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TRACTION DYNAMICS OF THE ALL-WHEEL DRIVE MACHINE TRACTOR UNIT WITH HINGED SOIL PROCESSING EQUIPMENT

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Summary. In the article methodical positions of the parametrical analysis of dynamics of the all-wheel drive machine tractor unit (MTU) including hinged soil processing equipment with active working bodies (AWB) are performed.

Keywords: tractor's hinged unit, soil processing equipment, active working bodies, dynamics, analysis, methodical positions.

INTRODUCTION

The choice of rational parametres of a technological part with AWB and parametres of connection of links MTU allows to provide for an efficient unit design and application of a wheeled tractor power means in the unit. Such units are created on the basis of all-wheel drive tractors equipped with wheels with tyres of a special complete set, including doubled, that allows to name them mobile power means (MPM). It creates a necessary stock of load-carrying capacity of running system, high traction and coupling properties of passableness of the unit as the equipment processing soil seems the most power-intensive. Generally, irrespective of appointment of active working bodies MTU, the hinged equipment includes driving from an independent shaft of selection of capacity (SSC) MPM a monoblock with attached modules AWB. Under such scheme, units for milling of mineral and peat marsh soils, including soils with turf, for example milling cultivator KFG-3,6 for superficial processing of soil, the milling cultivator forming crests, KFG-2,8 for strip milling of soil, a mill processing soil, Ф-200 for soil milling by active working bodies, destruction of weed vegetation and microrelief alignment, and also the milling equipment for continuous milling of peat marsh soil FBN-1,5 (drawing 1), milling and forming equipment НТК-2 for extraction of lumpy fuel peat (drawing 2), the equipment for cleaning of roots and tubers of vegetables with drived shaking row unit and others are carried out.

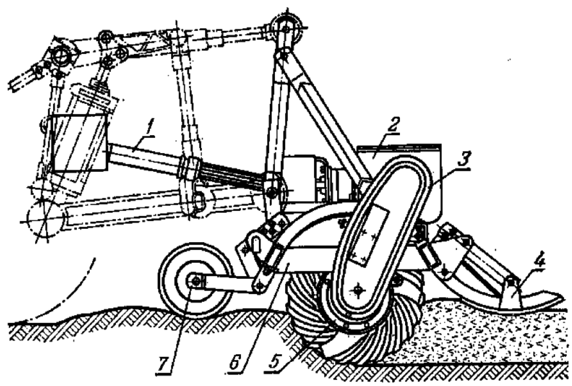

Fig. 1. Mill FBN-1,5: 1 - a shaft from tractor; 2 and 3 - reducers;
4 - the terminator of depth of soil processing; 5 - a milling drum; 6 - a frame; 7 - a basic wheel

The general structure and the scheme of application of forces to AWB in the listed equipment allows to carry out an analysis of traction dynamics such as MTU on the generalised settlement scheme, and to specifically consider a given unit, considering features of formation of working loadings from a processed soil ground on concrete active working bodies.

Let's consider as an example MTU as a part of an all-wheel drive tractor and the milling and forming hinged equipment. The last consists of a disk mill and a screw processing press with a forming mouthpiece (Fig. 2). A disk mill, at the milling counter, cuts off peat material elements from a peat deposit. The material moves to a reception window of a press where it is subjected to processing, and then receives a desired form. At the mouthpiece, the material breaks off on an exit under the influence of a body weight in the form of the formed pieces of some length and it is spread on a surface of a peat deposit where it dries in natural conditions. After drying, the ready lumpy fuel is cleaned. The resulted power settlement scheme of the given unit can be considered as generalised, invariant in relation to an appointment of the unit processing soil.

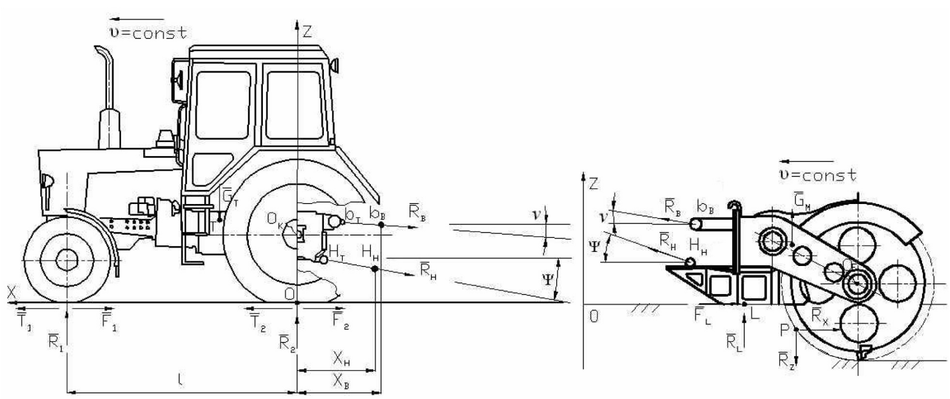

Fig.2. Settlement scheme of the milling tractor unit

In Fig. 2 are designated: normal reactions of ground R_i, forces of resistance F_i, theoretical traction efforts of leading bridges T_i, efforts in draughts back hinged device R_b, R_H, reactions of a ground to disk mill R_x, R_z, forces of weight of a tractor and equipment G_T and G_M, and also the characteristic sizes and points of the tractor unit.

On the basis of the resulted settlement scheme we will receive necessary analytical expressions for carrying out an analysis of the dynamics of a created MTU. On the basis of such an analysis it is possible to solve the problem of the choice of parametres of the equipment and connection parametres by the accepted criteria of development of the given kind of cars.

DYNAMICS OF THE TRACTOR UNIT AT THE ESTABLISHED SPEED OF MOVEMENT

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 of it affects the overall performance indicators of the wheel system in the unit. Casual character of disturbances from a basic surface on wheel system and disk mill MTU is brought by the contribution to dynamics of movement of the unit and its operational indicators.

The methodical approach to the choice of rational parametres AWB and the parametres of MTU as a whole should be based on the results of MTU dynamics analysis

At creation of such units it is necessary to consider, that the maximum values of efficiency of running system of an all-wheel drive car with the blocked interaxal communications are reached at minimising of a kinematic mismatch between driving wheels [1,2,3]. At slippings of each driving wheel, characteristic for close to linear from slipping of a wheel, loss in running system is lower at the site of dependence of specific tangents of efforts than on nonlinear sites of the mentioned dependences [1,2,3,8]. From this follows, that it makes sense to solve the task in view within sites of curves of slipping of the driving wheels close to linear [3], and to select such complete set of tyres which have such sites of the mentioned dependences.

Among the major factors which are subject to the analysis at research of dynamics of the tractor unit, the most important are the constructive and layout scheme, parametres of kinematics of a drive, a disk mill, screw processing press MTU, traction and coupling characteristics of tyres and the characteristic of resistance to giving of a mill from the peat soil, forming character of entrance influence on MTU [1,2,3,4,9].

The operating modes defining indicators of operational properties of the milling and forming wheel tractor unit include e.g. dispersal, movement with the established speed on roughnesses of a basic surface of a peat card, at transport position and at work of the milling equipment hung on a tractor, turn and maneuvering, unit braking.

Modelling and analysis of the listed modes of working process of the milling and forming unit, at research of dynamics MTU, are also necessary, as they allow to reveal their properties and to carry out their analysis, for the purpose of the subsequent choice of rational design data of transmission and system of a suspension bracket projected MTU. Thus it is in addition necessary to consider characteristics of elements of a suspension bracket of a tractor, and also casual character of a profile of a way.

The variety of casual combinations of parametres and properties of a peat card leads to essential changes of technical and economic indicators of the working process and quality of a formed peat piece. In particular, change of slipping of driving wheels of a tractor, at fluctuations of a condition of a surface of movement taking place on a peat card and resistance to mill giving, leads to a mismatch of a balance parity work MTU on a course and on active working bodies. It also leads to a deviation of degree of processing of peat weight from the expedient. It worsens the quality of the received fuel, especially on peat deposits, with average and higher degree of decomposition of peat, and on deposits of the so-called crumbling peat [2, 5, 6, 7]. Change of other factors is possible to influence, to a certain extent, both operational indicators MTU, and the quality of a peat piece. Therefore the decision of a problem of operative adjustment, in the course of MTU movement, of parametres of a drive of its active working bodies providing minimisation of specific power expenses is possible, at stabilisation of productivity and quality of a formed peat piece, within the limits of the rational structural design scheme of the unit (Fig. 2).

For research of dynamic loadings of drives of working bodies the dynamic system of transmission of the milling and forming tractor unit is settled, the dynamic schematization of object of research is carried out, the mathematical description is made, results are obtained in work [3].

For the description of work of the unit, taking into account the mentioned work, we will also enter the following designations:

$M_{fk2}, f_{k2}, M_{fk3}, f_{k3}$ – The moments and resistance factors of wheel drive of forward and back bridges of a tractor;

$N_2, N_3, r^o_{k2}, r^o_{k3}$ - Normal loadings and radiuses in a conducted mode of wheels of forward and back bridges of a tractor;

v_4 - Current speed of movement of the tractor unit;

$a_2, a_3, b_2, b_3, K_2, K_3, L_2, L_3$ - Constants of approximation of dependence of the twisting moment *i* developed by a leading or lagging behind wheel, from its slipping by expression of kind $M_{ki}(\delta_i, N_i) = \varphi_{i\max} N_i r^0_{ki}\left(1 - e^{-k_i\delta i}\right)$;

ω_i, ω_{i+1} - Angular speeds, accordingly, *i* and (*i+1*) wheels of leading bridges of a tractor.

For an estimation of redistribution of normal loadings on bridges of a tractor, efforts in draughting back outboard equipment, slippings of wheels of bridges, the expressions also allow to estimate traction dynamics, traction and coupling properties and passableness of the unit.

At the established speed of movement, the equation of balance of unit links of in the accepted system of co-ordinates look like (Fig. 2):

- For the hinged milling and forming equipment:

$$-R_{â} \cdot \cos\nu - R_{i} \cdot \cos\psi + R_{ë} \cdot f_1 + R_x = 0;$$
$$R_{â} \cdot \sin\nu + R_{i} \cdot \sin\psi + R_{ë} - G_{ì} - R_z = 0;$$

$$R_{â} \cdot \left[\cos\nu \cdot \left(z_{âì} - z_{ii}\right) - \sin\nu \cdot \left(x_{ii} - x_{âì}\right)\right] + R_{ë} \cdot \left[\left(x_{ë} - x_{ii}\right) + \left(z_{ii} - z_{ë}\right)\right] + R_x \cdot \left(z_{ii} + \left|z_{ð}\right|\right) -$$
$$R_z \cdot \left(x_{ð} - x_{ii}\right) - G_{ì} \cdot \left(x_{ì} - x_{yì}\right) = 0; \qquad (1)$$

where: in the system of three equations (1) there are available three unknown sizes: R_a, R_i, R_e;

- for a tractor, considering, that it is possible to present the valid traction effort of the leading bridge a difference of theoretical traction effort and conditional force of resistance moving bridge wheels, we will write down:

$$T_1\left(\delta_2\right) - R_1 \cdot f_2 + T_2\left(\delta_3\right) - R_2 \cdot f_3 - R_{â} \cdot \cos\nu - R_{i} \cdot \cos\psi = 0,$$
$$R_1 + R_2 - G_{Ò} - R_{â} \cdot \sin\nu - R_{i} \cdot \sin\psi = 0,$$

$$G_{Ò} \cdot x_{Ò} - R_1 \cdot \left[\left(l + \left|x_{iò}\right|\right) - f_2 \cdot z_{iò}\right] - T_1 \cdot z_{iò} - R_2 \cdot \left(\left|x_{iò}\right| - f_3 \cdot z_{iò}\right) - T_2 \cdot z_{iò} -$$
$$-R_{â} \cdot \left[\cos\nu \cdot \left(z_{Âò} - z_{iò}\right) - \sin\nu \cdot \left(\left|x_{Âò}\right| - \left|x_{iò}\right|\right)\right] = 0. \qquad (2)$$

In case of the blocked interaxal drive, slipping of wheels of forward leading bridge δ_2 is defined through slipping δ_3 of wheels of the back leading bridge and constructive kinematic discrepancy k_{i23} to known expression [5]:

Then in the system of the equations (2) there are also available three unknowns : R_1, R_2, δ_3. The system of nonlinear equations (2) also assumes the method stated in work [5].

The moments and traction efforts on unit wheels (Fig. 2) were defined from expressions (taking into account designations in settlement to dynamic system [3]):

$$M_{fk2} = f_{k2}^{o} R_1 r_{k2}^{o}; M_{fk3} = f_{k3}^{o} R_2 r_{k3}^{o},$$

$$M_{34} = M_{k2}(\delta_2, R_1) = \varphi_{2\max} R_1 r_{k2}^{0} \left(1 - e^{-k_2\delta_2}\right); M_{54} = M_{k3}(\delta_3, R_2) = \varphi_{3\max} R_2 r_{k3}^{0} \left(1 - e^{-k_3\delta_3}\right), \tag{3}$$

where: R_1 and R_2 - accordingly, normal loadings on tyres of forward and back bridges of a tractor (Fig. 2).

For radius definition moving wheels in a conducted mode as pressure of air in the tyre and vertical loading on a wheel which is accepted as uniform settlement radius at dynamics research moving wheels, the offered V.A. Petrushovym, S.A. Shuklinym and V.V. Moskovkinym experimentally revealed dependence [3] is used:

$$r^0{}_j = r_{jc} \cdot \frac{r_{jc} p_{wj} + \nu_{1j} \cdot N_j}{r_{jc} p_{wj} + \nu_{2j} \cdot N_j}, \tag{4}$$

where: ν_{1j}, ν_{2j} - empirical constants of approximation of results of experiments by the offered modelling expression; P_{wj} - pressure of air in the tyre; N_j - vertical (normal) loading on a wheel; r_{jc} - free radius of a wheel with the tyre.

The twisting moment on a disk mill is defined from laws of work of this active working body [1,2]. It is caused by expenses of energy for peat and stub milling in the deposit mill knives, on the transfer to a material of kinetic energy, on lifting of the peat separated from a deposit to a reception window of a press and on a friction of this peat about directing surfaces of a casing:

$$M_ф = \frac{N_ф}{\omega_9}; N_ф = N_{фт} + N_{фпн} + N_{фкин} + N_{фпдм} + N_{фтрн} =$$
$$= (1-\alpha)p_т Q_х + \alpha p_{пн} Q_х + N_{фкин} + N_{фпдм} + N_{фтрн} =$$
$$= Q_х p_т (1 + 100\alpha) + N_{фкин} + N_{фпдм} + N_{фтрн}; Q_х =$$
$$= bh\vartheta_д; p_{пн} = 70..100 p_т,$$

where: N_f - capacity on deposit milling; N_{ft} - capacity on peat milling; N_{pn} - capacity on stub milling; Q_h - productivity of the unit on a course; b - width of milling; h - depth of milling; □δ - the valid speed of movement of a tractor; α - level include of wood deposits; p_m, $_{грп}$ - specific expenses of energy for peat and stub milling, accordingly; ω_9 - angular speed of a mill; $N_{фкин}$ - capacity on the message to a material of kinetic energy; $N_{фпдм}$ - capacity on lifting of the peat separated from a deposit to a reception window of a press; $N_{фтрн}$ - capacity on a peat friction about a casing. Expressions for a power estimation of a disk mill and components $N_{фкин}$; $N_{фпдм}$; $N_{фтрн}$ are received by F.A.Opejko and are widely used [4]. Values of the last listed components are small, in comparison with ($N_{фт}+N_{фпн}$). Specific expenses of energy for milling of a peat deposit by a disk mill [1] are defined from expression:

$$p_m = \frac{20000}{\sqrt{\delta_{мах}}} = \frac{20000}{\sqrt{\frac{4\pi\vartheta}{z\omega_9}\sqrt{\frac{h}{D}}\sqrt{1-\frac{h}{D}}}}. \tag{5}$$

Neglecting sizes $N_{фкин}$; $N_{фпдм}$; $N_{фтрн}$, we will receive;

$$N_{ф} = \frac{20000bh\vartheta(1+\alpha)}{\sqrt{\frac{4\pi\vartheta}{z\omega_9}\sqrt{\frac{h}{D}}\sqrt{1-\frac{h}{D}}}} = K_{фр}\sqrt{\vartheta\omega_9},\ \text{if to designate}\ K_{фр} = \frac{20000bh(1+100\alpha)}{\sqrt{\frac{4\pi}{z}\sqrt{\frac{h}{D}}\sqrt{1-\frac{h}{D}}}}, \tag{6}$$

where: $\square_{\mu\alpha\eta}$ - the maximum thickness of a shaving; z - number of knives in a cutting plane; h - depth of milling; D - diameter of a mill.

Then:
$$M_{ф} = \frac{K_{фр}\sqrt{\vartheta\omega_9}}{\omega_9} = K_{фр}\sqrt{\frac{\vartheta}{\omega_9}}. \tag{7}$$

The twisting moment on a shaft of a screw processing press will be defined from expressions:

$$M_{sh} = \frac{N_{ш}}{\omega_8};\ N_{ш} = \tau\omega_8 S + p_m Q_x, \tag{8}$$

where: ω_8 - angular speed of a screw shaft; $\tau = 2500.\ 5000\ Pa$ - pressure of shift of layers of peat; S - the static moment of an internal surface of a casing screw concerning a rotation axis; $p_м$ - specific resistance to peat formation through a mouthpiece. The S is given by equation:

$$S = \frac{\pi D^2}{4}L;\ p_m = 4\tau\frac{l}{d}; \tag{9}$$

so
$$M_{sh} = \tau S + p_m bh\,\frac{\vartheta}{\omega_8}, \tag{10}$$

where: D - internal diameter of a casing ; L - length screw; d - internal diameter of a mouthpiece; l - length of a mouthpiece.

CONCLUSION

The resulted expressions of mathematical model consider various conditions of movement, parametres of the milling and forming equipment, a tractor, running system and allow to define: loading, slipping and draught of a wheel system; and also possibility of realisation of dispersal; the twisting moments on transmission shaft. The developed mathematical model allows to consider an influence of slipping of wheels system on the working process of a mill and a press, to make an estimation of mutual influence of parametres of the unit and modes of loadings of working bodies on operational indicators of the unit, for the purpose of a choice of their rational values and management system engineering by active working bodies for essential decrease in specific power expenses. The model provides reception of characteristics of AWB drive. Their comparison with results of natural tests of the unit allows to estimate adequacy of a picture of modelled processes, an event in a unit operating time. By means of the given model realised on the computer, the settlement analysis of indicators unit a wheel tractor is made. Machine experiment is spent at a various complete set by tyres of wheels system, c milling and forming (or only milling) the equipment of various layout schemes, parametres and appointment, for the purpose of the choice of the best, for example, on indicators of specific power expenses or other indicators of quality of working process, a combination of parametres of the hinged equipment and parametres of connection of units in MTU structure.

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DYNAMIKA PROCESU ROBOCZEGO AGREGATU CIĄGNIK – ZAWIESZANE URZĄDZENIE FREZUJĄCE DO GLEBY

Streszczenie. W publikacji przedstawiono metodyczne podstawy analizy parametrycznej dynamiki procesu roboczego ciągnikowego agregatu z zawieszanym rotacyjnym spulchniaczem frezującym do gleby.

Słowa kluczowe: agregat zawieszany, rotacyjny spulchniacz frezujący, aktywne organy robocze, gleba, dynamika, analiza.