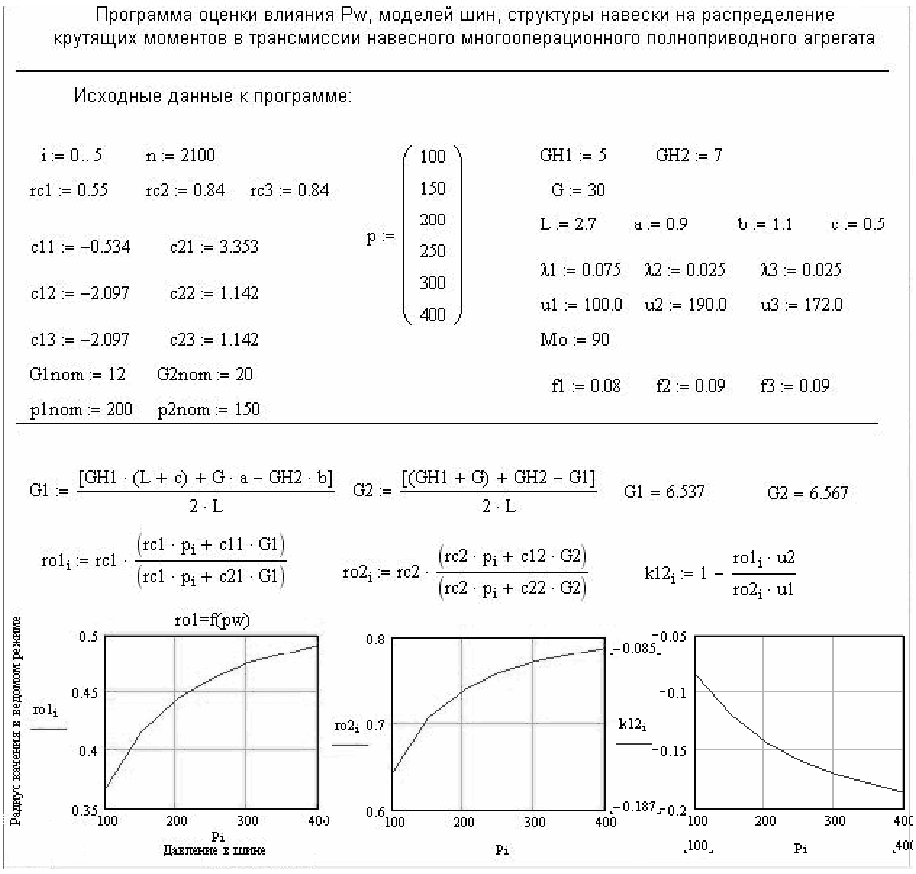

Fig. 1. A fragment of the program with the initial data and a part of calculation for the hinged unit on the basis of power means with the wheel formula 4K4

As a whole, the received settlement results correctly reflect the character of occuring processes in transmission of the hinged unit in base traction power means at change of pressure inside trunks and parameters of the agricultural instruments attached to it.

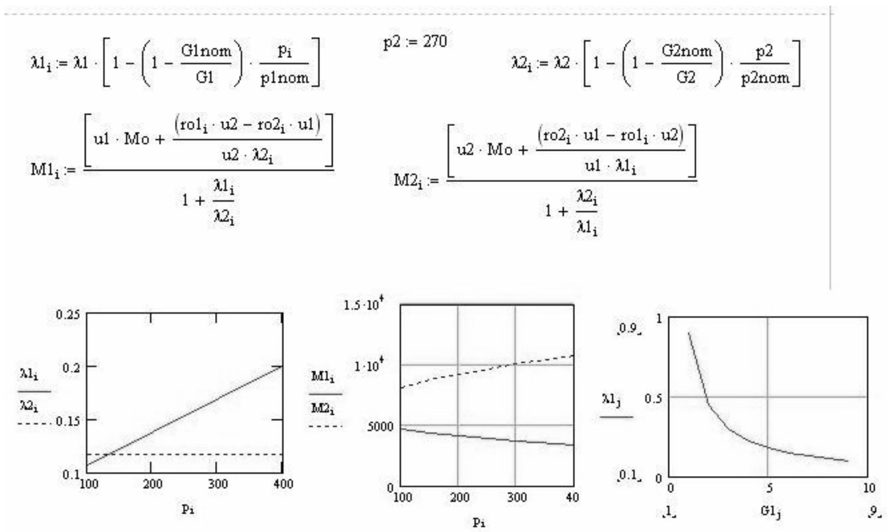

Fig. 2. A fragment of the program with schedules $\lambda_j(G_j, p_{wj})$ and $M_j\left(p_{wj}\right)$ for the unit with the wheel formula 4K4

CONCLUSION

The developed technique of the parametrical analysis of distribution of loadings in transmission of traction power means with all driving wheels with system of inflating of trunks at work with the various attached instruments in structure of the multioperational agricultural unit adequately reflects processes in the blocked transmission, and the program appendix realizing a technique represents convenient engineering toolkit for the carrying out of researches at a stage of creation of new agricultural units.

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