

Theoretical research of parameters of combined top-gathering aggregate

V. Adamchuk,

Dr. Sc., academician of NAAS,

National Science Center "Institute of Mechanization and Electrification Agriculture"

V. Bulgakov,

Dr. Sc., academician of NAAS,

National University of Bioresources and nature use of Ukraine

Ye. Ignatyev, eng.,

Tavria state agrotechnological university

The purpose. To increase productivity of combined top-gathering aggregate, which is used as a part of top-gathering machine frontally mounted on a wheel tractor and hooked on behind the cleanser of heads of root crops from the remnants of haulm, on the basis of development of original positions of the theory of building-block design with the maximum productivity and minimum power expenditures. Methods: theories of mathematical simulation, theory of a tractor, bases of use of machines in plant growing, creation of programs and numerous accounts for PC. **Results.** Mathematical model is developed of justification and sampling optimum parameters of machine-and-tractor aggregates which consists of a tractor, frontally mounted top-gathering machine and hooked on behind the cleanser of heads of root crops from the remnants of haulm. They determined analytically dependence of working speed of such combined top-gathering aggregate and its productivity on the resistivity created by the top-gathering machine and cleanser, calculated optimum parameters of these aggregates by criteria of productivity and power consumption. **Conclusions.** As the result of multiple simulations on PC it is fixed that integral-tilling wheel tractor of the 3rd class will ensure the greatest productivity at use of the combined top-gathering aggregates for all range of width of cut and in all range of changes of specific draught resistance. Owing to power reserve there is an opportunity of application of additional drives, in particular root-gathering machines.

Key words: *sugar beet, haulm, harvesting, aggregate, tractor, mathematical model, parameters.*

Widely used nowadays in the world, modern technologies for collecting sugar beet hooks assume, initially, a continuous, uncompromising cut of the main massif of green mass, and the subsequent individual extraction of root crop heads from the remnants of the hook at the root. At the same time, the first technological operation for cutting the main mass of the green wedge involves collecting its harvest (continuous crop cut, harvesting the beveled mass and unloading), transporting it for further use as a feed for cattle, as a green fertilizer, which then bumps into the soil or raw material for obtaining biogas. The use of hoeing machines and head cleaners from the hook residues as independent harvest modules allows you to aggregate them with different types of propulsion tractors. This calls for the need to determine the conformity of one or another hoeing machine and a cleaner to the traction energy parameters of the aggregate tractors, which will ensure the high efficiency of the use of the proposed harvesting machine-tractor aggregates. However, the high efficiency of the functioning of the harvesting agricultural machine-tractor unit is achieved due to the correct correlation between its technical parameters, operating regimes and external production conditions, such as the physical and mechanical properties of the soil, the inclination of the surface of the field, the characteristics of the material to be collected, specific resistance of the technological process and other concrete agrotechnical conditions. Therefore, the question of

aggregation of hoeing machines and roothead cleaners from the remnants of the hook with different types of driven wheeled tractors is relevant and requires appropriate scientific substantiation.

ANALYSIS OF LAST PUBLICATIONS. The theoretical study of the aggregation of agricultural machines is connected with the obligatory construction of the calculated mathematical models of the functioning of various self-propelled and trailer machine aggregates. These questions are sufficiently detailed in the scientific literature [1-5]. In this case, the construction of calculated mathematical models of trailed agricultural machines, including beet-harvesting works [6, 7].

Fundamental theory of aggregation of trailed and rear-mounted agricultural machines is widely presented in the works [8-11].

In addition, the profound issues of forecasting the degree of productivity of beet-harvesting machines, depending on specific investments, are discussed in the monograph [12]. However, the choice of the optimal parameters of front-mounted hoeing machines and rear-mounted head cleaners for root crops from the remains of the hinge on the criteria of the power of the aggregate wheeled tractor were not considered.

Ways of obtaining performance characteristics of various machine-tractor units made up of aggregate tractors and mounted in front and behind the machines and implements are widely represented in the works [13-15].

Therefore, on the basis of all the foregoing, we see that the efficiency of using aggregated beet-harvesting machines must first be evaluated as part of the aggregate tractor and substantiate this efficiency by means of quantitative criteria that would reflect with a sufficient degree of accuracy their operational properties and technical excellence. Among such criteria are, first of all, the productivity of such an aggregate, the minimum operating costs, the specific productivity of 1 kW of aggregate tractor power and other performance indicators.

THE AIM OF THE STUDY. Increasing the efficiency of using a combined hoeing machine, consisting of a front-mounted hook-picking tractor tractor and a hinged hook attached behind the head cleaners of root crops, based on the development of the basic principles of aggregation theory with maximum productivity and minimum energy costs.

RESEARCH METHODS. During theoretical studies, methods of the theory of mathematical modeling, the theory of the tractor, the basis of machine use in crop production, as well as programming and numerical calculations on the PC were used.

RESULTS OF RESEARCH. The use of combined hoeing machines as independent technological modules for sugar beet harvesting allows them to be aggregated with different types of wheeled tractors equipped with the front hauling device and the front shaft of power take-off. The aggregate tractor must be propagated, that is, equipped with narrow tires fitted to the appropriate width of the track, that is, the corresponding rows of sugar beet root crops. In addition, hook-picking machines must necessarily be front-mounted to the aggregate power tool, and the head cleaners of the root crops from the rest of the grip should be back-trapped on the tractor.

We have developed a new combined unit, which consists of a front-mounted hook-on tractor tractor and a rear-mounted root crop head cleaner from the remains of the hook (Fig. 1). This combined hook-up unit can be manufactured in a different layout, ie, different rows - from the two-row, to the six-row variants.

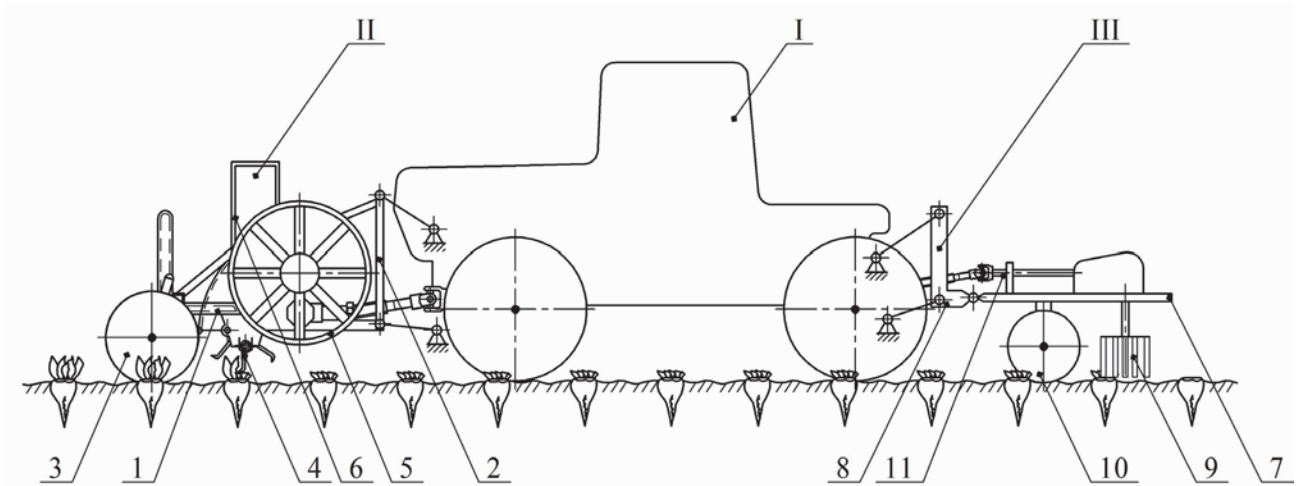


Fig. 1. Combined aggregate for collecting sugar beet hooks: And - a tractor; II - front-mounted hinged machine: 1 - frame; 2 - coupling device; 3 - copier wheel; 4 - rotary hiccirculator; 5 - transportation and supply working body; 6 - boot device; III - cleaner of heads of root crops from remnants of a stick: 7 - frame; 8 - coupling device; 9 - cleaning shaft; 10 - copier wheel; 11 - drive

To develop a new theory of efficient aggregation of a front-mounted wagon tractor and a rear-mounted cleaner of root crops from the remains of the hinge, we first use the well-known dependencies to determine the performance of this combined machine-tractor unit. Since the harness and head cleaner of the root crops are driven (from the front and rear shafts of the tractor's power take-off), it is necessary to have the traction balance equation and the equilibrium equation of the capacity of this hoisting machine for the determination of their productivity. In this case, the relationship between the width of the gripping machine and the cleaner and the speed of the machine-tractor unit can be described by such a well-known expression [14]:

$$N_e \cdot \xi = \frac{R \cdot V_r}{3600 \cdot \eta_t (1 - \delta)} + \frac{N_p \cdot B \cdot V_r \cdot H}{360 \cdot \eta_v}, \text{ кВт}, \quad (1)$$

where: N_e — nominal effective power of the engine, kW; ξ - load factor of the engine; R_a - traction resistance of the front-mounted hoist and head cleaner tractor, N; N_p - specific total costs (for the mowing of the main mass of the hinges and the cleansing of the heads of root crops from the remnants of the stick) of energy for the process of collecting the honeycomb sugar beets, kWh·kg⁻¹; H - yield of sugar beet hooks, c·ha⁻¹; η_t - coefficient of efficiency of the transmission of the wheeled aggregate tractor; η_v - coefficient of efficiency of the front and rear shafts of the power take-off of the tractor; δ - towing a wheeled tractor.

Determine the following components that are part of the analytical expression (1). The tractive resistance R_a of a front-mounted trailer of the hoist and rear-mounted cleaner can be determined by the following expression:

Determine the following components that are part of the analytical expression (1):

$$R_a = R_i + R_f + R_{top}, \text{ Н}, \quad (2)$$

where: R_i, R_f — resistance of the wheeled aggregate tractor to lifting and moving, N; R_{top} — traction resistance of the harvesting machine and root crop head cleaner during the process of collecting sugar beet hooks, N.

Since the traction balance equation (1) is a product $N_e \cdot \xi$ is numerically equal to the driving force of a wheeled aggregate tractor, which provides for overcoming all resistance forces acting on this combined hook-lifting unit, the components included in expression (2) can be determined by such dependencies:

$$R_i = mg \cdot \sin \alpha, \quad (3)$$

$$R_r = mg \cdot f \cos \alpha, \quad (4)$$

$$R_{top} = k \cdot B, \quad (5)$$

where: α — angle of ascent, rad.; m — mass of the wheel aggregate tractor, kg; g — acceleration of free fall, m (s²)-1; f — propulsion coefficient of the wheel aggregate tractor; k — Specific resistance of the front-mounted hoe and the cleanser of the heads of root crops from the remains of the hook, N·m-1.

The coefficient f of rolling resistance of the wheeled aggregate of the tractor takes into account all useful technological deformations carried out during the collection of sugar beet hooks and the resistance to the movement of the front-mounted hoist and the rear-mounted cleaner along the direction of movement. At small corners α the value $\sin \alpha \cdot 100$ represents the percentage of lifting i .

On the basis of the use of equations (2) and (3), (4) and (5) of equation (1), the balance of power of a wheeled aggregate tractor can be represented as follows:

$$N_e \cdot \xi = V_r \frac{(kB + mg \cdot \psi) \eta_v + 10N_p B \cdot H \eta_t (1 - \delta)}{3600 \cdot \eta_t \eta_v (1 - \delta)}, \quad (6)$$

where: ψ — coefficient of resistance to the movement of the wheel aggregate tractor.

In general, the coefficient ψ of resistance to moving the wheeled tractor can be represented by this dependence:

$$\psi = \sin \alpha + f \cos \alpha, \quad (7)$$

where α — angle of ascent, rad.; f — tractor rolling resistance coefficient.

If we solve the equation (6) of the balance of power of the wheel aggregating tractor relative V_r , then it is possible to determine the value of the speed of movement of this combined harvesting unit in the field:

$$V_r = \frac{3600 \cdot \xi \cdot N_e \eta_t \eta_v (1 - \delta)}{(kB + mg \psi) \eta_v + 10N_p B \cdot H \eta_t (1 - \delta)}, \text{ km} \cdot \text{h}^{-1}. \quad (8)$$

In analytical terms (8) to determine the speed of movement V_r of a wheel aggregate tractor with a front-mounted hook-and-cut machine and a rear-mounted head cleaner of the root crop from the remains of the hinge, which is necessary to determine the productivity of this harvest machine-tractor unit coefficients ξ , η_t and η_v can be considered as given.

And the loading of the machine-tractor unit must be determined on the basis of the use of different empirical formulas based on the construction of the curve of the wheel tractor towing. In this case, we will use a known dependence to determine the towering position [14]:

$$\varphi = \varphi_m - a e^{-b\delta}, \quad (9)$$

where: φ — coefficient of use of coupling weight; φ_m — coefficient of adhesion; a, b — constant coefficients depending on the type of wheeled aggregating tractor and agrotechnical background, on which the harvesting of sugar beet hooks is carried out.

In expression (9), the dependence of locking on the coefficient of use of coupling weight is given in an implicit form, which makes it difficult to carry out numerical calculations. To bring the expression (9) to a more convenient form, we will perform some algebraic transformations, on the basis of which we obtain an expression for determining towing in the following form:

$$\delta = -\frac{1}{b} \ln \frac{\varphi_m - \varphi}{a}. \quad (10)$$

Next, the coefficient of coupling weight of the aggregating tractor included in expression (10) will be determined using such an analytical expression:

$$\varphi = (mg \cdot \psi + kB)(\lambda \cdot mg)^{-1}, \quad (11)$$

where: λ — coefficient of coupling weight of tractor.

Thus, there are every reason to believe that in the expression (8) all input values in it are given. Next, in order to determine the performance of this combined hitch, it is necessary to take advantage of the dependence on the course of the operation of the machine-tractor park. [15]:

$$W = 0,1B \cdot V_r, \text{ га} \cdot \text{год}^{-1}, \quad (12)$$

where: B — working width of the front-mounted hook-on tractor tractor and rear-mounted root canal head cleaner, m; V_r — translational speed of the combined aggregate, km·h⁻¹.

Substituting in expression (12) all previously determined dependencies, finally, we obtain the value of productivity of a combined harvesting machine-tractor unit consisting of a wheeled aggregating tractor, a front-mounted hitch and a rear-mounted head cleaner of root crops from the remains of the hinge:

$$W = 0,1B \left\{ \frac{3600 \cdot \xi \cdot N_e \eta_v \left[1 + \frac{1}{b} \ln \varphi^m - \frac{[(mg \cdot \psi + kB) \cdot (mg \cdot \lambda)^{-1}]}{a} \right]}{(kB + mg\psi) \eta_v + 10N_p B \cdot H \eta_t \left[1 + \frac{1}{b} \ln \frac{\varphi_m - [(mg \cdot \psi + kB) \cdot (mg \cdot \lambda)^{-1}]}{a} \right]} \right\} \quad (13)$$

The expression (13) is obtained and is a mathematical model of the aggregate of a hook-picking machine frontally mounted on a wheeled tractor and a seamlessly cleaned head of root crops from the remnants of the hook. Using expression (13) we have the ability to determine the performance of this machine-tractor unit, depending on the initial parameters of a tractor and hook-picking machines and cleaners of different rows and layouts.

Based on the developed program of numerical calculations on the PC in the system MathCad we carried out calculations of this mathematical model and built the corresponding graphs (Fig.2-4).

In carrying out numerical calculations were taken into account the agronomic requirements relating to the restriction of the speed of the translational motion of the harness and head cleaner root crops from the remnants of the hinge, which should be in this interval $1,5 \leq V_r \leq 4,0$, m·s⁻¹, as well as restrictions related to the grip of the propulsion of the aggregate wheeled tractor with the soil, with its movement along the beet field. In this case, this restriction has this form:

$$\varphi < \varphi_m. \quad (14)$$

For a given agrotechnical background, calculations were made for several types of wheeled aggregate propulsion tractors, with which the effective operation of a front-mounted hoe and a rear-mounted head cleaner of root crops is possible from the remnants of the hook. It should also be emphasized that, when performing numerical calculations, we took into account the fact that each type of wheeled propagating tractor of the corresponding traction class has its own mass m , engine power N_e , coefficient λ . Value of coefficients φ_m , a and b Accepted specifically for agrotechnical background, which is operated by a hook-picking machine and a head cleaner root crop. In addition, for each variant of numerical calculations yield yields of sugar beet huts were given. H , specific costs for the entire technological process N_p , maximum lifting percentage i slopes of beet field, coefficient of resistance of tractor movement f , coefficient of efficiency of the tractor's power take-off rollers η_v . Traction efficiency η_t was adopted for wheeled tractors, equal $\eta_t = 0,92$. Resistivity k the front-mounted hoe and the rear-mounted cleanser of the heads of the root crops from the remnants of the hook were given for their various rows and varied for each type of wheeled tractor in the range from 2100 to 3500 N·m⁻¹. Change the width B of a front-

mounted hook-on tractor and a rear-mounted root canal head cleaner is carried out within the range of 0,90 m to 2,7 m, with step 0,45 m, that is from a two-row to six-row variants.

For each variant of numerical calculations, as a result, the specific resistance for each hiccupper and the cleanser of the roots of the root crops of the appropriate trapping width and the speed corresponding to them was determined. V_r — the motion of this combined machine-tractor unit, its performance W , traction resistance of the unit R_a , coefficient of use of coupling weight ϕ and slipping δ .

Conducting computations of a composite mathematical model is carried out using specified (averaged) parameter values. So, in numerical calculations, it was accepted: the yield of sugar beet hooks — $H = 150 \text{ c}\cdot\text{ha}^{-1}$; specific energy consumption for the process of collecting sugar beet hooks — $N_p = 2,7 \text{ kW}\cdot\text{s}\cdot\text{kg}^{-1}$; coefficients — $\xi = 0,90$; $\eta_v = 0,95$; $f = 0,07$; It is also assumed that in the beet field there are no more than 5% increase; Specific resistance of the front-mounted hinged machine and the rear-mounted head cleaner of root crops from the remains of the hinge in the wheel-aggregating tractor (its average value) $k = 2100\text{...}3500 \text{ N}\cdot\text{m}^{-1}$ (step change in specific resistance $\otimes k = 200 \text{ N}\cdot\text{m}^{-1}$). The technical characteristics of the universal-propagating and integral wheeled tractors, which can be combined with a front-mounted hoe and a rear-mounted head cleaner from the remains of the hook, are given, according to the data [14] in the table..

Tabl. - Technical characteristics of universal multi-purpose tractors

Traction class of tractor, appointment	m_g , kg	N_e , kW	φ_m	a	b
0,9 universally-driven, wheeled	3000	36,8	0,6	0,75	8,81
1,4 universally-driven, wheeled	3810	58,9	0,6	0,75	8,81
3 universally-driven, wheeled	8200	117,7	0,65	0,753	9,52

For given input parameters of the considered system, which was solved on the PC, numerical calculations were performed, the results of which are based on graphs presented on rice. 2-4.

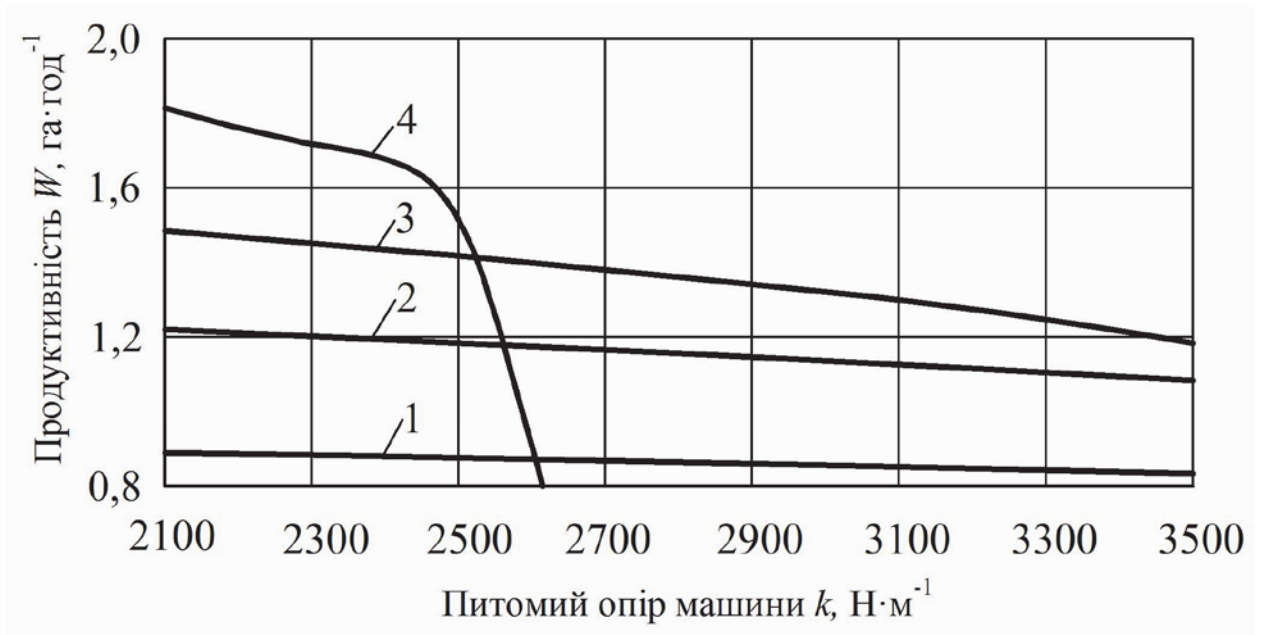


Fig. 2. - Dependence of productivity W a combined hook-up unit in the composition of a tractor-haul tractor of a pulling class of 0.9 from specific resistance k at different widths of capture:

- 1 — $B = 0,9$ (two-row version); 2 — $B = 1,35$ (three-row version);
 3 — $B = 1,8$ м (four-row version); 4 — $B = 2,7$ м (six-row version)

From the obtained dependencies (Fig. 2), we see that effective operation of the self-assembly unit on the basis of a wheeled tractor of the pulling class 0.9 is possible only with the use of two-, three- and four-row machine tools. In case of assembly of a six-row unit, its operation will be possible only at low values of resistivity, in the range from 2100 to 2400 $N \cdot m^{-1}$.

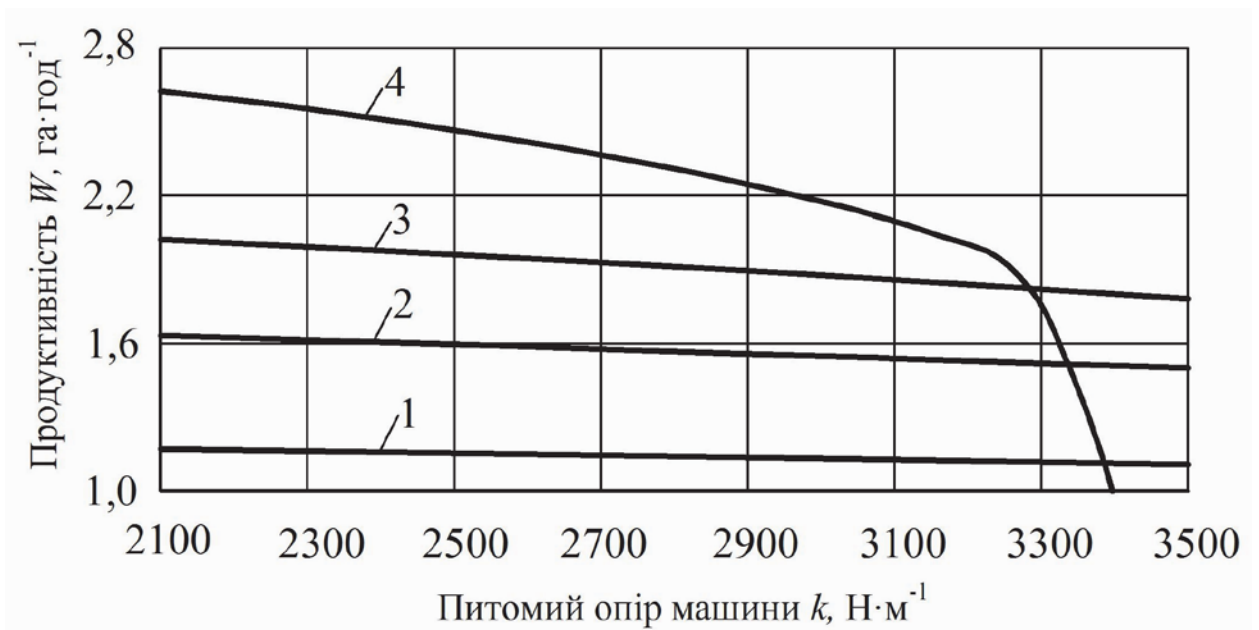


Fig. 3. - Dependence of productivity W a combined hook-up unit in the composition of a tractor-haul tractor of a pulling class of 1.4 from specific resistance k at different widths of capture: 1 — $B = 0,9$ (two-row version); 2 — $B = 1,35$ (three-row version); 3 — $B = 1,8$ м (four-row version); 4 — $B = 2,7$ м (six-row version)

As we see from the obtained dependencies (Fig. 3), for a tractor of traction class 1.4 there is a higher productivity than a tractor of a pulling class 0,9 in the case of the acquisition of two-, three- and four-row hoeing machines. When using hexagonal guns, the range of possible resistance values for operation is $k = 2100 \dots 3200 \text{ N}\cdot\text{m}^{-1}$.

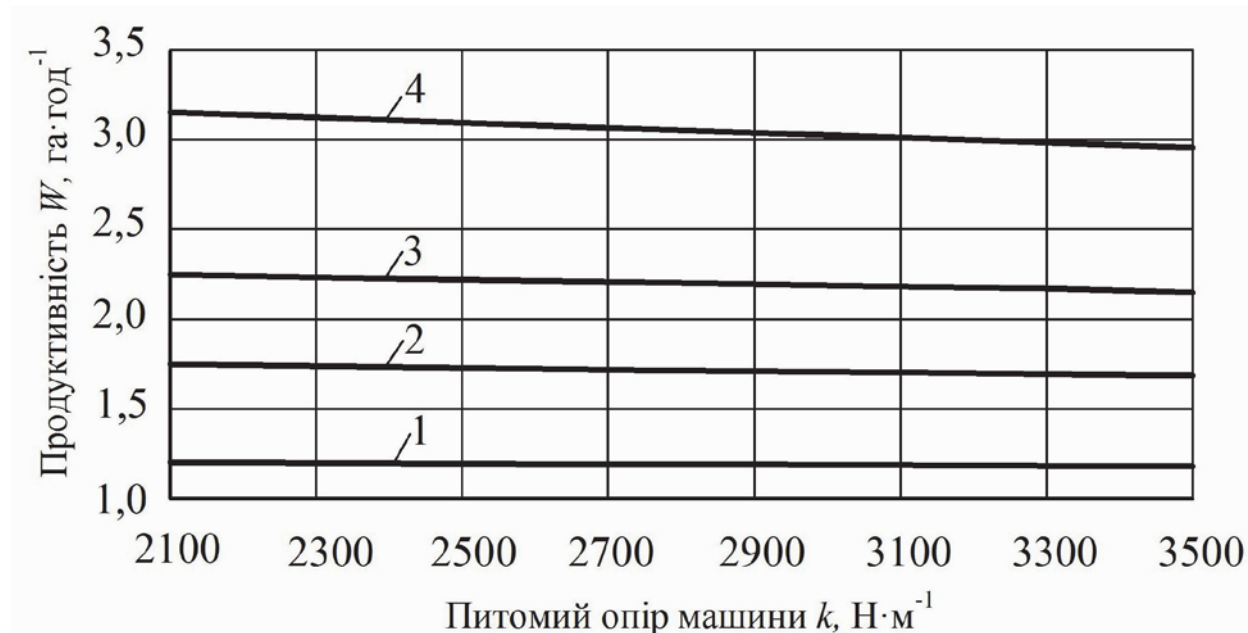


Fig. 3. - Dependence of productivity W a combined hook-up unit in the composition of a tractor-haul tractor of a pulling class of 3.0 from specific resistance k at different widths of capture: 1 — $B = 0,9$ (two-row version); 2 — $B = 1,35$ (three-row version); 3 — $B = 1,8 \text{ м}$ (four-row version); 4 — $B = 2,7 \text{ м}$ (six-row version)

Numerical simulation (Fig. 4) of the parameters of the combined hitching unit on the basis of the traction class 3 wheeled tractor showed that it provides the greatest productivity when completing the combined hitching units throughout the range of changes in the specific traction resistance and the width of the traction due to its traction-coupling properties.

Conclusions

Based on the conducted analytical studies a new mathematical model of efficient aggregation of front-mounted wheel assembling tractors of haymaking machines and rear-mounted root canal head cleaners from residual hinges, which describes the conditions of effective aggregation, and provides an opportunity to determine the working speed and productivity of various combined machine-tractor aggregates.

As a result of numerical simulation on PC, it has been established that Class 3 integral wheel drive tractor will provide the highest productivity with the use of combined hoeing assemblies for the whole range of seizing width and throughout the range of changes in the specific traction resistance, and due to the power reserve, the possibility of using additional drive devices, for example, root cropping machines.

Modeling of performance of combined assemblies on the basis of 0.9 and 1.4 class wheeled tractors showed that they are capable of providing sufficient and stable performance only when aggregating three or four-row machines, and the use of a six-row unit is possible only for a class 1.4 tractor with small yield and sufficiently low values of specific resistance.

The results of the conducted analytical research, as well as the developed numerical simulation program on the PC, make it possible to determine the optimal parameters not only of this combined hook-up unit, but also of other aggregates according to the criteria of productivity and energy intensity.

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